International Conference

CONSTRUCTION: A CHALLENGE FOR STEEL

Commission
of the European
Communities

Luxembourg,
24/26 September 1980

Westbury House

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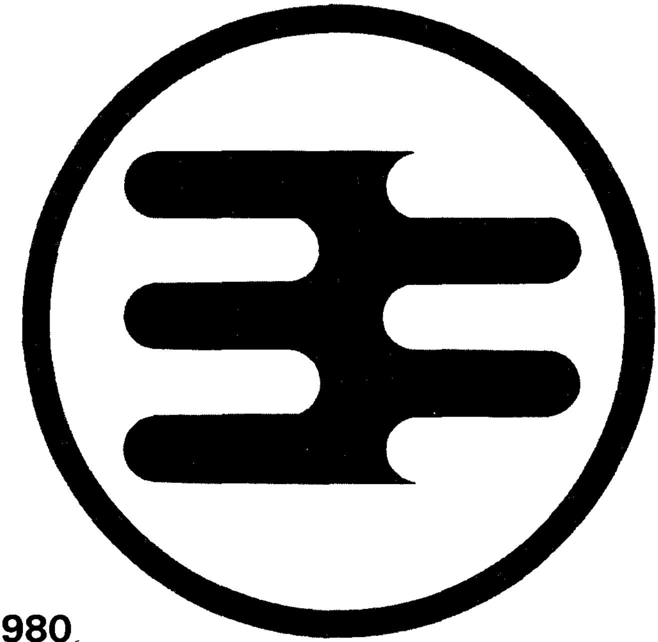

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WELCOME ADDRESS

J. BARTHEL
Minister of Transport, Communications and Informatics
Grand Duchy of Luxembourg

Mr. Chairman,
Commissioner,
Ladies and Gentemen,

The International Conference on "Construction : a challenge for steel" has come at the right time. I am pleased you have decided to meet in Luxembourg, which has often hosted events devoted to products covered by the Treaty of Paris.

As spokesman for the Luxembourg Government I would like to welcome you to our capital and to wish the conference every success.

Looking through your programme I find a happy balance between the four central themes, with a very timely emphasis on the role of steel in relation to the major economic zones, present demand, development opportunities, use in the developing countries and to the restoration and adaptation of our architectural heritage.

Thus the circle closes, steel having been considered from the point of view of practical uses, new developments, and finally, an aspect which embraces philosophy and art.

The President of the Luxembourg Government was to have addressed you, but since other professional commitments prevented him from doing so he delegated responsibility to me, no doubt thinking that my engineer's training and the fact that I head several ministries of a technical nature qualified me to address a meeting of renowned specialists. However, I do not propose to encroach on your debates and considerations.

I would like instead to emphasize the importance of your work in the present depressed situation, to outline once again the special situation in the Grand Duchy and to stress the need to tackle the problems in the spirit of cooperation, solidarity and unity necessary to maintain an efficient and enlarged market.

We know the position with regard to steel, for which construction represents an important market.

The recession only needs to bite in a few consumer branches for the phenomenon to snowball and for steel, as a precious material, to be dealt a severe blow.

Detailed studies have been made, and works have been produced in steel which defy the creative imagination.

It is essential to continue to explore new uses for steel, and conferences of this nature stimulate the comparison of ideas and encourage experimentation and an enterprising and bold approach.

Clearly, the situation in Europe and the wider world offers no grounds for optimism.

The market continues to be weak in the EEC, demand from third countries is declining, steel consumption is generally decreasing, the fight is on to protect direct and immediate interests, markets are becoming blocked and prices are changing weekly.

The only bright spot is the recognition that the descent has begun to level out and that it will be possible to reestablish a trigger mechanism in the United States, at a higher level and wihin an environment which for the moment remains unclear.

Nearer home, further job losses have been announced in Lorraine, Röchling-Burbach's markets are declining, and new plans are being drawn up for the various Belgian steel sites.

The second Davignon plan is coming to an end and the most penetrating analyses do not find agreement between the parties involved.

It is clear that we need a new framework of discipline, based on the following proven strong points :

- internal aspects : with regard to prices in particular;
- external aspects : organization of public aid;
  restructuring to be camed through successfully.

The arguments between the European producers are continuing more fiercely than ever, and for the moment it is impossible to say which faction will carry the day : the abstainers, the diehards counting on the eliminating heats, the wise men preaching flexibility and a desire to do better, or those who advocate strict application of the rules and of sanctions.

For my part, I fervently hope that common sense and a determination to succeed will prevail, so that action can again be determined by the principles of the market economy and a desire to pull through in a spirit of discipline, unity and solidarity.

This platform is not the place for me to present an exhaustive analysis of the steel situation in my country.

After the tripartite agreements of August 1978 and March 1979, and the implementation of the law of 8 June 1979 on the modernization and restructuring of the steel industry, the brutal reversal of the situation since May 1980 has forced us to revert to the Luxembourg model, where steel policy is developed by the triumvirate of government, employers and trade unions. Work on these lines is in progress.

The basic data concerning our steel industry are too well known for me to go into details here.

I would simply like to point out that, despite expansion in the service industries, the steel industry still represents 45 % of industrial production in my country and the value of our exports of steel and processed steel products accounts for 65 % of our foreign sales.

These two statistics tell everything, in terms of production, finance and balance of payments, in a context characterized by dwindling orders, tumbling prices and institutionalized egoism which tries to get off scot-free.

However, I am confident of a tripartite solution which takes due account of the essential factors : maintenance of the site here, together with development opportunities; specific medium-term restructuring programme founded on this basic principle; satisfactory financial planning, adequate and bearable support arrangements; general consensus; active solidarity; observance of the rules at European level.

Ladies and gentlemen,
I said at the outset that I did not propose to encroach on your subjects for discussion, and I have no intention of doing so.

However, I hope you will not resent my having mentioned various problems which, in truth, form an essential background to your discussions.

I very much appreciate the philosophical subject chosen by Professpr van Melsen : "Construction on a human scale".

I find this an exciting theme and one which gives a true dimension to your studies. It is a difficult situation, requiring new leaps of the imagination and daring initiatives for new projects.

Edmond Rostand expressed it admirably when he said : "C'est la nuit qu'il est beau de croire à la lumière". (The night is the best time to believe in the light).

I wish you all every success in your work.

May your thoughts be inspired by the Parisian architect-artist who constructed this beautiful building!

OPENING ADDRESS

R. VOUEL
Member of the Commission of the European Communities

Minister, Mr Chairman, Ladies and gentlemen

On behalf of the Commission of the European Communities, I am pleased to welcome you today to Luxembourg, thus continuing a tradition of long standing, since it was here that the first Steel Conference was organized by the High Authority for Coal and Steel in 1954.

I firmly believe that, this Conference, like the previous ones, will lead to important advances in steel utilization. I am particularly convinced of this since the Conference this year is focusing on the relationship between two key sectors of our Community's economy which are, however, proving particularly sensitive in this time of crisis.

The steel and the construction industries are closely linked in the EEC, where 5 to 10 % of steel production goes to the construction industry and steel accounts for 30 % of the materials used in construction work. I am convinced that your efforts will draw this bond even closer.

The Commission has always taken an active interest in the two sectors which are the subject of this Conference.

This is axiomatic in the case of the construction industry, which traditionally has a considerable causal and cumulative effect on economic development. It is a key sector of every economy and its level of activity has direct repercussions on the production of many materials, and particularly of steel. A decline in activity in the construction sector is therefore inevitably felt by the whole economy. Furthermore, it is one of the most important industrial sectors for the labour market : almost seven million workers are directly employed in this sector within the Community!

It is therefore not surprising that the Commission tries with all the means at its disposal to exert a positive influence on development in this sector. It does this by drawing up proposals for Directives 1), by carrying out analyses and by participating in research programmes and specific construction projects. Numerous working parties have been set up to examine these problems which cover such wide and diverse areas as the study of development prospects, energy conservation or the technical control of products and materials used in this industry, to quote just a few. Let me say also that the Commission does not promote the construction industry solely by industrial measures proper, but also pays special attention to this sector in the context of its other policies, particularly credit and investment or regional policy. Thus it can be said that, while the means employed vary,the Commission's approach remains consistent as it initiates, harmonizes and coordinates with a view to the balanced and strong development of the construction industry, in the widest sense of that term.

In the case of the <u>steel sector</u>, which is the cause of such concern today, nobody can reproach the Commission with not having shouldered its responsibilities at the first sign of crisis. Its action, in particular in connection with the anti-crisis plan, had a twofold objective : firstly, not to allow this vital sector of the Community's economy to collapse and, secondly, to restore its competitiveness in the new world competitive situation. It is essential that when the time comes for the recovery of the Western economy, the Community steel insutry should be able to assert itself effectively in a context of fair competition which is the very cornerstone of our economy.

The first measure, by its very nature temporary, and which can be compared to an oxygen mask applied to a patient who must be revived at all costs, had three facets,to it :

- temporary protection of the Community against imports after consultation with our trading partners;
- maintenance of a reasonable price level by introducing Community legislation;
- coordinated reduction in capacity by means of a system of voluntary supply commitments while retaining a vital minimum of outlets for the various entreprises.

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1) Mainly the Directive on construction materials, currently being discussed in the Council.

However, this temporary support measure is to no avail unless a determined Community steel industry restructuring policy is implemented at the same time. Progress has been made with this restructuring, which is absolutely essential, but the process is far from being completed.

Furthermore, a return to competitiveness within our steel industry was based on the hope that the upturn in the world economy would be too long in coming. Unfortunately, as we all know, it is doubtful whether this can be fulfilled in the near future.

For this reason, I cannot conceal from you certain things which are causing the Commission grave concern. The truth is that between the beginning of the crisis and 1980 the Community steel industry lost 180 000 jobs! To be sure, it was possible to combine Community funds with national social measures to limit and alleviate the consequences of unemployment. What will happen to employment, however, if there is a further depression in the Western economy or if the present situation continues? In any event this threat should strengthen our will not only to continue our unavoidable restructuring work lucidly and with determination, but also to persevere in initiating in-depth discussions and research such as this Conference.

Such discussions are particularly necessary at the present time when all products, however uninterchangeable they may be, are in fierce competition. Consequently our steel industry must display exceptional imagination in order to increase its share of supplies to the construction industry. For this it will have to offer products which are perfectly suited to the special and very varied requirements of the construction sector, whether this be resistance to corrosion, ease of assembly and dismantling, energy saving or many others about which you are undoubtedly better informed than I. The steel industry will also have to advertise the quality and advantages of its products and promote them. Above all it will have to ensure that they are competitive in every way. In this respect, the subsector manufacturing prefabricated components is a very promising area.

My remarks here apply to the whole steel industry, from the crude steel stage right through to the finished product stage.

Mr. Chairman, there is therefore room for a certain degree of optimism if we succeed in making the necessary effort. The same is true of the construction industry where new potential outlets exist, both on the domestic market and above all in the newly industrializing countries, in the countries which can afford to substantially increase their imports by virtue of their energy or other raw material resources. Our industry must gain access to this vast market for capital goods. It is absolutely essential that we take account of this geographical shift in industrial patterns. The cards are being dealt again and the Community must stay at the table or the game will be played without it!

We are engaged in a bitter strugle in an area where competition is intensified by lasting differences in the cost of certain production factors such as labour and raw materials. However, to offset this we have encouraging assets, and I am convinced that if the spirit of entreprise which is invoked so often and which is one of the traditional assets of our industrial society remains a reality - or is restored -, we have nothing to fear from this challenge. The spirit of initiative and innovation will enable us to maintain a significant foothold on most markets in the future.

For its part, the Commission will continue to do its utmost to support your efforts. Thus, for example, the budget allocated to the measures which you will be discussing in the next two and a half days represents about 20 % of the annual "Steel" research budget, or roughly 5 million ECU a year. In any event, the Commission will draw up new proposed measures on the basis of the results of your work at this Conference.

Mr. Chairman, it only remains for me to wish your Conference the success which work of such fundamental importance deserves.

However, I will not conclude without advising you to do someting which I believe could be both useful and pleasant : if you have a few moments' respite from your work, have a look around you : here in Luxembourg you will discover magnificent creations in steel, which are tangible examples of the subject of your Conference and will definitely inspire you to the highest eloquence.

WHAT IS HUMAN BUILDING?

A PHILOSOPHICAL ANALYSIS

A.G.M. VAN MELSEN
Catholic University of Nijmegen

Summary

The paper discusses the problems connected with "human building" in the general context of the humanization of technology. What is truly human in technology and why is that a problem for us today? The answer has to be sought in the fact that modern technology did not make its appearance until a late stage in cultural development. Even Western civilization was not prepared for it. Cultural and religious traditions were shaped over a period of more than two thousand years in which there could hardly be room for the idea that the material conditions of human existence would change.

The problem is to find a new balance between, on the one hand, a continuing technological development with its material and social consequences and, on the other, a civilization that uses this technology without being dominated by it. This will take time, as we lack the necessary experience. In what way can the great traditions of the past help us in finding this balance?

1. INTRODUCTION

I should like to begin by apologizing for my approach to this topic, which I propose to discuss in general terms. This is partly due to the fact that I have no special knowledge of the problems connected with building, but partly - and this is a more important reason and also the reason for my accepting the invitation - because I am convinced that the problems connected with human building are of a general nature.

In consequence, the greater part of my paper will deal with general questions such as : what is truly human and why is that a problem for us today? I sincerely believe that everyone who tries to build a human world - in the literal and metaphorical sense of the word - should try to find an answer to these general questions. A philosopher can help a little to elucidate the questions and perhaps even suggest some answers, but he cannot express these answers in terms specific to the different fields of human activity.

The structure of my paper will, therefore, be as follows. After a short analysis of some aspects of human building, we shall discuss the development of technology, its influence upon civilization, and the cultural crisis resulting from the impact of technology upon civilization. Then follows an analysis of the problems connected with the humanization of our technological civilization. In conclusion we shall return briefly to some specific problems of human building.

2. AN INITIAL ANALYSIS OF HUMAN BUILDING

When we reflect upon the different aspects of human building, the first considerations that come to mind are those that are already summarized in the famous triad of the Roman architect-engineer Vitruvius : firmitas, utilitas and venustas. Each building must have structural stability, it must be useful and it should have an attractive appearance. It is clear that this triad does not only concern the construction of buildings, but also of many other technical structures; yet in building this triad is so important that it virtually characterizes the art of building; i.e. architecture.

The most interesting point about this triad is, of course, the combination of practical requirements such as stability and utility with a requirement of a totally different order - beauty. It is the combination of utility and beauty that gives architecture such a special place both among the technological skills and among the arts. In this connection it is interesting to note that the Greek word "technê" and the Latin word "ars" mean both art and technics as the terms are used today. Why do we distinguish between art and technics? Why did the ancients not make that distinction?

In answer to this question, let us first draw attention to the two ways in which material things can be used, namely a natural and a symbolic way. For instance, a barrier and a certain traffic sign both indicate : "no entry", but they do it in quite a different manner. The barrier physically blocks the road, and I can enter only by using a certain amount of physical force. A traffic sign, on the other hand, is not blocking my way in a physical sense; its material properties, a certain form and colour, are used only to express a symbolic message. The barrier expresses the same message, but it does more than expressing the message; the road is effectively blocked.

It is characteristic of many human activities, in distinction to those of animals; that they combine a material and symbolic function. Eating and drinking are not only natural means of satisfying physiological needs, they also have a cultural function. For this reason there is much wisdom in the twofold meaning of the word technè in ancient Greek. The making of useful things had artistic overtones, and vice versa. The Greeks did not know "l'art pour l'art".

In our times with the general tendency towards specialization, art and technics have taken separate roads. It is the price we have had to pay for the development of technology. Yet, in some forms of art, they are still combined. Architecture is one of them. We shall return to this point later, but must first consider further the different aspects of human building.

One of the striking aspects of human technology and consequently also of human building, is the fact that the human race develops its technology. It is another point of difference from the technics of animals. In the animal kingdom we come across many marvellous examples of technical skill, but animals make no conscious effort to develop this skill. Human civilization has been developing from its earliest beginnings, but their is a marked difference between past and present rates of development. The reason for this difference is obvious : it is the result of modern science. This answer is, of course, not incorrect, but like so many answers, it raises new questions. Why did it take such a long time (more than 20 centuries) for science and technology to come together? What are the implications for the history of our civilization?

3. THE DIFFERENT PHASES OF CIVILIZATION

It is an interesting fact that the first periods of history are denoted by reference to technology. We speak, for instance, of the stone age, the bronze age and the iron age. These very names stress the importance of technological developments for civilization in general, at least in the first phase of history and in prehistory.

In the second phase of history (in Western civilization) between the 5th century B.C. and the 17th century A.D.) we do not come across such technological labels : historians speak of Greek, Hellenistic, Roman and mediaeval civilization, of the Renaissance and of the Age of Enlightment.

In the most recent phase of history, however, we again find periods characterized in technological terms : the first and the second industrial revolution, the atomic age, the computer age etc. Although these later designations are not yet sufficiently crystallized, because only the future will decide what is and is not really important, it is nevertheless clear that in our times technological developments again have a decisive influence upon civilization. This fact makes the second phase in history the more interesting; what happened at its beginning that caused the development of technology to lose its leading role? What happened at the end of that same phase to restore the leading role of technology?

There can be no doubt that on both occasions science was a decisive factor, albeit in very different ways. The beginning of the second phase of history coïncides with the coming into existence of science (in the broad sense of this word = Wissenschaft). How did the Greek, in whose civilization science originated, look upon science? Analysing the course of events that led to the birth of science, Aristotle (4th century B.C.) epitomized the attitude of his time when he remarked that science could come into existence when the necessities and the comforts of life had been provided for. Science was considered as a kind of intellectual luxury, as one of the highest human achievements, but with no material consequences for the problems of everyday life. These problems had to be solved by empirical knowledge and technical skill.

The main reason for this view of science was that the first sciences were almost exclusively rational : mathematics, logic and philosophy. These sciences did not deal with reality in its specific empirical aspects; they covered only those aspects where intellectual insight was possible. Science had of necessity to confine itself to certain privileged realms : the realm of quantity (mathematics), that of the formal aspects of reasoning (logic) and that of the general principles of nature, and of human existence and activities (philosophy). In consequence science and technology went different ways.

Another point to be noted is that the Greeks believed that technology had, as it were, natural frontiers, which they thought had already been reached in their time (cf. the words of Aristotle). Technology had to have such frontiers because it was based upon natural experience of the properties of natural things and processes. Once these properties and the ways of using them were known, the natural frontiers of technology had been reached. For two thousand years the Greeks seemed to have been right in their judgment. Man's place in nature with its consequences for society seemed to be determined once and for all. The material possibilities of human existence were limited to those which "natural" technology could offer.

Not only technology, but also science seemed to have natural frontiers. Science was based upon intellectual insight into first principles (e.g. the axioms of geometry). Once these principles were known, the main task of science was to draw logical conclusions from these principles. This means that after a certain time science reached its limits. The idea of a continuous advance of science did not yet exist. In this connection it is worthwhile to note that such great thinkers as Aristotle and Thomas Aquinas, who were fully aware of the limitations of their philosophy and science, never thought in terms of a further development of scientific knowledge. In their writings we do not find the idea, so characteristic of modern thought, that what is not known today will probably be known tomorrow.

Given this situation in technology, in society, and in science it should, therefore, not surprise us that all civilizations until modern times were deeply convinced of the everlasting value of tradition. The main cultural task of each generation was to assimilate traditional wisdom, knowledge, skills, values and norms. Thus tradition was passed on from generation to generation.

From the short analysis of what happened at the beginning of the second phase of history it may be clear why in this phase the current status of technology did not exert as decisive an influence on civilization as in the former period. First of all, technology did not develop much, and secondly, the real core of civilization was considered as to be more spiritual than material; civilization was equated with culture or "Geisteskultur". This does not mean, of course, that there were no cultural changes in this phase of history. Their cause was, however, not of a technological nature.

There were, of course, some technological developments but, compared with what happened in the 19th century, they remained within fairly narrow limits. In building, for example, we see a gradual discovery of new construction methods. A Gothic cathedral differs from a Greek temple, but the principal difference between the two does not lie in their technological design, the difference in cultural expression being much more important.

In general it could be said that technological and cultural developments were not so radical that they undermined tradition. On the contrary, innovations were invariably judged by classical standards. All historical developments, whatever their nature, had to be evaluated in the light of tradition. It is, therefore, no coincidence that the names which indicate such great religious and cultural revolutions as the <u>Re</u>formations and the

Renaissance begin with the prefix "re". They were meant as a return to the true values of tradition.

Tradition dominated every sphere of life : agriculture, trade and handicrafts, education, politics, religion, science and technology. Tradition could play this dominant role because the possibilities of technological and societal development were limited, and the true standards of civilization were believed to have already been discovered in the past.

For a long period there was no reason to doubt the value of tradition, because there was no reason to doubt the basis of tradition, namely the conviction that human existence offered only limited possibilities of development.

One of the consequences of this conviction was the religious slant of society. This explains the primacy of the church in all aspects of life, a situation that was reflected in the realm of building by the dominating central position of churches in cities and villages.

Let us now turn our attention to the end of the second phase of history. Again science played a crucial role with the advent of modern science and technology. The first question which comes to mind is, of course, why such a long time elapsed before this development took place. It seems plausible to seek the reason in the conservative force of cultural tradition, which directed Man's capacities in directions other than those which were useful for day-to-day life. This seems all the more plausible as the few privileged groups which dominated the traditional civilization and profited from it and its social organization, were not likely to wish to change the situation from which they profited. I don't think that is the only reason however, and it is certainly not the main reason. The main reason has to be sought in the intrinsic difficulties connected with the coming into being of an experimental science. In a rational science, such as logic and mathematics, the theoretical principles can be directly abstracted from reality. In an experimental science, however, the theoretical principles have to be based upon experimental data. This constitutes a major problem for experimental science as experiments in turn have to be based upon theoretical principles. Otherwise, one does not know what experiments to carry out and, if experiments are carried out, what data are relevant. In short, the conditions for the genesis of an experimental science form a kind of vicious circle. It is thus more surprising that mankind has found a way of breaking out of that circle than that it took such a long time to do so. But once it was done, theory and experiment stimulated each other and science could develop very fast. This changed. the whole of civilization and launched a new cultural phase, in which the development of technology for the second time in history played a leading role.

Technology could play that role, because the new science, as a result of its experimental character, bridged the gap between science and technical skill. The frontiers of technology ceased to be static so that with science technology, too, became capable of progress. Science and technology became a means of improving the material conditions of everyday life and of reshaping society. This had far-reaching consequences for civilization as a whole.

4. THE CULTURAL CRISIS OF MODERN TIMES

In order to understand the full impact of the advent of modern technology, we should be aware that the cultural and religious traditions of Europe were shaped over a period of two thousand years in which there could hardly be room for the idea that the situation with respect to the material determinants of civilization and society would change. These material conditions of life seemed part of the natural order of things. Consequently, European civilization was in no way prepared for a situation that drastically changed the material conditions of life. No wonder that European civilization did not easily find the right answer to the scientific and technological explosion. The traditional religious, social, political and moral values and norms were, at least partly, based upon the premiss that human existence on earth offered very limited material possibilities. They were not suited to the new situation.

Moreover, not only did many specific traditional values and norms seem to be more or less obsolete, but the very idea of the value of tradition came to be questioned.

Whereas traditional science, on account of its belief in evident principles, is more or less dogmatic, experimental science is by its very nature "undogmatic". It always remains possible that even principles which have proved their worth in explaining certain phenomena may have to be revised in the light of new data. It was only logical that this "undogmatic" scientific approach should be extended to the whole of civilization, particularly as traditional principles were undermined by the technological and social developments which became possible. Many of the traditional religious, political, social, moral and artistic principles and values were suspected to be only the reflection of the former conditions of life on earth. Tradition became suspect. Could tradition still be of value in times that were oriented towards the furture and not towards the past? Tradition seemed by its very nature an obstacle on the road of progress. No wonder that the development of modern science and technology caused a general cultural crisis.

Yet in the first phase of modern times this crisis, notwithstanding the enormous changes which took place in nearly all aspects of life, did not really cause as much alarm as might have been expected. Of course, there was general unrest and there were many conflicts between those who put their trust in progress and those who mistrusted progress on account of its disregard of traditional values. We find conflicts in the intellectual fields (e.g. between faith and science); in the political field (e.g. French revolution); and in society (class struggle), but the protagonists of modern times considered these conflicts as regrettable incidents and sometimes even as necessary stages on the road to progress. In the 19th century the progressive view became the prevalent attitude. European society became so fascinated by the possibilities of progress that progress itself became the main value to be fostered. Progress in knowledge and in technology would eliminate all poverty and misery. Progress would liberate mankind from its material as well as from its moral and spiritual limitations. The faith in progress was indeed so great that it was assumed that progress in those fields where it could easily be attained would more or less automatically lead to progress in other fields and to progress in general. Progress in science would lead to progress in wisdom. Improvement of the material quality of life would lead to improvement of the spiritual and moral quality of life. The undermining of traditional values and norms thus did not cause much alarm : there was a new value, progress, that could take care of the future.

The spirit of modern times was expressed in the way Western civilization started to build a new world in both the literal and the metaphorical senses. One of the main characteristics of the new civilization was its experimental nature. In building, new materials, new designs, new layouts for cities and rural areas, new transport systems, and new production methods were tried out. The experimental approach was also expressed, however, in a more general sense.

In the traditional civilization there existed in each field classical norms which were more or less generally accepted, at least over a fairly lengthy period. In the classical view the universe was an ordered cosmos in which each thing had its natural place. The same applied to society. In modern times the universe has come to be viewed as an open universe, affording mankind much greater scope for its cultural activities. The result was a kind of intellectual unrest, which expressed itself in several ways. We find, for instance, a new conception of human creativity. Formerly this creativity remained within the general pattern determined by nature and tradition (natura artis magistra : nature is the teacher of art). Nowadays creativity seeks to express itself in something that is unique and that has never existed before (noch nicht dagewesen). This was, of course, partly the result of what in philosophical circles is usually called the discovery of the "subjectivity" of the human individual.

Partly, however, it was also an attempt to find a suitable new standard, the beginning of a new tradition. The result has been a rapid succession of "fashion waves" in all fields : in philosophy, in architecture, in art and in political and social ideals. Each new "fashion" in theory or practice sought to realize the infinite potential of humanity and it is understandable that when a new approach did not achieve its aim, disappointment followed and yet another approach was tried. Of course, this phenomenon is not enterely new; what is new, however, is the rapidity with which the different waves succeed each other.

In our times there is greater unrest than ever. One of the reasons is that mankind's faith in progress has been disappointed. This is to say, we are aware that "progress" will go on, but that is precisely the cause of our fears. The faith that progress will lead to a more human world is upset, modern technological civilization seems to cause ever greater de-humanization. For this reason Man tries to control progress, but this seems to be impossible. An increasing number of people looks upon progress as a kind of evolutionary natural process. What does this mean? In nature, plants and animals are in a certain sense the agents of their own evolution, because this evolution depends upon their activities as living beings. Yet, in another sense, they are the passive objects of evolution. They cannot direct its course. In the same way the human race seems to be the passive object of its own evolutionary history. By its intellectual, technological, economical and social activities mankind seems to cause an evolutionary process without being able to control its course.

It seems as if nature has taken revenge on Man. Human beings thought that by their intellectual and technological activities they could emancipate themselves from nature, but they are still subject to a natural process. The difference from the former situation is, however, that in the past Man did not feel responsible for nature or for what happened in nature, whereas in the new situation he does feel himself so responsible. The new situation is man-made, and yet we do not have it under our control. We seem to have overplayed our hand.

It is understandable, therefore, that today many voices can be heard which tell us to return to nature : i.e. to return to the place which nature seemed to have reserved for human beings, to return to a truly human scale. But what is a truly human scale?

5. WHAT IS A TRULY HUMAN SCALE?

The problem of the human scale is not an easy problem. As a slogan it sounds reasonable, but when we reflect upont it the difficulties arise.

It is true, of course, that despite the immense development of science, of technology, of our way of living, and of communicating with each other all over the world, human beings as such have not changed much. This is, first of all, obvious with respect to our life-span. Death is still unavoidable, and although normal life expectancy has been increased, it does not exceed a certain maximum. Apart from this, our natural capabilities are still the same as in the past and the same applies to our moral attributes. Modern anthropologists stress this point. And when we read

Greek philosophers or writers of 25 centuries ago it strikes us that with respect to the fundamentals of human existence, things have hardly changed. The difficulties the Greeks had with democracy, are mutatis mutandis the same as we have. Mankind still has the same ideals and although we have succeeded in realizing some of them, in other aspects we are even further from a solution than ever. The horrors of modern warfare, for example, are greater than they ever have been, and methods of repression are more effective than ever although we have abolished slavery. These considerations lead to the conclusion that if we have not changed much we should be better to return to our modest place in nature. We simply lack the qualities needed for the place to which we have aspired in modern times. There remains, of course, the problem of what this modest place is. Simply to return to an earlier historical period is impossible. And even if it were possible, to what period should we return : to the stone age, the iron age, the Middle Ages or the 18th century?

The greatest difficulty is, however, another one. Mankind has emancipated itself from its so-called natural place in nature by developing natural gifts : knowledge and technological skill. The fact that we are able to destroy all life on earth and even the earth itself, is the result of the natural place of Man on earth as a being endowed with that unique trinity of reason, senses and hands. In conclusion : the appeal to nature and the natural place of the human race does not help us much if we want to know what is truly human in order to being able to humanize modern technology.

If the answer to the question of the humanization of modern technology cannot be found in a return to nature, can that answer perhaps be found by a return to former ideals of humanity? Is authentic humanity to be found in the ideals of Greek civilization, in those of the Christian civilization of the Middle Ages as a blending of the Christian and the Greek views of man, or in the Humanism of the 16th century - all forms of civilization unspoiled by the development of modern technology. If one of these forms of humanism is the paradigm of true humanity, then it is obvious that modern technology has deviated from the ideals of true humanism. Humanization of technology would simply mean the correction of that deviation.

The question is, however, to what extent the rise of modern technology and science affects our understanding of the classical ideals of humanism. For what human beings are to be and what society ought to be is closely related to what the real human potential is, and it is evident that modern science and technology have thrown new light on this potential. Without saying that an appeal to what is truly human cannot help us much, it is nevertheless clear that it can no more provide us with an easy answer than could the appeal to nature.

The difficulty is not that these appeals do not make sense, the difficulty is that we still do not know what the real natural and cultural (including scientific and technological) potential of mankind is. Behind this difficulty lies another one, namely that the future is still unknown. In a sense, it is, of course, trivial to say that the future is unknown. The future has always been and will always be unknown. Yet, the way in which the future is unknown to us, is different from the way in which it seemed unknown to former generations. Formerly, the specific course of events affecting the individual human being as well as the group was unknown, but the same was not true with respect to the general boundaries encompassing human existence as such. People did not know what the future would bring by way of natural and man-made catastrophes, but they did know the general dimensions of what could happen. In this respect the future would not differ from the past.

Today these general dimensions are less known than ever. We can no longer rely on the past as a guide to the future. We do not know the future development of science and technology or the future shape of society. How fundamentally unknown the future is appears when we ask whether or not the development of science and technology is still in its first phase. We simply do not know the answer. The same applies to society. Which further developments are really possible and which not? We do not know.

It cannot be denied that our ignorance of the future frightens us. Yet this ignorance can also be viewed as ultimately encouraging because it proves that reality is not as rigorously fixed as it appeared before. This means that many human ideals which formerly appeared totally utopian and therefore by definition unrealistic may in the future be realizable.

We have already mentioned that an appeal to former ideals of true humanity cannot help us much because these former ideals were developed in times when the conditions of human existence were different from those of today and of the future. This statement was not incorrect, but we are now able to give a more adequate answer to the question.

The interesting point is that the difference between the past and the future does not lie in a major change in human ideals themselves. The ideals of the Gospel, of the French revolution and of the youth of today are more or less the same; what has changed is our view of the possibility of attaining them. It can be said, therefore, that in a sense tradition is as valid as ever - not as a source of ready-made answers but as a pointer to the essential ideals of a true humanity. Tradition can indeed teach us more than ever, if we question it in the right way. For in order to know the essentials of an authentic humanity we have to analyse how, at different times and in different circumstances, people have tried to formulate these essentials. The specific modes of formulation, i.e. the specific norms in which these ideals have found expression, differ considerably. All of these modes of expression and formulation, including, of course, those of our times, are individually inadequate but together they can help us to find their authentic core.

The future is unknown, and we do not know, therefore, what the most appropriate "mode of expression" in the future will be. For this very reason, we should not place too much trust in today's current modes. Comparison with the great traditions of the past or of other civilizations can help us on the one hand to be modest and on the other to know in what direction we should go. In conclusion, tradition can no longer provide us with a specific model of what is truly human, but this does not mean that it cannot serve as a guide to the everlasting ideals of humanity.

6. CONCLUDING REMARKS

To return to the question of what human building should be, it is clear that the foregoing considerations do not provide a specific answer. It is true, of course, that in a sense the traditional triad *firmitas*, *utilitas* and *venustas* is still of value. Buildings have to be stable and useful and must radiate a certain beauty. Of these requirements, the first - firmitas - gives rise to least difficulty. Technology can take care of that. The reason is, of course, that nature does not change much. The future may be unknown, but we may assume that the laws of nature can be relied upon. In the future they will remain what they were in the past.

Utilitas poses more problems. When designing and constructing a building we can only assess its usefulness as we see it today, but the real use lies in the future. I have been told that many buildings such as laboratories and hospitals are already outdated at the moment they are put into use. Yet the same technological developments that cause this remarkable phenomenon can also help us to construct the buildings in such a way that adaptation to new requirements is possible.

Much more complicated is the situation with respect to the way we build or reconstruct greater entities such as universities, cities and transport systems. For once built they determine the future. Large universities mean a great number of students in each university. Large hospitals mean concentration of patients. Large cities exert a major influence on the way of living of many people.

It is true, of course, that the way we build our cities today is the result of social changes in family structure and family life and of changes in the relationship between family life, work, education, recreation etc, but this is not the whole story. The way we build for technological, economic or ideological reasons in turn influences family life and family structure. We will discuss this question later in a more general context, but must first consider yet another problem in connection with the requirements of stability and utility.

While the construction of a building of adequate stability may not be a great technological problem, the construction of our modern world as a whole does pose an immense problem with respect to stability. We seem to have forgotten that infinite material progress is impossible within the limits of a finite earth. In consequence, we have also to redefine the requirements of utility. What is, and what is not, really useful and what are the priorities?

Somewhat unexpectedly, perhaps, this last question brings us to the third requirement : venustas, at least when this requirement is not taken in the narrow sense of "a pleasant appearance", but in the much broader sense of trying to express in the way we build our world a certain conception of life, of society, of civilization, and of Man.

Is this conception one of infinite material and technological progress or does it reflect the belief that the value of Man is not, and certainly not exclusively, to be found in technological achievements? I am afraid that the greater part of the world we are building today primarily reflects an attitude to life that is largely determined by economic and technological factors. This does not mean the total absence of a perspective that sees in human beings more than mere makers and users of the products of technology, but modern building confronts us with so many varieties of this wider perspective that the whole gives a rather chaotic impression.

It can be argued, of course, that this lack of cultural homogeneity is the very characteristic of our times and the honest expression of our present cultural situation, and that it is, therefore, as it should be. However, for many critics of modern architecture and town planning, it is a frightening thought that, for a long time to come, the chaotic fashion in which we build our modern world will exercise a determinant influence on people's lives and minds. Is this fear fully justified? I have my doubts.

First of all, it is clear that we cannot stop building because we have not yet found a generally accepted answer to the cultural crisis. A more important consideration, however, is that the only way to find this answer is to experiment with different solutions and different concepts in mind. Finally, is it really true that environmental influence is as great as the critics suppose? Purely technologically inspired surroundings do not make people technocrats. Chaotic surroundings do not necessarily result in chaotic minds.

We came across this question earlier when discussing the influence of modern building and town planning upon family structure and life. The suggestion that people's lives and minds would be totally determined by the physical environment and the spirit emanating from that environment is based upon a supposition that underestimates one of the most essential characteristics by which human beings differ from other living creatures, namely their freedom. The behaviour of other beings is totally determined by their nature and the circumstances. There is, so to speak, no "distance" between their nature and the way they act. By their cognitive facilities human beings create this distance, which enables them to evaluate a situation and act upon this evaluation.

This fundamental human characteristic is, of course, no reason to conclude that the way we build the world does not matter at all, because human beings are able to give their own answer to what is imposed upon them. Such an idea would be a travesty of the concept of human building.

It would, however, also be a travesty of human building if we were to think that, in principle, there is only <u>one</u> way of building that satisfies the requirements of <u>human</u> building. First of all, our cultural and social situation is such that we are not in a position to know what that unique way would be. Each interpretation would only reflect the ideological or artistic fashion of the day. To impose that interpretation exclusively would come down to a kind of dictatorship. A more important objection, however, is that such an univocal idea of human building is, even in principle, wrong. Human beings have different subjective wishes and tastes. Experimentation in building is, therefore, necessary in order not only to find the best solution to our common problems, but also to leave room for variety, thus allowing for the subjective element.

The fact that experiments are necessary does not mean, however, that every experiment is good, simply because it is an experiment. Experiments make sense only when they are conducted with reference to certain fundamental ideas and guidelines. This principle applies not only to scientific experiments but also to technological and social experiments. On the other hand, such experiments should provide a deeper insight into the relevant principles. One of the things we have learned from the way we were building our modern world is that nature is not inexhaustible and not indestructible. This means that we have to find by experiment how to build in a manner which makes economical use of materials and energy.

In this connection it is instructive to compare how materials and energy are used by living nature and by our technology. Our technology is noisy, wasteful and crude. This could be an indication that we are still in a rather primitive phase of technological development. Perhaps we are still living in a kind of stone age, although iron and steel have for many centuries been the "backbone" of our technical products. But do we use this "backbone" in the refined way in which nature uses its "backbone" materials? We have certainly not exhausted the technological possibilities. It is sometimes said that an energy crisis and a shortage of raw materials could ruin Western society. This could be true, but, on the other hand, this very crisis could stimulate a real technological breakthrough.

Our technology is, however, not only primitive in terms of its wastefulness, it is also primitive with respect to human civilization. Instead of serving this civilization, technology dominates it. The second period of history, the period that precedes our technological era, may have been mistaken in its assumption that no further technological development would take place but was certainly not mistaken in its idea that human development ought to be sought, first of all, in the spiritual and moral sphere.

Consequently, the task of the future will be to find a new balance between, on the one hand, a continuing technological development with its material consequences and, on the other hand, a civilization that uses this technology without being dominated by it. The fact that we have not as yet found that balance should not alarm us too much. We have simply lacked the necessary historical experience. The technological age is still young. The fundamental human ideals and principles that guided us in the past have to be rethought and adapted to a new and unexpected situation. That takes time - time to experiment. Within the overall process of cultural experimentation, experimentation with building is one of the most important aspects because building is concerned with one of the basic human needs : to have a place in which to live and to work, to love and to pray, to meditate and to help each other.

THE ROLE AND PROSPECTS FOR STEEL CONSTRUCTION IN THE MAJOR ECONOMIC ZONES

Chairman: P. BORCHGRAEVE, Director, Centre Belgo-
Luxemourgeois d'Information de l'Acier,
Bruxelles

- Introduction by the chairman
- The role and prospects for steel construction in North America
- The role and prospects of steel construction in Japan
- The role and future outlook of steel construction in Western Europe
- Steel in the Middle East - A challenge
- Steel construction in the developing countries
- Summary of the session and discussion

INTRODUCTION

to the session on

THE ROLE AND PROSPECTS FOR STEEL CONSTRUCTION IN THE MAJOR ECONOMIC ZONES

P. BORCHGRAEVE, Chairman

When we devised the programme for this conference we thought it would be interesting to stand back a little before getting down to details, and to consider the position as regards steel construction in various economic zones of the world.

Why the need for this broader view?

Although we are more familiar with the situation in Europe, it is essential for us, faced with diminishing outlets, to take the trouble to diagnose the position clearly, to set out our objectives and to evolve the most appropriate courses of action to meet those objectives. Success will almost certainly depend on a more dynamic and imaginative approach.

Examination of the position in the other major economic zones can help us considerably. It is useful to study the opportunities and conditions of competitions which exist elsewhere. The way problems are tackled; the methods used, the organizational structure, development programmes to maintain and expand outlets in competition with other material; the results obtained : these are all aspects which could point the way towards specific solutions and remedies.

For this reason we have invited a number of key speakers to explain to us the situation in their own economic zones.

We hope this comparison will help to increase our awareness of the markets open to steel construction by virtue of a dynamic and creative approach within the context of a planned overall strategy. Let us hope the message of this meeting can sustain our faith in the future.

THE ROLE AND PROSPECTS FOR STEEL CONSTRUCTION IN NORTH AMERICA

S. E. CHEHI

Manager, Sales Engineering
Bethlehem Steel Corporation

Summary

Throughout the last century, steel and construction have been mutually dependent upon one another. Modern construction would not be possible without steel; many steel developments would not have occurred if the needs of construction had not required our industry to develop new and better products.

But what has been developed into a traditional market for steel is not necessarily going to remain our market, at least not without some determined effort on our part. Traditions are changing, especially through advanced materials technology and design innovations by our competitors. To meet the challenge of competitive materials in construction, the North American Steel Industry has developed a response, a response based on technical market development. This can take many forms, but all are oriented toward providing a meaningful support service to architects and engineers.

In North America there are still tremendous opportunities for constructional steels. We believe that our approaches to marketing, our technical work with designers, will assist in insuring that future for us.

1. INTRODUCTION

The title of this presentation is lengthy; the nature of the topic is equally lengthy, for a complete discussion would span a century of history. The prospects for the future are no less impressive, for steel is the predominant construction material of the past - the present - and the future.

Throughout this century of history, steel and construction have been mutually dependent upon one another. Modern construction would not be possible without steel; many steel developments would not have occurred if the needs of construction had not required our industry to develop new and better products.

2. MARKETS AND PRODUCTS

Figures 1-3 identify the construction market in North America, in 1979 a consumer of about 32 million tons (29 M.t) of steel.

Figure 1 shows the relationship of construction to other key markets. Figure 2 traces these markets over the past decade. Only Automotive shows a decline in recent years, principally through production of smaller cars and an increasing use of plastics and aluminum.

Although the usual concept of structural steels is one of either shapes or plates, a broad cross-section of other steel products is predominant. Figure 3 shows relative percentages. The major part, 69%, is made up of sheets, bars, wire and other products. The remainder, 31%, is the normally recognized shapes, plates and piling.

Typical examples of the non-shape and plate group are shown in Figures 4 and 5. To set the stage then, construction in North America is a big market; it's a diverse market; it consumes a wide range of steels. The North American steel industry has every reason to consider it a prime opportunity market for years to come.

3. COMPETITIVE MATERIALS

But what has been developed into a traditional market for steel is not necessarily going to remain our market, at least not without some determined effort on our part. Traditions are changing, especially through advanced materials technology and design innovations by our competitors. And they are very good at what they do; Figures 6-8 show the best of modern North American concrete construction.

What does this mean? Simply that competitive materials are no longer on the horizon. Just as steel replaced iron and wood a century ago, steel's competitors are here to stay and gain an increasing share of the construction market. But what is important to all of us - their market growth will come at the expense of at least part of our market position.

4. STEEL INDUSTRY REACTION

Past is prologue, prospects for steel construction in North America are largely dependent upon how we react to the existing and future threats of competitive materials. Steel's future can be bright, but only if we fully recognize and understand all aspects of the competitive material situation and their approach to our traditional markets.

First of all, competitive materials do not just appear or gain a share of the market without reason. Designers, architects and engineers, select building materials on the basis of a lengthy and complicated decision process. Their responsibility to an owner is to find the best material for that particular job. In some cases there can be no question about material selection, such as the steel strands of a suspension bridge. But for a growing number of applications, steel's functions and costs can be matched by competitive materials.

Figure 9, two buildings in Chicago, shows an excellent example. On the left, Water Tower Place, 77 stories of modern high-rise construction using the latest innovations in both high strength concrete and reinforcing steel. On the right, the John Hancock Building, 100 stories of steel.

To meet the challenge of competitive materials in construction, the North American steel industry has developed a response, a response based on technical market development. This can take many forms, but all are oriented to providing a meaningful support service to architects and engineers. In one form we assist in what is called a Preliminary Framing Analysis, a proposed design scheme or variety of schemes. Its intention is not to design a structure; we do not do the work of the architect or structural engineer. But what we do is relate our industry's many man-years of experience to the job in hand, suggesting to the designers the most recent innovations for economical and practical use of steel framing. Key sections of the structure are sketched out; recommendations are made for flooring, ceiling systems, and fire protection

A number of different framing systems and steel grade selections are run through a computer to determine required steel quantities. And these quantities, along with estimates for the other components making up the in-place structural frame, are given price estimates. This results in bottom line costs, on a square foot basis, for typical structural analyses. This information allows the designer to compare various types of proposed steel framing systems, selected for their applicability to steel, as well as make comparisons with competitive materials. He and the owner make the final decision; we apply our technical expertise to insuring that they are considering the best ways of using steel.

If needed, involvement continues through construction. The key point is that all of this work is done by the steel industry. In the U.S.A. this marketing approach is done by individual steel producers. If a job goes to steel, the materials order quite often goes to a producer not involved in the marketing effort. But we do not object, for all construction in steel benefits all of us in the long run. In Canada the situation and trade practice laws are a little different. A joint industry approach can be made on a national basis at a trade association level.

The more interesting of these market developmental jobs are followed up by technical brochures. Information is often reproduced in advertisements in architectural and engineering magazines. Through this type of promotion, steel industry technical marketing efforts are well identified to the design professionals who, in turn, recognize the contributions we make to their efforts.

To summarize this section, the above approach has yielded the greatest success in our technical market development. Competitive materials, as mentioned before, often can perform similar structural functions - at similar or lower costs. Our job, on a total industry level, is to make sure that the designer has in front of him the most recent information on design innovations and materials technology.

5. CASE HISTORIES

There are many variations on this marketing theme, each one meeting a particular challenge and leading to further opportunities for steels in construction. A few brief case histories follow:

a. Open-Deck Parking Structures

In the early 1960's, practically all open-deck parking structures were of concrete construction. Steel had less than 10% of a market that was predicted to show some extraordinary growth. The reason for concrete's dominance was a general building code requirement for the fire protection of steel framing. This, particularly in garages where physical damage to the protection must be considered, can be expensive in both first cost and maintenance. The result - it was less expensive to build in concrete than to protect a steel frame.

Now if only bare steel could be used! The steel industry, through American Iron and Steel Institute, started working on this problem. We surveyed the experience of garage owners, found that parked automobiles were not a fire hazard, and published a report on the excellent fire experience of open-deck parking garages. It convinced a few people that bare steel was safe, but we needed more evidence to change the codes and insurance rates. So, parallel to testing done elsewhere in the world, we burned cars in a bare steel parking structure - while it was open for business. With the results recorded on film and promoted to insurance underwriters, designers, owners and code officials, we made our point that fire would not spread and that steel indeed was safe.

Finally the major codes were revised to permit widespread use of bare steel framing. Figure 10 shows what happened to steel's share of the market. Back in the 1960's we had 9%. Today, steel's share is 30% and gaining - at the expense of concrete - in a growth market.

b. Cold Formed Steel Design

American Iron and Steel Institute's "Cold-Formed Steel Design Manual" is recognized even beyond North America for the structural design of light gauge steel members. Without this document, designers would not have available to them rational and widely recognized methods for designing constructional steel products made from sheet and strip rather than shapes and plate. And of even greater importance, without this manual many attractive markets for sheet steel would not have developed as quickly, nor as completely, in favor of steel. To prove this point, the pre-engineered steel building market uses sheet products almost exclusively for structural end uses. Figure 11 shows the trend line of what has happened to this market in the U.S.A. during the past 20 years. Steady growth, no sign of a saturated market; today a consumer of 1.4 million tons (1.3 M.t) of steel a year. But most important of all is that steel industry research leading to the Design Manual began back in 1939. Perceiving a market need, research initiated and sponsored by AISI continues today for the further development of innovative and economical light gauge structural solutions.

c. Load and Resistance Factor Design

This is the North American method of proportioning structural members and connections so that strength and serviceability limit states are greater than factored load combinations. Simply it's this: The anticipated strength of any structural component falls within a reasonably predictable Gaussian curve. Loads fall within a similar curve, although over a wider range of predictability. The design concept then is the selection of members such that their resistance does not fall within the shaded area below anticipated loads - the area of predictable failure. The steel industry goal is to incorporate these new design concepts into the standard specifications for constructional steel design.

d. New Materials

Most exposed exterior steel in construction is left bare and unpainted, what we call Weathering Steel. Its first major architectural use was by Eero Sarrinan in his John Deere Corporate Headquarters built back in 1964. This use of steel has worked out so well that an addition to the original building, finished in 1978, uses the same concept of exposing the frame. But as beautiful as this new product is for architectural applications in buildings, it can be a real money-saver in bridge work. A new product - a low maintenance product for crowded high traffic areas where maintenance and repainting are difficult and expensive, was needed.

Weathering Steel fits this need and has increased the use of steel in this market area, typified by the grade separation bridges shown in Figure 12.

e. Trade Associations

The American Institute of Steel Construction represents the steel fabricators of America working in cooperation with the steel producers. Just north of the border, the Canadian Institute of Steel Construction parallels American efforts.

In 1927, AISC came out with their first industry-wide manual which contained, within one cover, all specifications and structural shape descriptions needed for the design of any steel framed structure. This effort has continued and grown over the ensuing decades. Today, AISC publishes a variety of technical and promotional documents. And in further support of steel construction, they conduct an annual Engineering Conference plus design seminars and courses around the country. To emphasize peer recognition, they conduct a biennial competition for the most beautiful bridge structures of various categories.

Similarly, representing American, Canadian and South American producing mills, is American Iron and Steel Institute. Within AISI, the technical marketing approach comes under jurisdiction of a major committee, the Committee to Promote the Use of Steel. It is their task to pull together, for the good of the industry, the technical and research efforts of the Committee on Construction Codes and Standards and those Product Promotional Committees responsible for structural shapes, plates, pipe, wire rope, sheet and others. Supplementing these efforts, AISI's Engineering Division is charged with the responsibility of insuring that the American building codes are constantly updated to follow the latest advances in steel designs and materials. In addition to these two principal groups, the list of those working on constructional steels can go on and on - the Metal Building Manufacturers Association, the Steel Joist Institute, the Steel Deck Institute, the Steel Structures Painting Council, the Industrial Fasteners Institute, the Research Council for Structural Joints, the Column Research Council and others.

And we have yet another ally, the steel fabrication and erection trade unions. They recognize that our efforts insure their jobs, and toward this end they lend financial and code support to many of our activities.

6. GROWTH MARKETS

All the preceding stories have been of the past and present. All cited efforts on technical market development shall continue, but we see some particular areas where continuation will be emphasized, others where new efforts will be initiated, growth areas such as:

The production of synthetic fuels

Residential construction, single and multi-family

Public transportation

Pipelines

Security measures

And in some areas of past growth, we see re-growth opportunities. In my country alone, it is estimated that over 100,000 highway bridges in service today are in need of either major repair or replacement within the next few years. Steel can have a good share of this market, particularly in the rehabilitation of existing steel bridges.

7. CONCLUSION

The challenges to steel are many and growing in number. But if we are prepared to search for them, opportunities are there as well. And we cannot relax in this search, for although there may have been many recent innovations in the production and development of new steels, steel is still a traditional constructional material. Our competitors can make their gains principally at our expense, and they are aware of it.

But the fact that steel is a traditional material also gives us an advantage. We know the structural characteristics of our existing steels, quite precisely and with a high degree of reliability. We also know that steel is a remarkable metal, a metal that can be varied to meet the as-yet specified needs of our construction customers.

In North America, there are tremendous opportunities for constructional steels. Steel is a dominant constructional material and the steel industry, whenever possible, will meet the challenges of competition. To this end we have developed technically-based methods to aggressively market our products to the construction industry. For steel is a material of the past, a material of the present, and can be a significant material of the future. We believe that our approaches to marketing, our technical work with designers, will insure that future for us.

CREDITS

Many have contributed to both the contents and photographs used for this paper and its presentation. In particular, acknowledgement is given to American Iron and Steel Institute, the American Institute of Steel Construction, the Canadian Institute of Steel Construction, Engineering News-Record, the Metal Building Manufacturers Association, the Portland Cement Association, Stelco, U.S. Steel Corporation and Bethlehem Steel Corporation.

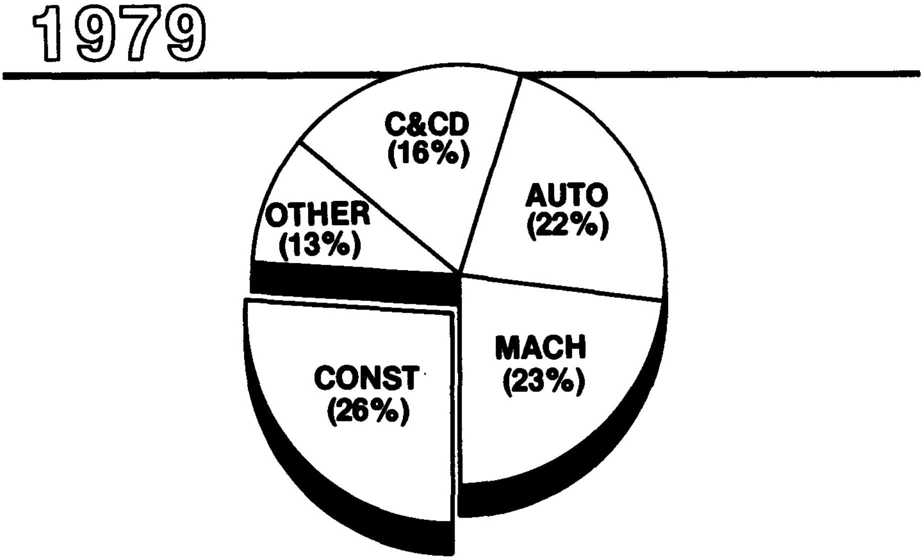


Figure 1.
Steel Market Distribution - North America

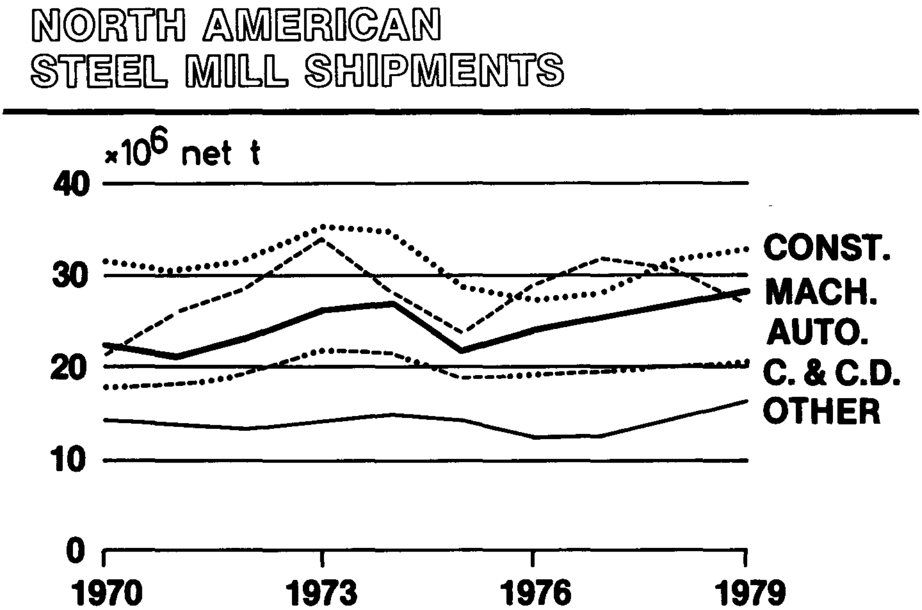


Figure 2.
Steel Market Growth - North America

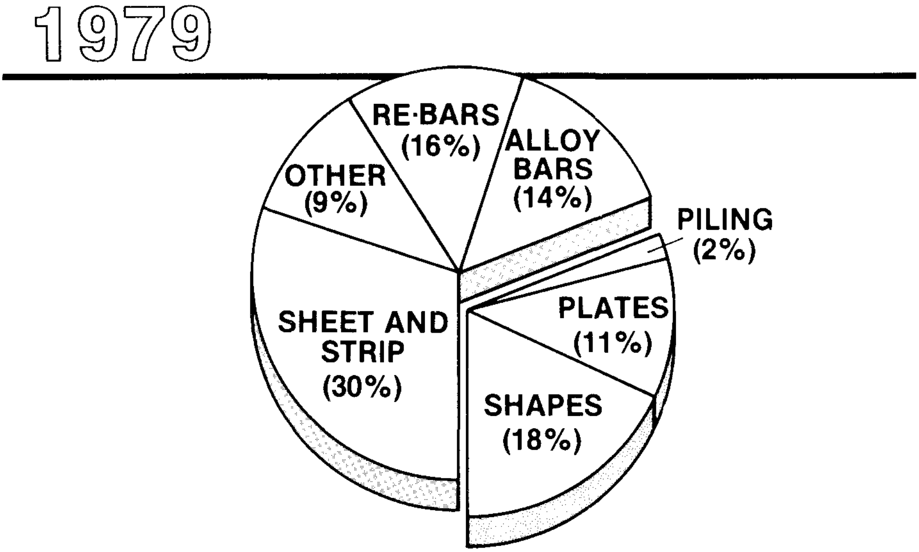


Figure 3.
Steel Product Distribution - Construction Market

Figure 4.
All-Steel Industrial Roof System

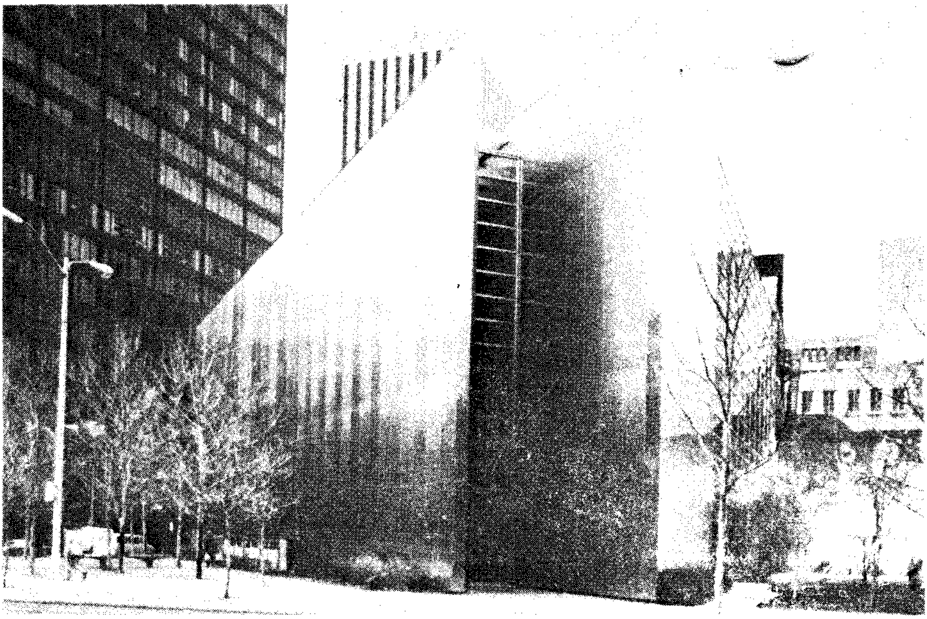


Figure 5.
Stainless Steel Facade, Dayton

Figure 6.
City Hall Complex, Toronto

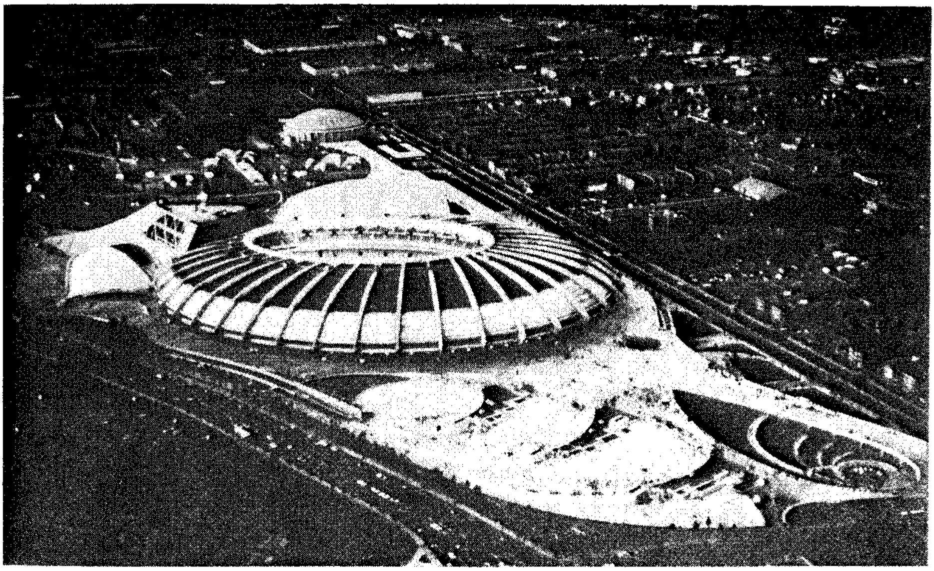


Figure 7.
Olympic Stadium, Montreal

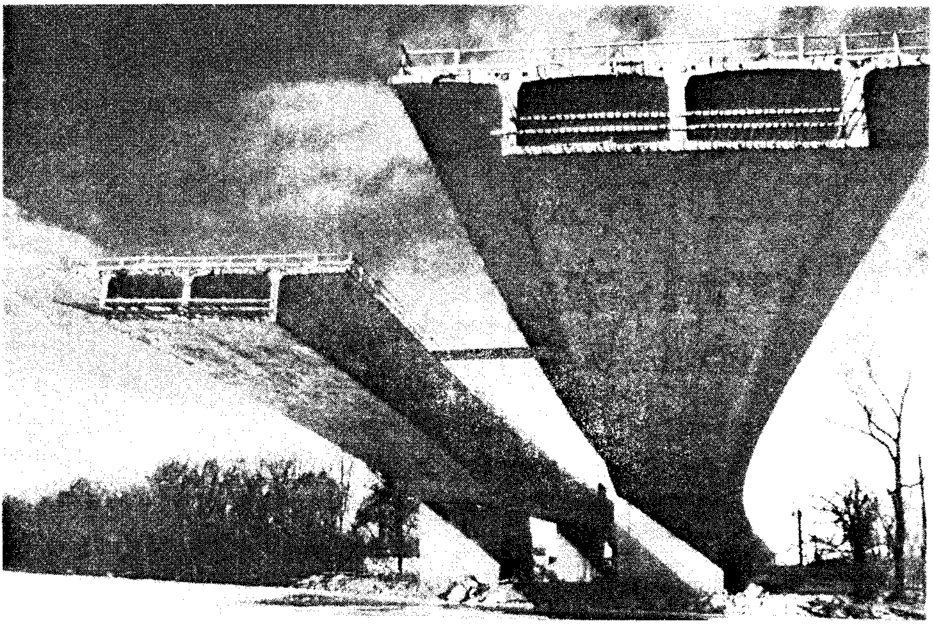


Figure 8.
Cast-In-Place Concrete Box Girders, New York State

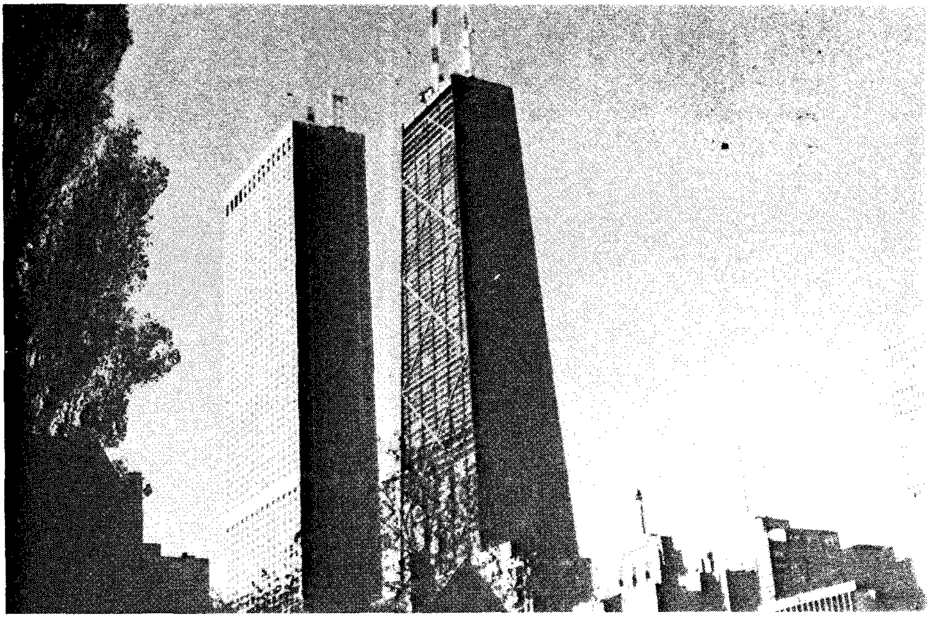


Figure 9.
Water Tower Place and John Hancock Building, Chicago

1979

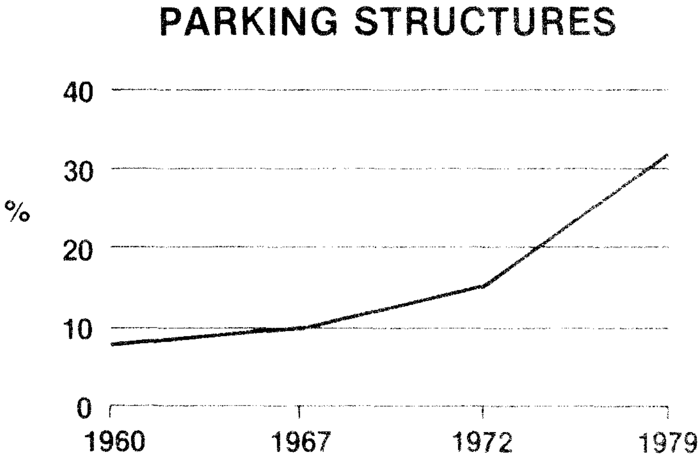


Figure 10.
Steel's Share of Open-Deck Parking Structure Market

METAL BUILDING MARKET GROWTH

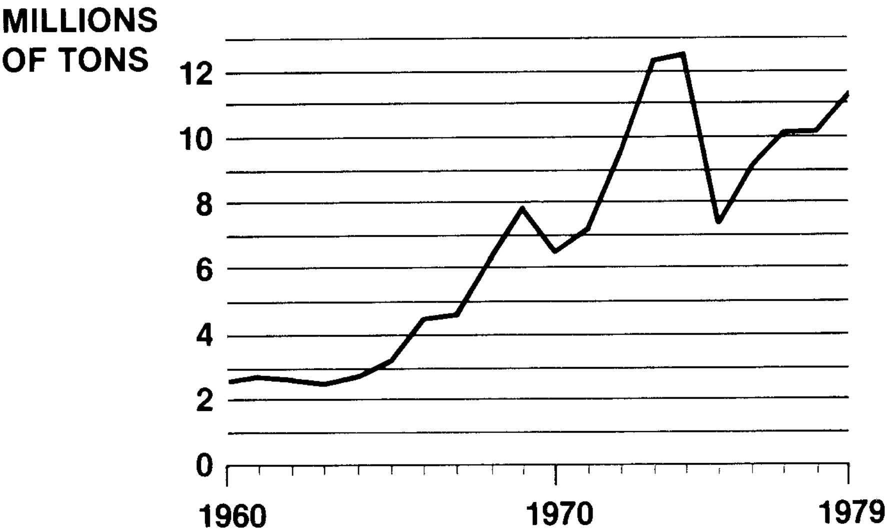


Figure 11.
Growth Trend, Pre-Fabricated Steel Buildings

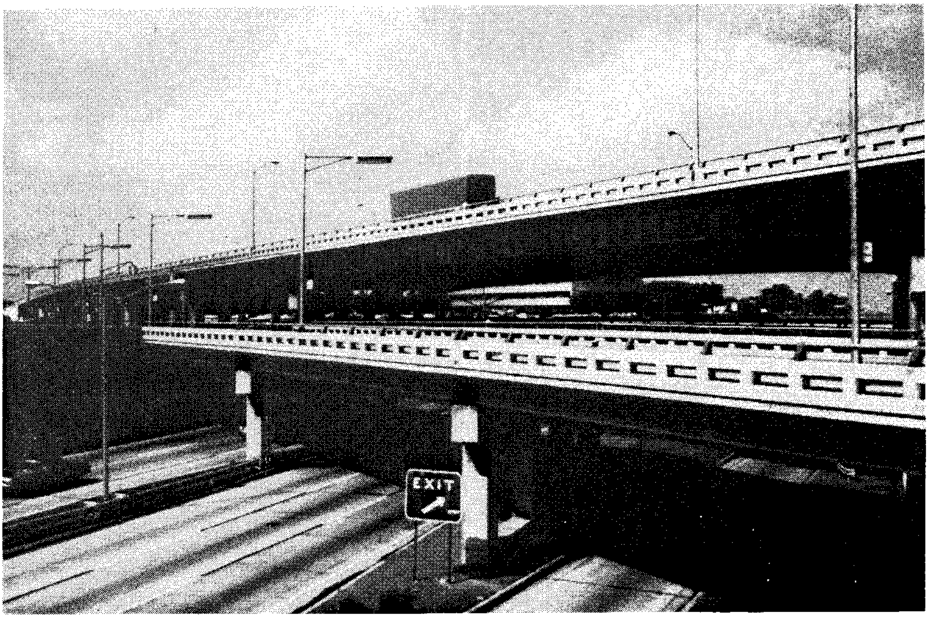


Figure 12.
Grade Separation Bridges, Detroit

THE ROLE AND PROSPECTS OF STEEL CONSTRUCTION IN JAPAN

T. HORI

Counsellor

Market Development Committee
The Kozai Club

Summary

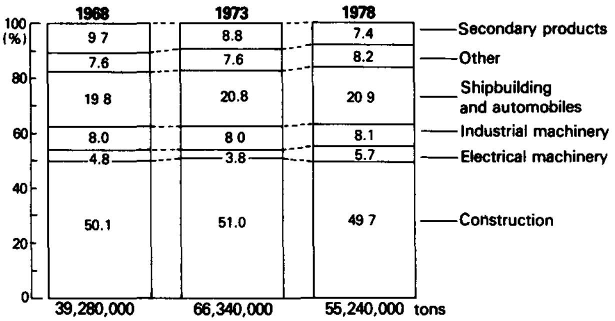
Japanese industry is famous for its rapid progress since World War II. This report provides an overview of the current status of the steel industry and the construction industry, which together have served as the prime motive force behind Japan's industrial growth. Factors contributing to the development of the steel industry are covered in three sections: 1) search for better processes and products; 2) joint efforts for market development; and 3) cooperation with other industries. As for the construction industry, summaries of representative construction projects in Japan are presented, followed by a brief survey of the role of steel structures in construction. In the final section, the prospects of steel are considered. A new situation has arisen worldwide in the areas of resources, energy and the environment. All industries are doing what they can to respond to these changes. There are still numerous unexplored areas where steel can be applied with advantage if the right steel is put to the right use. As long as the steel industry continues its active research for new ways to serve new needs, there is no doubt that the "Age of Steel" will continue into and through the 21st century.

1. INTRODUCTION

After World War II, all industries rose to the task of rebuilding Japan's economy from the ruins. At the center of these efforts, the steel industry endeavored to learn new steel technology from its counterparts in advanced nations. At the same time, the industry set out to strengthen its own technological development capability. As a results, Japanese steelmakers first made improvements in the technology they received from abroad, and today are contributing their original developments to world steel technology.

Fig. I shows the pattern of Japanese consumption of ordinary steel products. One of the charactristics of steel demand in Japan is that construction always accounts for something like 50% of total domestic demand. Sustained economic growth and a continuing need for infrastructure improvement have supported this strong demand for steel in construction.

Fig. I. Consumption of ordinary steel products by market in Japan



Source: Japan Iron & Steel Federation

Now let us consider some of the reasons for the growing use of steel in so many demand sectors.

2. STEELMAKERS' SEARCH FOR BETTER PROCESSES AND PRODUCTS

Japanese steelmakers have engaged in fierce technological competition in their struggle for corporate survival. Efforts to improve their technological advantage took place on three fronts.

2-1. Improvement of Equipment and Operating Technology

Until the early 1970's, steelmakers were primarily concerned with expanding their capacity and raising productivity so as to keep up with Japan's rapid economic growth. All steelmakers thus operated large plants of advanced design.

But emphasis changed sharply with the oil crisis of 1973. Resources, energy, labor and environmental protection have all emerged as restraints.

The focus of steel industry attention has shifted to stable operation, greater service life of equipment, rationalization and automation of processes, changes in raw materials and fuels and recovery of resources and energy. All these efforts are aimed at boosting product yield, saving energy and cutting costs.

Table I shows typical examples of recent technological developments in the Japanese steel industry that help to achieve these goals. Among them, particularly striking results have been achieved with large-capacity blast furnaces, BOF steelmaking, continuous casting and hot-direct rolling. These developments are largely responsible for the present yield of almost 90% for steel products from crude steel, and for reduced fuel consumption. Wider application of computers to production processes and plant administration, meanwhile, has improved both operating efficiency and the level and consistency of product quality.

Table I. Major technological developments in the Japanese steel industry in the 1970's

Ironmaking:	* Large-capacity blast furnace * Movable armor for adjusting burden distribution at blast furnace top * Fine coal blowing into blast furnace * Power generation utilizing blast furnace high top-pressure gas * Computer control of blast furnace operation * Coke dry quenching * Briquette-blend coke manufacture
Steelmaking:	* Combination blowing in BOF operation * Pre-treatment of hot metal * Secondary refining by ladle * Ultra-high voltage electric furnace * New continuous casting technology (variable-width mold, mold-level control, electromagnetic stirring, compression casting)
Rolling:	* Hot-direct rolling of shapes and hot coils * Controlled rolling of plate * Automatic shape control of plate and sheet * Continuous annealing and processing of cold rolled sheet * On-line flaw detector for rolling of sections, plate, hot coils and pipe and tube

The concept of IE (industrial engineering) has been introduced and promoted by all steelmakers to speed rationalization. Equally important, *Jishu Kanri* activities (workers' voluntary group activities to improve job performance) by the men on the production floor have been remarkably effective in cutting costs and improving operating technology. This has been possible because of the high morale of employees and effective in-house training programs. And the availability of well-trained and highly motivated technical staff who are quick to respond to a company's needs can make a great difference in the level of its technical performance.

Table II. Comparison of steel industries of major countries (1978)

	Number of large capacity blast furnaces (over 2,000 m^3 total volume) in operation*	BOF steelmaking capacity (million tons)	Output of primary products by continuous casting (million tons)	Energy consumption per ton of crude steel produced (1,000 Kcal)
Japan	38	123.0	47.2	4,767
U.S.A.	7	98.9	17.6	6,258
Canada	2	10.4	3.0	5,040
W. Germany	8	50.6	15.7	5,236
U.K.	1	21.8	3.1	6,118
France	4	23.7	6.2	5,733
Italy	5	17.6	10.0	4,158
Holland	2	7.2	-	4,284
Belgium	0	18.4	2.7	-
Luxembourg	0	6.7	-	-
U.S.S.R.	31	41.0	14.4	-

* 1978 year-end for Japan, June 1979 for other countries

Source: IISI, Japan Iron & Steel Federation

2-2. Development of New Products and Construction Methods

Product development programs must meet requirements of quite different kinds: a widening range of applications, increasingly strict customer demands, energy conservation considerations and the need for lower-priced steel products for general use. As a result, product development shows a pronounced tendency to concentrate at the two ends of the scale: high-quality grades of steel for special uses and lower-priced materials for general use.

Recent product development advances include: 1) high-purification technology to reduce impurities in steel, 2) utilization of the fine grain phase and 3) improvement of processing and heat-treating technology. Attracting more and more attention in new product development are new alloys, composite materials of steel and amorphous materials, and new surface-treated materials.

New construction methods are very much a part of steelmakers' research and development interests. Table III shows some of the most important steel products for construction that have recently appeared, and Table IV summarizes examples of new construction methods.

The following trends are notable in the development of steel products for construction:

* Increase in fabricated and composite products (prefabrication)
* Increase in atmospheric corrosion-resistant steels and surface-treated steels (maintenance-free, long life)
* Development of new fabrication and utilization technologies (welding, press-forming, automation, etc.)
* Development of new construction methods (labor saving, rationalization, energy conservation, rapid construction, etc.)

Table III. New steel products for construction use developed in Japan

Steel products	Fabricated products
* Weldable high-strength steel (60-80 kg/mm^2 grades)	* Non-negative friction pipe pile * Box column, box truss
* Lamellar-tear resistant steel	* Centrifugally-cast pipe column
* Seawater-resistant steel	* Heavy-wall pipe column
* Atomospheric corrosion-resistant steel	* Steel segment for shield tunnel * Tunnel support
* Non-magnetic steel	* Road-cover deck
* Extra-heavy section plate	* Soil saving dam
* Heavy column section	* Slope protector for road construction
* High-strength, high-toughness large-diameter line pipe	* Retaining wall * Noise-absorbing panel
* Line pipe for sour gas use	* Prefabricated H-beam bridge
* Coated pipe	* Grating for bridge flooring
* High-strength steel chain	* Decorative panel
* Pipe piling	* Swimming pool
* Vibration-damping laminated sheet	* Stainless steel bath
* High-quality pre-coated sheet	* Car-parking building

Table IV. New construction methods developed by the Japanese steel industry

Foundations
* Walled pipe pile
* Underwater steel cell
* Soundproof pile driving
* Underwater cutting of pipe pile
* Automatic field welding of pipe pile
* Multi-column bridge foundation

Embankment
* Jacket-type steel embankment
* Walled pipe pile embankment
* Steel cell embankment

Bridges
* Prefabricated parallel wire strand for suspension bridge cabling

Pipeline
* Automatic field welding
* Capsule-tube transport
* Slurry transport

Offshore structures
* Wide-flange beam laying for circular-arc sliding prevention
* Steel breakwater

Building frame structures
* Construction by wide-flange beam and pre-cast concrete slab
* Prefabricated frame
* Building package system (frame, wall, roof, electrical equipment, finishing material supplied as a package)
* Flooring and roofing system (equipped with duct, electrical equipment)
* Steel quake-resistant bearing wall
* Large-size exterior wall panel

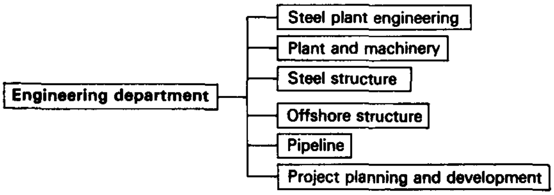
Joining
* High-tension bolt joining
* Joining of large-diameter RC bar
* Factory-assembled steel reinforcement
* Field welding

2-3. Advance into Engineering Services

Steelmakers have begun to advance into plant engineering services, a high added-value field. They typically offer comprehensive project services, including design, layout, equipment manufacture and installation, operating and technical guidance.

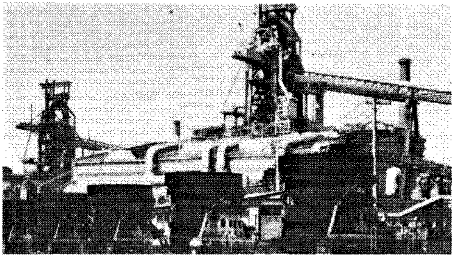
A marked trend is also visible among steelmakers to seek tie-ups with general contractors, heavy machinery manufacturers and other sectors for

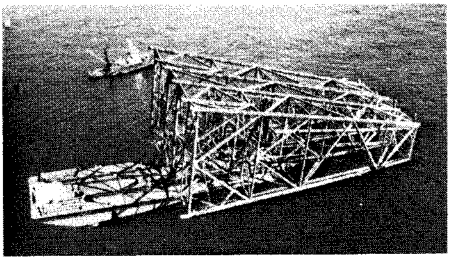
Fig. II. Example of organization of engineering department in a steel company

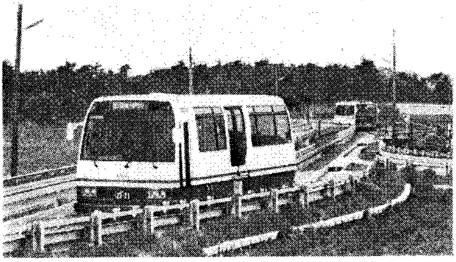


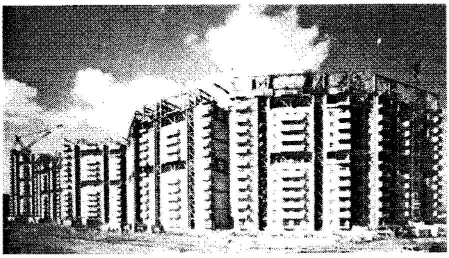
mutually beneficial joint activities. This move is aimed at effective use of the expertise and technological capabilities related to these fields that have been built up within the steel industry. Steelmakers have established sizeable engineering divisions, allocating considerable manpower to them.

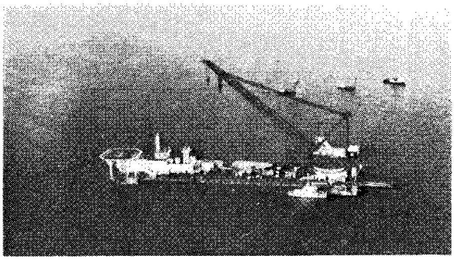
The wide range of engineering and construction projects undertaken by steelmakers is indicated by the following list of typical projects:

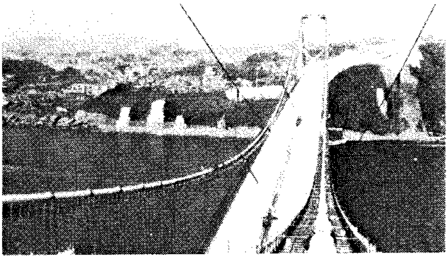

Blast furnaces at new steelmaking complex

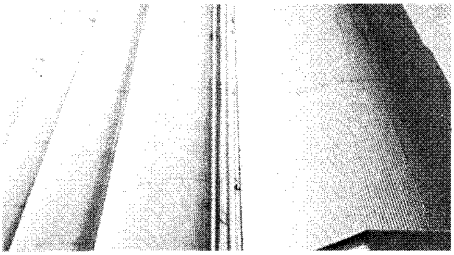

Oil/gas production platform

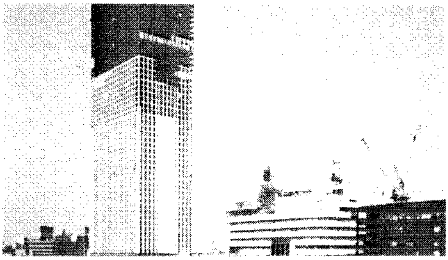

New transportation system (dual-mode bus system)


High-rise housing complex


Offshore gas pipeline construction


Long-span bridge cabling

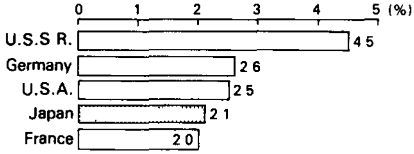

Steel silos


Building construction

2-4. Research Expenditures

Research and development expenditures in Japan, as can be seen in Figs. III, IV and V, are rather low compared to those in the United States and Europe. Most of Japan's R&D spending is in the private sector, with government outlays accounting for a relatively small percentage share.

Fig. III. R&D expenditure on natural science and its proportion to national income (1977)

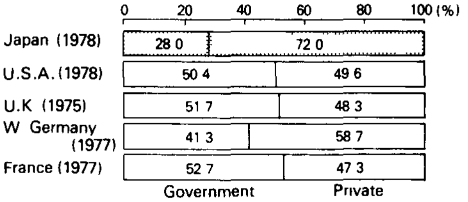


Note: (1) Estimates for W. Germany and France

(2) Expenditure of U.S.S.R. includes that on cultural and social sciences

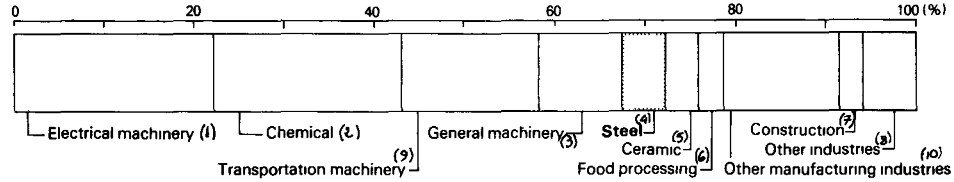
Source: Science and Technology Agency

Fig. V. Ratio of R&D expenditure by government and private sectors



Source: OECD, Prime Minister's Office, Japan and U S. NFS

Fig. IV. Japan's R&D expenditure by industry (1977)



Note: (1) Total expenditure in 1977 amounted to ¥2,100 billion, of which steel accounted for 4 9% and construction 2.9%
Source: Prime Minister's Office

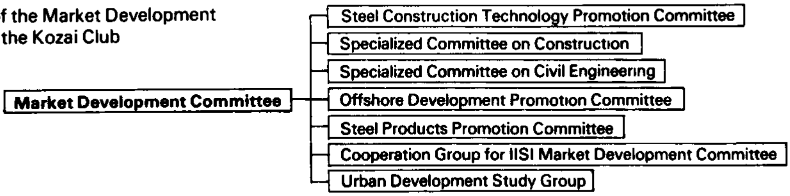
3. STEEL INDUSTRY'S JOINT EFFORTS FOR MARKET DEVELOPMENT

Among the major associations in the steel industry are the Kozai Club, the Japan Iron and Steel Federation and the Iron and Steel Institute of Japan. A major activity of these associations is market development for the steel industry as a whole.

To promote broader application of steel and use of a greater variety of steel products, extensive public relations activities are carried out to provide useful information about specific products designed to meet specific user requirements.

An example of how this important task is carried out is provided by the market development activities of the Kozai Club -- a business association established by steelmakers and trading firms in 1947. For its promotion activities, the Kozai Club has established its Market Development Committee and related ad hoc committees (see Fig. VI), composed of specialists and experts of member companies.

Fig. VI. Organization of the Market Development Committee of the Kozai Club



The Kozai Club Market Development Committee works in close cooperation not only with member companies but also with the Ministry of Construction, the Ministry of International Trade and Industry and other government agencies, academic institutions and research organizations, as well as with other trade associations of the steel industry and of many steel-consuming industries.

Among the Committee's major activities are:

* Supply and exchange of information and data
* Participation, guidance and cooperation in studies and research
* Sponsorship and execution of research programs
* Joint implementation of promotion activities, and assistance and cooperation in such activities
* Publication of special reports, manuals, guidebooks and the like

To date, the Market Development Committee has published 300 reports, the total number of copies approaching 1 million. It has also sponsored courses in about 900 locations, with total attendance of around 220,000. These wide-ranging market promotion activities have recently won official commendation from the Construction Minister.

The Committee's major publications are listed in Table V. Among them, various kinds of guidebooks and manuals are intended primarily for the practical training of design and construction engineers. They provide detailed descriptions of proper welding and inspection procedures, for example, and guidelines for earthquake-proof designs. The aim of these publications is to ensure dissemination of information about proper steel usage.

Other textbooks and guidebooks are intended mainly for sales staff of retailers and for buyers and design engineers in steel-consuming firms, to improve their knowledge of steel products. Pamphlets and the like covering specific steel applications are directed not only to retailers and buyers but also to a general readership. They contain good examples of steel use in various fields and identify the advantages of steel in these areas.

There are still few specialists in steel structures among construction engineers, who traditionally feel more at home with concrete than with steel. It is most important to focus more attention on construction engineers in the making, while they are university students, and to make such pamphlets more widely available to help them become more knowledgeable about steel structures.

In addition to the activities described above, the Kozai Club also maintains close cooperative relations with the Japanese Society of Steel Construction and business associations of steel fabricators as part of its on-going efforts to broaden the use of steel and to develop better products and utilization technologies.

Table V. Major publications of the Market Development Committee (in the Japanese language)

(1) Architecture

* Guidebook for Construction of Steel Structures
* Guidebook for Design and Construction of Steel-and-Wood Combined Structures
* Guidebook for Fireproof Design of Steel Structures
* Damage to Steel Structures Caused by Earthquake, Strong Wind and Heavy Snow, and Design and Construction Manuals for Prevention of Such Damage
* Construction and Design Standard and Commentary for Floor Plates
* Manuals for Steel Structure Construction Inspection
* Manuals for Welding Galvanized Steels
* Guidebook and Commentary for RC Structures Using Large-diameter Deformed Bars
* Quake-resistant Design of Steel Structures
* Quake-resistant Design Method for Low- and Medium-rise Steel-frame Buildings
* Steel Structures and Their Ease in Construction
* Standard Joints for Wide-flange Beam Structures
* Design Method for RC Structures Using Deformed Bars
* Practices of Steel Structure Construction
* A Collection of Design Methods for Steel Pipe Structure Joints
* Design Exercises for Joining Steel Structural Members
* Standardized Construction of School Buildings
* A Collection of Temporary Construction Using Steel Structures
* Steel Structures in Japan (No.2-10)
* Report on Damage Caused by Miyagi Earthquake in 1978

(2) Civil Engineering

- * Guidebook and Commentary for Pipe Pile Construction
- * Manuals for Design and Construction of Light-gauge Steel Structures
- * Knowledge for Steel Products for Construction Engineers
- * Data for Corrosion Protection of Steel Products
- * Manuals for Steel Fence Construction
- * Study on Noise-proof Steel Bridges
- * Guidebook of Road Design for Environmental Protection
- * Steel and Construction--Diverse Applications of Steel in Construction

(3) Offshore Development

- * Design Guidebook and Commentary on Offshore Structures
- * Guidebook for Corrosion Protection Methods for Offshore Steel Structures
- * Design Manuals for Offshore Working Platforms
- * Corrosion Protection of Offshore Structures in Japan
- * Offshore Development and Steel
- * Development of Marine Products and Steel

(4) Urban Development

- * Urban Development and Podium (man-made space)

(5) Introduction of Steel Products

- * Steel Bars for Construction
- * Steel Shapes for Construction
- * Steel Products for Noise Prevention
- * Steel Plates for Construction
- * Steel Sheets for Construction
- * Steel Pipe and Tubes for Construction
- * Steel Silos
- * Gardening Facilities and Steel Products
- * Atmospheric Corrosion-resistant Steel
- * Steel Fibers
- * Sewage Facilities and Steel Products
- * Roads and Steel (for Safety and Disaster Prevention)
- * Harbours and Steel
- * Bicycle Parking Lot and Steel
- * Automobiles and Steel

(6) Other

- Environmental Protection and Steel
- Food Problems and Steel
- Knowledge and Business Guidebook for Steel Products for Construction Use
- Guidebook for Steel Products in Japan
- List of Available Sizes for Steel Products in Japan

4. COOPERATION WITH OTHER INDUSTRIES TO PROMOTE CONSTRUCTION ACTIVITIES

The status of promotion of construction activities among related industries in Japan is best indicated by a brief description of the Japan Project Industry Council (JAPIC), an organization created by steel industry initiative in November, 1979.

JAPIC is a private association comprising eight organizations within the construction, steel and other related industries. Senior executives of member companies represent these eight organizations in JAPIC, which aims at realizing an affluent, vigorous society in the 21st century. To this end, JAPIC promotes large-scale construction projects designed for the most effective use of Japan's land space -- which is limited to 370,000 km^2 -- and improvement of the infrastructure.

In particular, JAPIC attempts to build a consensus not only in industrial circles but also in other non-governmental sectors of society so that the vigor of private initiative can be marshalled and effectively focused. JAPIC seeks understanding and cooperation at the level of individual citizens, and also makes requests or proposals to the government regarding overall planning and implementation of large-scale projects.

At the moment, JAPIC's activities are being channelled through the following working groups:

- Urban Development Committee:
  Urban development, particularly utilization of space above railway facilities, rivers, streets and the like and rebuilding the existing Tokyo beltway systems as underground highways
- Water Resources Development Committee:
  Effective water utilization for wider-area service, particularly the promotion of an overall water utilization plan for Tokyo and neighboring areas and removal of silt behind dams

- Energy Development Committee:
  Energy development, particularly the promotion of small and medium-size hydroelectric stations
- Coastal Area Development Committee:
  Promotion efforts to achieve early realization of highways around and across Tokyo Bay and development and redevelopment of coastal areas
- Osaka Area Project Committee
  Promotion efforts to achieve early realization of Osaka International Offshore Airport; construction of highways around Osaka Bay and development of academic towns

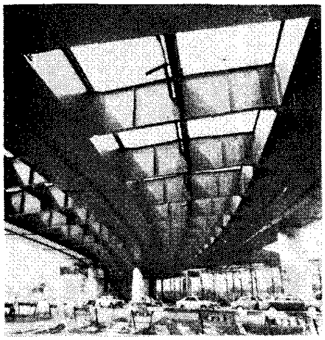
In addition, JAPIC from time to time organizes committees, study groups and conferences to undertake special studies, public relations, communications with related organizations and various other activities.

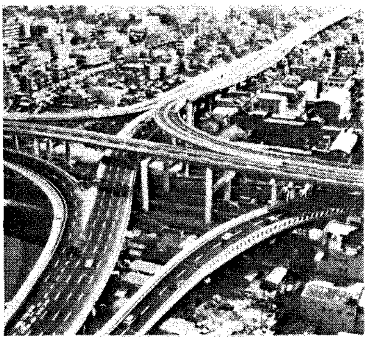
5. LARGE-SCALE CONSTRUCTION PROJECTS IN JAPAN

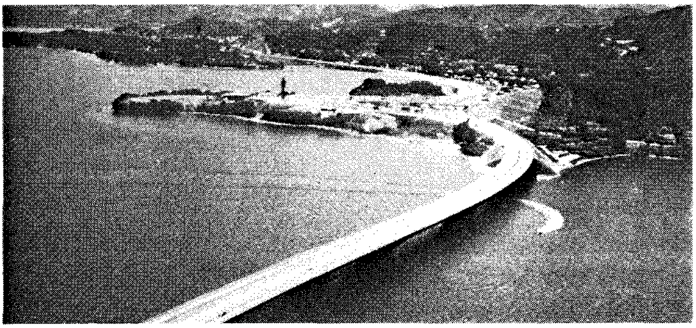
In Japan, large-scale construction projects have given much impetus to development of new technologies and materials. In addition, these projects naturally require huge tonnages of steels. The following are representative examples of large-scale construction projects, some still in progress, that are closely linked with recent developments in steel demand and steel technology.

Expressway

To cope with the growth of automotive traffic, construction of new expressway networks — both within and between cities — is proceeding at a rapid pace throughout the country. Plans call for the construction of nationwide expressways totalling 10,000 km in length, of which 2,200 km is already in service. In Tokyo, metropolitan expressways cutting directly through the urban center were designed to solve traffic congestion problems. Routes totalling 140 km are now in service, handling an average traffic volume of more than 700,000 vehicles a day. New expressway networks involve underground, bridge and viaduct sections. Most of them are made of steel, because steel permits both the complex design and faster construction.

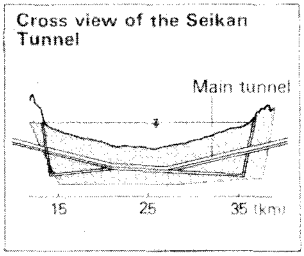




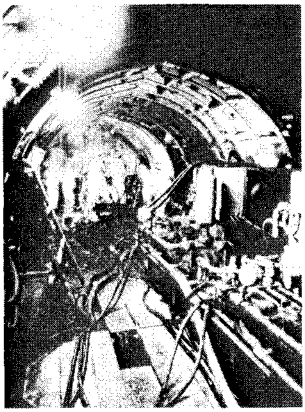


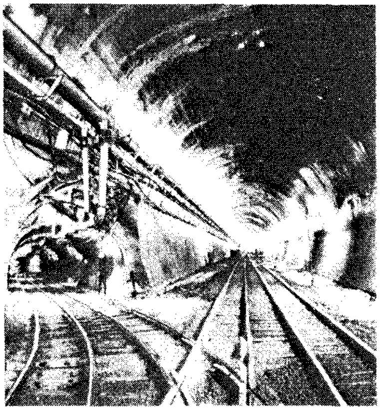
Seikan Undersea Tunnel

The world's longest undersea railway tunnel, extending 53.9 km, is being constructed under the strait between Honshu and Hokkaido. Begun in 1964, the project is scheduled for completion in 1982 at an estimated cost of ¥400 billion. The main tunnel is 9 m high, 11 m wide and has a cross-section of 80 m^2. It will be used for the Shinkansen superexpress rail service. When the new line is completed, travel time between Tokyo and Sapporo, Hokkaido will be slashed from the present 17 hours to 5.5 hours. About 60,000 tons of steel supports, mainly pipe and wide-flange beam supports, will go into the construction of the tunnel.



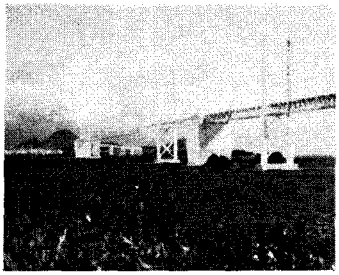
Cross view of the Seikan Tunnel

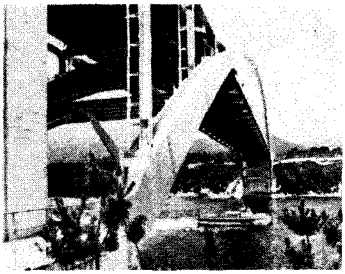


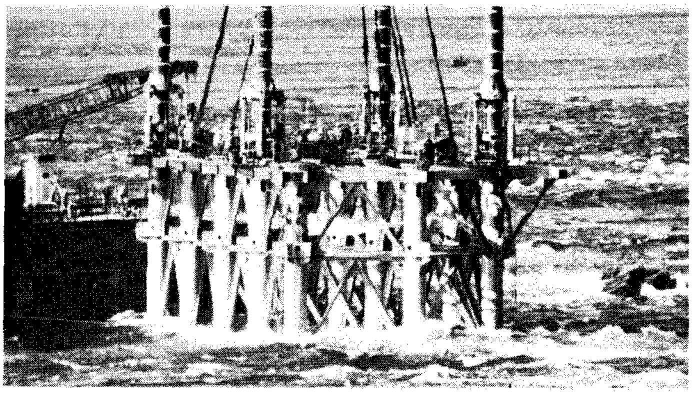


Honshu-Shikoku Bridge Project

The largest civil engineering project ever undertaken in Japan, this work involves the construction of 18 bridges — of truss, arch, suspension, girder and PC types — on three separate routes linking the main islands of Honshu and Shikoku. Among them is the Akashi Kaikyo Bridge — the world's longest, 3,560 m in total length with a center span of 1,780 m. Estimated total cost of the project will be ¥2,400 billion and steel requirements will total about 3 million tons. As of now, the arch-type Omishima Bridge (photo) is open to traffic and construction of two suspension bridges is under way. The photo at right above shows an artist's sketch of the Bisan Seto Bridge Complex.

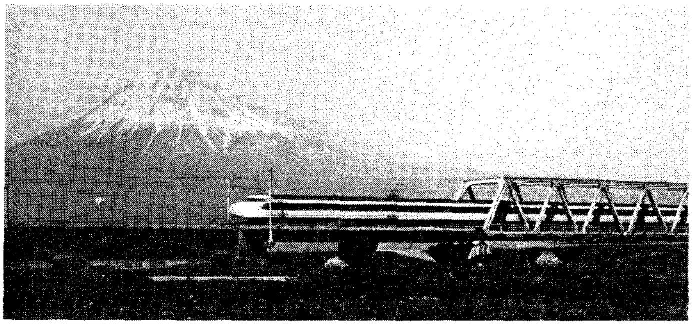


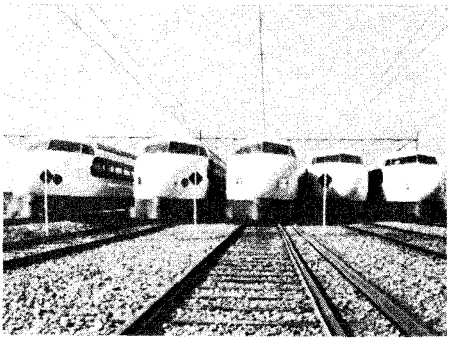


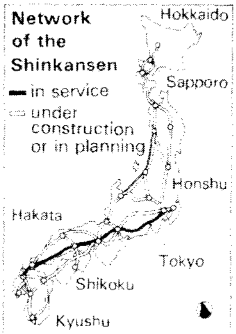


Shinkansen Superexpress Line

The Shinkansen superexpress rail service began its 515-km run between Tokyo and Osaka in 1964, stimulating the development of high-speed rail worldwide. Today the Shinkansen system extends all the way to Hakata, Kyushu. At a service speed of 210 km/hour, the 1,069-km run between Tokyo and Hakata requires only seven hours. The line serves an average of 500,000 people daily. Its construction cost was ¥1,320 billion. Plans call for extension of the Shinkansen network throughout Japan, to an eventual total length of 7,000 km. Among technological developments related to the project was a new type of rail that reduces maintenance work and ensures high-speed mass transportation.

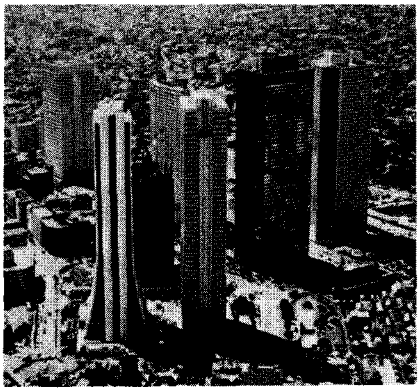


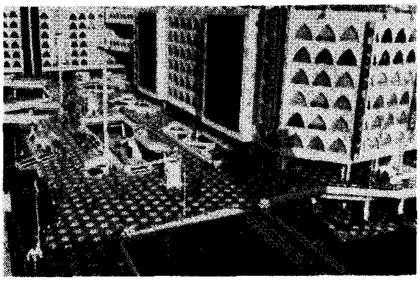


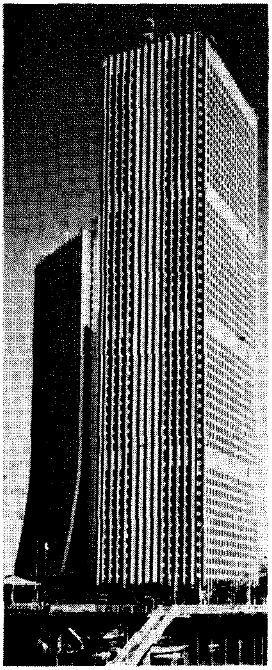


Urban Development

Large-scale urban development projects are taking shape in the major cities of Japan. A commercial center being developed in Shinjuku, a downtown district of Tokyo, for example, will eventually include 11 high-rise buildings over the 40-ha. site. Each building features an original design and each design employs steel in different ways. Some 23,000 tons of steel went into construction of the highest of these towers, a 54-story building. Another kind of project was realized in the shopping quarter in front of Kashiwa Station, northeast of Tokyo. Its design makes extensive use of podium structure (elevated concourse), an effective means of increasing the space available in congested city centers.

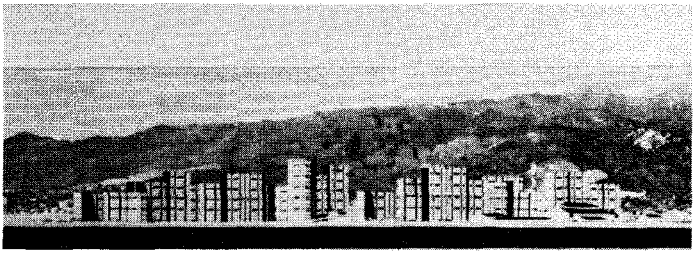


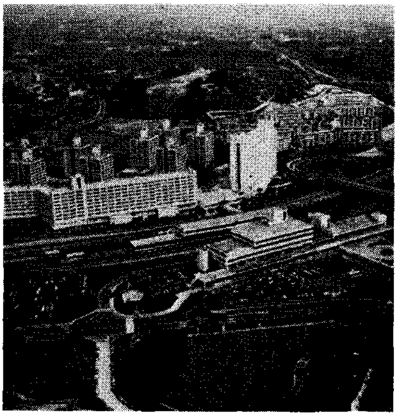


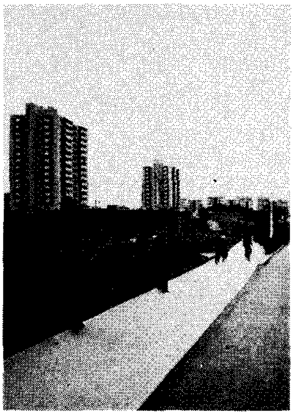


New Town Development

One of the largest new town development projects in Japan is Senboku New Town, located 20 km south of Osaka. Built on a 1,520-ha. site, Senboku is designed for a total population of 200,000. With a public works budget of ¥152 billion covering development of land, parks, roads and rivers, this project was constructed between 1964 and 1978. Another noteworthy development project is a major high-rise residential complex at Ashiya, near Osaka. A total of 52 buildings were constructed by a five-company consortium including a steel company. Its construction featured the maximum possible use of prefabricated steel building frames and housing units.

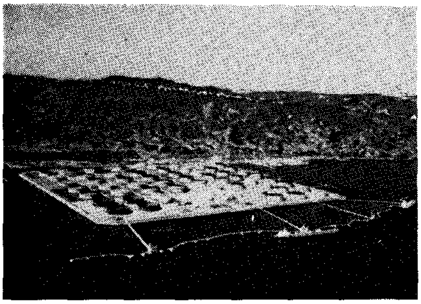


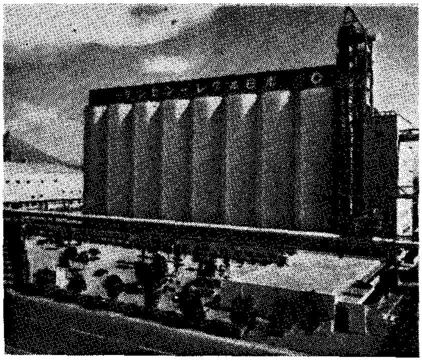


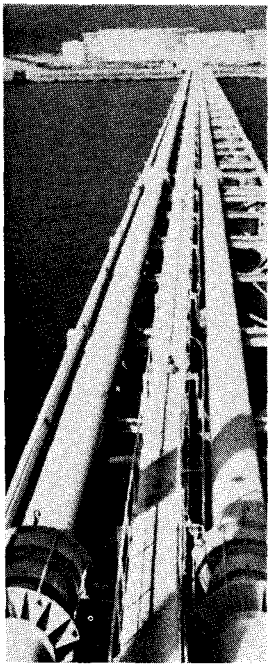


Storage Terminals

The crude trans-shipping station at Kiire, the southernmost tip of Kyushu, has emerged as one of the largest of its kind in the world, boasting a storage capacity of 6.6 million kl of crude oil. Some 170,000 tons of steels went into construction of the station. Project completion took 8 years and cost ¥50 billion. For grain storage, steel silos are now replacing concrete silos due to their greater suitability. The light weight of steel silos means lower construction cost. Steel also affords flexibility in design, excellent air-tightness and waterproofing. The steel silos in the photo have a storage capacity of 100,000 tons of grain.

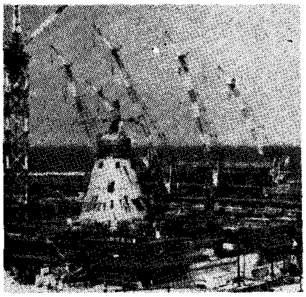


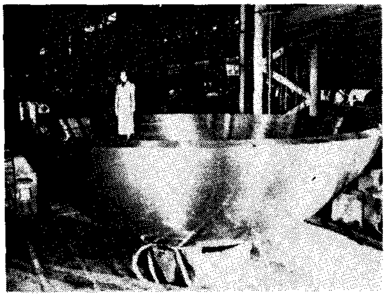


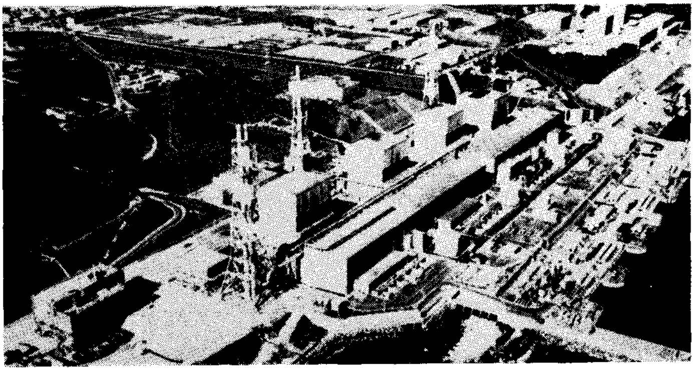


Atomic Energy Development

In 1978 atomic power accounted for 12% of Japan's total electricity supply. According to the government's forecast for energy supply, however, atomic power will provide 39% of the total electricity supply by 1995, surpassing the 10% for oil, 17% for LNG, 12% for hydropower and 14% for coal. The largest atomic power plant in Japan is the Fukushima No. 1 Atomic Power Plant of Tokyo Electric Power Co., where six reactor units totalling 4,696 MW output capacity are in operation. Construction began in 1966 and the sixth unit began operation in 1979. Total construction cost was ¥510 billion.

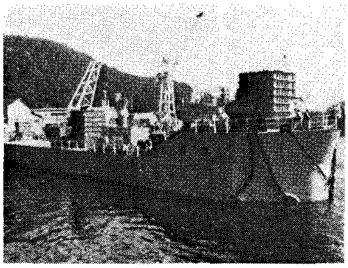


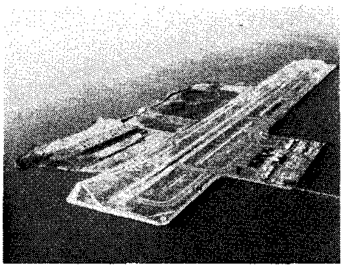


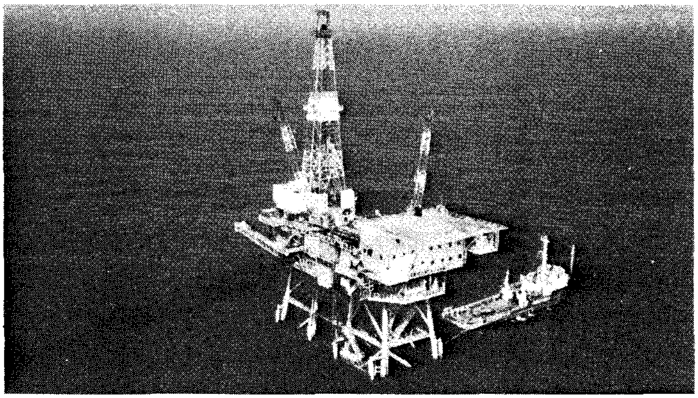


Offshore Development

Japan's first full-scale offshore oil/gas development project was completed recently in the Sea of Japan. The drilling/production platform was engineered and constructed by two steel firms. Because Japan is a crowded country, offshore space utilization is another important offshore development prospect. Nagasaki Airport, opened in 1975, is a good example of effective use of offshore space. Construction of a new international airport for Osaka is now being planned for a location 5 km offshore. Scheduled to open in 1985, the new airport will have three runways. Its estimated construction cost is ¥2,000 billion. A recent noteworthy development is a power generation plant driven by wave energy, trials of which are now under way.

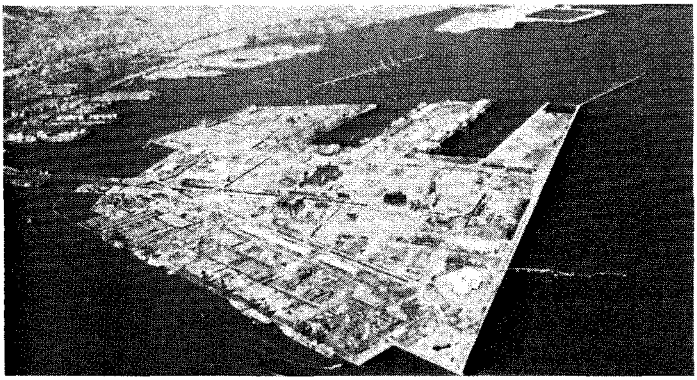


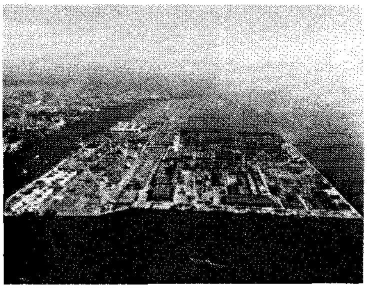


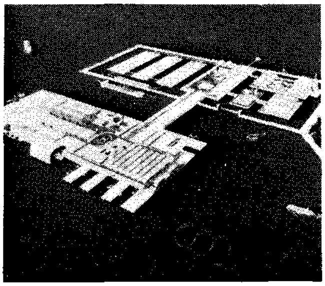


Man-made Islands

In Kobe, the port island project is proceeding rapidly. This island, covering 496 ha., will have large quays capable of berthing 30 container ships simultaneously. It will also serve as a port city, with a business center and a residential zone. Reclamation cost will total ¥210 billion, and steel requirement for the whole project 270,000 tons. On Tokyo Bay, a new steelmaking complex has been completed on a 550-ha. man-made island. Construction cost ¥800 billion and required 1.4 million tons of steel. The Kozai Club has recently worked out a far-seeing plan for a man-made island built of steel where an industrial complex centering on a coal-fired power plant would be built.







6. ROLE OF STEEL STRUCTURES IN CONSTRUCTION

The pattern of industrial materials consumption in Japan is shown in Table VI.

Table VI. Item-wise consumption of industrial materials in Japan (Share of each material in the total)

(Weight %)

	1955	1965	1975
Wood	35.3	20.2	11.2
Cement	28.9	30.3	30.3
Steel	25.7	38.3	47.3
Fiber	2.5	1.6	0.8
Glass	0.9	0.7	0.7
Plastic	0.3	1.5	2.4
Copper	0.3	0.3	0.4
Aluminum	0.2	0.4	0.7
Other	5.9	6.7	6.2
	100.0	100.0	100.0

Source: Industrial Materials Research Institute

While use of cement has remained almost constant at about 30%, steel usage rose from 25% to 47% over a 20-year period. Plastics and aluminum also show rapid growth rates, but the quantities used are still of modest size. Thus steel, despite its long history as an industrial material, even today continues its volume expansion.

6-1. Reasons for Popularity of Steel Structures in Japan

Among the reasons for the widespread use of steel structures in Japan are: improvement in steel manufacturing equipment and operating technology; development of numerous new products; improvement of fabrication and assembly technologies to suit specific applications; and consolidation of design and construction guidelines. Another important factor is the fact that promotion of steel use has been actively conducted both inside and outside the steel industry.

Moreover, Japan's geography and construction conditions have favored the spread of steel structures:

* Japan is an earthquake-prone country having many volcanic regions. This demands earthquake-proof design.

* Japan is also visited seasonally by typhoons. Thus wind-resistant design is necessary.
* Population and industry are concentrated in seaside areas with soft ground conditions, calling for corrosion protection and lightweight structures.
* Demanding climatic conditions range from high temperature and humidity in summer to severe winters in some districts. Thus corrosion prevention is not a problem of seaside areas alone, and heavy snow loads must be considered in building design.
* A shortage of land and concentration of population in cities have led to much high-rise construction.
* Japan is poor in resources and energy, necessitating large harbor and port facilities to handle a large volume of import goods and heightening the need for design and construction approaches that conserve both resources and energy.

Japan has lagged behind in building up its infrastructure, making it necessary in recent years for the government to place great emphasis on public works. This may also have been a significant source of sustained construction demand.

6-2. Concrete and Steel

Concrete is a major industrial material comparable in importance to steel. Let us compare concrete and steel on the basis of recent advances in utilization technology.

Until recently, concrete-making in Japan followed old-established practice. With the positive adoption of quality control methods and standardized operations, however, there have been significant improvements in concrete quality (see Table VII).

Table VII. Concrete quality improvement

High strength:	* Improvement of compression strength by development of suitable mixing rate and autoclave curing
Composite structure:	* Fiber-reinforced concrete, plastic concrete, pre-stressed concrete
Light weight:	* Mixing of light-weight aggregate
Durability:	* Prevention of gradual neutralization * Prevention of corrosion of RC bar caused by concrete cracking

For comparison, Table VIII lists major advantages claimed for concrete and steel.

Table VIII. Advantages claimed for concrete and steel

Concrete	Steel
* Rigid structure	* Flexible structure
* Compression strength	* Uniform quality
* Fire proofing and heat resistance	* Tensile, bending and impact strength
* Noise prevention	* Toughness
* Low material cost	* Ease of maintenance
	* Reduction of structural weight and sectional area
	* Less construction time

Designers choose between concrete and steel in accordance with the intended uses of a structure. Recent trends indicate that concrete and steel are increasingly being used together -- as complementary, composite materials -- so that each offsets the deficiencies of the other. Reinforcing bars, steel fibers and the like are used to compensate for the weakness of concrete, while concrete lining is effective in preventing corrosion of steel. The two materials are also combined in steel-and-reinforced concrete structures (composite structures), composite beams for bridge construction, composite flooring for building construction and earthquake-resistant walls. In Japanese construction, concrete and steel are regarded as "friendly competitors."

6-3. Examples of Steel Construction

(1) Performance of steel and its application

As stated earlier, the Japanese steel industry's intensive R&D efforts have produced a variety of new products and application technologies that either develop still further the inherent advantages of steel or offset its inherent disadvantages. Steelmakers have made extensive studies of building structures from design through construction, and of civil works projects. The result is a range of new products and application technologies to meet exactly the many requirements of the construction industry.

The following are good examples of structures that make the most of steel's advantages.

* Large-scale structures:

  Long-span bridge, tall stack, tall power transmission tower, wide-span building such as aircraft hanger, gymnasium and power station

* Quake-resistant structures:

  Port and harbor facilities, high-rise building

* Faster construction:

  Walled pipe pile foundation, large-block bridge erection, prefabricated frame, grating

* Weight reduction:

  Steel road-cover deck, corrugated pipe, bridge floor section, deck plate

* Flexible structures:

  Steel fence, dolphin, guard rail

Steel does have some drawbacks. A good many effective measures to offset these disadvantages are already in practical use, and R&D by the steel industry is adding to the means by which such drawbacks can be avoided. Among the outstanding techniques recently developed are:

* Measures against corrosion:

  Coating and covering of steel, electrical corrosion protection, atmospheric corrosion-resistant steel

* Measures against noise:

  Vibration-damping laminated sheet, noise-absorbent panel, soundproof pile driving, concrete-encased bridge girder

* Measure against fire:

  Fireproof cladding

(2) Steel building construction

An important role of steel in building construction is to provide strength in the form of a steel frame. Also important is the application of steel in roofing, flooring and interior and exterior finishing materials that protect the building from the environment. Among the products developed to utilize steel's strength most effectively in construction are:

* Steels tailored to specific needs:

  High-strength steels, atmospheric corrosion-resistant steels and steels having good weldability

* Products of specialized section shape:

  Light-gauge shapes, wide-flange beams, pipe and box-shaped members

Development of such products and advances in utilization technology have considerably widened the range of choice for designers, to ensure the availability of suitable steel products for each construction application.

There has also been progress in methods of joining steel members when assembling structural frames. Conventional bolts and rivets have been replaced by advanced welding techniques and high-tension bolts. Organic combination of steel products and advanced joining method have each contributed to further advance in the other, propelling the spread of steel-frame construction observed today.

Wooden structures are traditional in Japan because of the country's geography and climate. If the market is analyzed by type of construction, however, steel construction shows a pronounced gain in market share.

Table IX. Indexes of building construction by type of structures (in terms of floor space, construction started)

	1960	1965	1970	1975	1977
Steel structure	100	243	773	710	738
Steel-and-reinforced concrete structure	100	210	422	364	538
Reinforced concrete structure	100	207	406	325	397
Wood, other	100	136	221	239	255
Total building construction	100	166	334	319	356

Source: Ministry of Construction

The emphasis on earthquake-proof design is understandable in a country where quake-induced disasters have been frequent. In 1924 the world's first set of earthquake-proof building design codes were put into effect in Japan. This opened the way for the popularity of Japan's unique steel-and-reinforced concrete construction approach.

Structural design engineers weigh a great many factors before deciding on type of structure to employ. Among them are:

* Functional factors:

Use, scale, dimensions, service life, fireproofing, heat insulation

* Construction factors:

Construction period, location, construction method, environmental regulations

- * Economic factors:

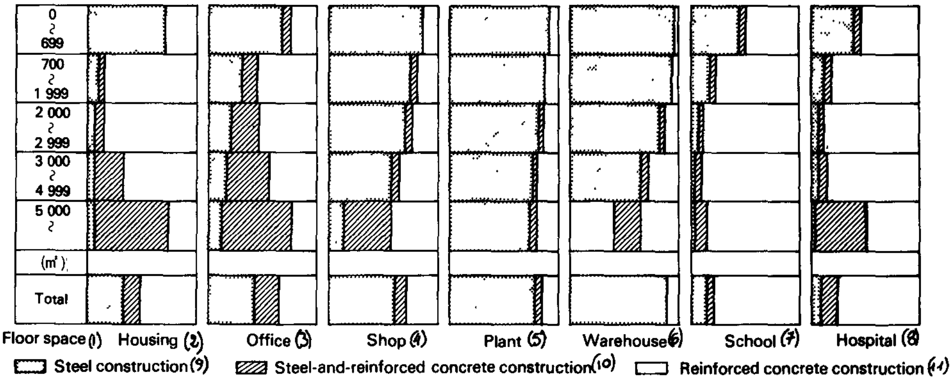
  Construction cost, investment efficiency, economic conditions

In practice, steel structures are most often chosen in Japan, except in the case of housing. The wide use of steel may be attributed to:

- * Steel's excellent toughness
- * Steel's suitability for prefabrication and rapid construction: ease of standardization, ease of quality control, dimensional accuracy and advances in joining methods
- * Variety of structural member types: flexibility in design
- * Steel industry support: development of steel utilization technology and activities promoting use of steel

Fig. VII shows the types of structures (other than wooden construction) by use in Japan today.

Fig. VII. Building construction by type of structures (1976)



Source: Ministry of Construction

From cost considerations, buildings from 3 to 9 stories in height are predominantly of reinforced concrete construction. Hospitals and school buildings, too, are reinforced concrete structures in many cases for the sake of better sound insulation. For the rest, however, steel construction and steel-and-reinforced concrete construction are the leading choices.

Several kinds of surface-treated steel sheets and products fabricated from them are available as finishing materials, used for roofs, floors, external walls and partitions. System buildings -- prefabricated frames and finishing materials supplied as a package -- have rapidly gained popularity in recent years.

(3) Recent topics in steel construction

Some construction applications in which steel has replaced concrete, or concrete has replaced steel, are examined below.

a) Bridges

Judging from recent statistics, the growth rate of steel bridge construction seems to have reached a ceiling. Prestressed concrete bridges, on the other hand, are on the rise -- due in large part to their lower maintenance cost and, especially in the case of railway bridges, lessened noise. As of April, 1975, bridges in Japan totaled 2,134 km in length, of which concrete bridges accounted for 52.2%, steel bridges for 35.9%.

Table X. Indexes of concrete and steel bridge construction (1975=100)

	Concrete bridge*		Steel bridge**	
	Road	Railway	Road	Railway
1966	81	55	81	117
67	79	78	82	199
68	-	-	126	178
69	-	-	101	148
70	-	-	131	156
71	90	163	164	147
72	120	104	154	195
73	114	91	134	228
74	102	85	110	89
75	100	100	100	100
76	110	126	103	106
77	133	140	122	107
78	145	175	-	-

* Number of bridges constructed

** Tonnage of bridges constructed

Source: Ministry of Construction

Offsetting the disadvantages of steel bridges has been the target of much R&D by the steel industry, with good results. They include the application of atmospheric corrosion-resistant steel to bridge construction, development of composite steel/concrete structures and other developments whereby steel and concrete offset the other's deficiencies.

Damage to concrete bridges during earthquakes that struck the northern district of Japan in June 1978 also inclined designers toward steel for bridge construction. As for long-span bridges, steel is the only practical choice. Steel-bridge construction overall is expected to resume its expansion in the near future.

b) Silos

Some of the advantages gained by using steel in silo construction, and measures to offset its disadvantages, are listed in Table XI.

Table XI. Advantages, and measures against disadvantages, of steel silo

(Advantages)	
Light weight and economy:	* Reduction of structural weight leads to lower construction cost (simplified foundation work, savings in materials cost, construction expenditure and construction term) * More advantageous for construction on coastal, soft ground
Fabricability:	* Flexible design * Safety * Air tightness, water proofing
Toughness:	* No cracking by earthquakes
(Measures against disadvantages)	
Corrosion resistance:	* Application of atmospheric corrosion-resistant steel, galvanized and coated steels
Heat resistance:	* Double-wall heat insulation structure, zinc-rich painting

Steel silos are increasing in Japan. As can be seen in Table XII, silos built of steel have in recent years surpassed those of concrete in terms of storage capacity.

Table XII. Construction of concrete and steel silos (1,000 tons storage capacity)

	Concrete	Steel
1966	105	42
67	311	61
68	252	129
69	332	128
70	222	42
71	239	153
72	342	95
1973	81	120
74	49	105
75	71	90
76	99	119
77	191	182
78	220	198

Source: Ministry of Construction

7. PROSPECTS

The many design advantages of steel make it a highly versatile and effective material for the construction of a great variety of structures. Its position as a leading structural material will remain unshakable.

Not much can be expected in the way of further growth in demand for steel, however, if steelmakers simply wait for the orders to come in. It is essential that the steel industry carries out a positive public relations campaign by preparing and disseminating useful information about the advantages of choosing steel. Equally important, the industry must continue actively to probe new markets. Most future demand for steel structures is likely to be the result of the steel industry's own initiatives along these lines.

7-1. Market Development Efforts

The market development activities of the Japanese steel industry have been mentioned above. A summary of these activities, current or planned, is given below.

In response to new market needs, first of all, the industry has attempted to combine its best 'seed technology' into new and marketable products and processes. Such attempts are directed mainly toward improved production equipment and technology, so that steel products can be made at lower cost and with higher quality. But the industry's effort also extends to development of new steel utilization technology and construction methods, along with ingenious devices that make it easier for users to adopt steel products. Active promotion of steel use and distribution of steel information are another part of the program.

Secondly, the industry has stepped up its effort to establish and maintain close cooperative relations with other sectors of the economy. This includes not only the preparation of reference materials for use among steelmakers, but also cooperation with other industries. One such activity is to propose appropriate construction projects and to help translate them into reality.

Thirdly, the industry is moving into closer contact with steel users. The objective is two-way communication: to confirm the kinds of steel products and services users really need and to keep users informed about the status of seed technology through which the steel industry will provide for users' needs in the future. Substantial exchanges of information between users and steelmakers provide hints for new products and enable steelmakers to tailor their products and to devise utilization technology so as to fit users' needs more exactly. One result of such exchanges is that the industry has already begun to manufacture some principal structural members to order.

Finally, the industry is putting much emphasis on the training of qualified manpower. Internally, the steelmakers' own personnel training programs are expanding each company's total capability by improving skills at the individual level. Among these programs are IE (industrial engineering) and *Jishu Kanri* (voluntary improvement) activities, which help to create an open, stimulating atmosphere in the workplace, heighten individual motivation and group spirit, and increase workers' awareness of what is needed by the company and steel users.

Externally, steelmakers hold lectures and seminars for distributors, who are then better able to use product information for the benefit of steel users. The industry also directs a vigorous "use steel" campaign to builders, who seem sometimes reluctant to depart from traditional ways and materials. The goal is to give users a clear understanding of the full merits of choosing steel. Looking ahead, the industry also carries its promotion campaign to future architects and design engineers still at university.

7-2. Promotion of Large-scale Construction Projects

One effective means of promoting widespread use of steel structures is to propose innovative construction projects. The most immediate effect of a large-scale project is a welcome increase in steel demand. Such projects may also present many technological problems to be faced and resolved.

In that way a large-scale construction project can lead to technological innovation, with benefits for the entire industrial world.

The central theme of this meeting is "Construction: A Challenge for Steel." Today there are many areas that call for effort by the steel industry, either by sharing out the work within the industry itself or in cooperation with other industries. Some of these new challenges are:

- * Food:
  Ensuring adequate food for all is an urgent global problem involving infrastructure, distribution and storage for emergencies.
- * Energy:
  Finding alternate sources of energy is an obvious necessity. Energy conservation should go hand in hand with studies of which new sources should be developed and to what degree, and implementation of these studies.
- * Resources:
  Resources are finite, and technical ingenuity will be required to ensure that the most appropriate resource is chosen for a given use, thereby achieving the most effective overall utilization of the resources that remain.
- * Land:
  Concerted effort is needed to achieve full utilization of Japan's limited land area and to realize the possibilities of offshore development.
- * Environment:
  Hand in hand with all these efforts must be the preservation of a livable environment.

****

Low levels of public works and other infrastructure, together with the peculiarities of Japan's geography and climate, have certainly assisted the spreading use of steel structures in the past. To encourage further expansion of construction demand for steel, the Japanese steel industry is emphasizing new product development, joint promotion of large-scale construction projects and closer cooperation with other industries and with steel users themselves. As long as the steel industry continues its active efforts for technological innovation as well as market development and promotion, there is no doubt that the "Age of Steel" will continue into and through the 21st century.

THE ROLE AND FUTURE OUTLOOK OF STEEL CONSTRUCTION IN WESTERN EUROPE

P. METZ
Administrateur-Directeur général, ARBED, Luxembourg

Summary

The author begins by analysing the new competitive conditions in which the steel construction industry is operating. He describes the current situation in Europe as regards the following areas of steel construction :

- industrial buildings and warehouses,
- housing,
- multi-storey buildings,
- buildings for social, cultural and sport activities,
- bridges and other civil engineering structures.

The author then examines strategies to adopt in the future to make steel construction more competitive. His structural analysis offers solutions which entail the reassignment of tasks and roles in the construction market.

Next, his review of structural design aspects shows that a fresh approach is required to take account of the pressing need for efficient synthesis of all current research and to encourage innovation generally, including, for example, a more extensive use of computers.

Finally, he surveys the problem of promoting steel where current regulations, technical advice to users and the training of engineers are concerned.

The author concludes that the outlook for steel in construction will be improved only if creativity is enhanced at the levels of both production and construction.

1. INTRODUCTION

Ever since steel was first made, it has been used in construction and has come to be regarded as an indispensable material. In western Europe, the construction industry as a whole currently absorbs between 25 and 30 % of all steel products and is therefore the main customer of the steel industry.

Steel became popular in construction as soon as it was possible to produce the beams and sections needed for the metal frameworks of large bridges and sheds on an industrial scale.

After the second world war, rapid developments took place in the manufacture and continuous forming of flat rolled steel, especially of coated flats, and it became clear that steel - which until then had been considered a framework material only - could also be employed as a completion and finishing material for construction elements.

Favourable developments continued to contribute to the success of steel in construction for quite a long time with the result that steel was used in a great variety of different structures. Nowadays, however, we are forced to recognize that steel construction is faced with competition from other materials.

2. CURRENT STATUS OF STEEL CONSTRUCTION

The situation varies from one European country to another according to the type of building and structure considered. Generally speaking, it seems that steel construction is predominant in industrial buildings, that it is hardly used at all in the construction of dwellings, and that it is faced with fierce competition in the bridge building sector.

2.1 Industrial buildings and warehouses

This market absorbs over half of all traditional metal construction. For a long time the market changed little and metal framework had no technical competitors. This is still true today where traditional industrial buildings are concerned, even though some interest has been shown in concrete for this sector.

Steel construction is now faced with an entirely different situation, due to the trend towards small and medium-sized buildings and the considerable technical progress made in the prefabrication of prestressed concrete and glu-lam elements. There has been a corresponding growth of interest by building firms in these latter products.

The position of steel is still quite strong of course where large storage buildings are concerned and where different technical procedures provide a more rational solution.

It is however questionable whether full use has been made of steel's potential in the construction of the smaller type of standard, prefabricated buildings for small and medium-sized industry. Indeed, constructors of industrial buildings must be seen by users to satisfy their ever-increasing requirements where facilities connected with the building as a whole are concerned.

2.2 Housing

Steel construction is relatively uncommon in this sector as customers prefer traditional architecture.

Many attempts have been made to promote the use of steel in industrialized construction but they have come up against all kinds of difficulties, namely :

- the traditional and individual tastes of users,
- the unsuitable organization of the building trade,
- the building and public works regulations which have not yet adapted to this new type of construction.

At the moment, it seems that the future of steel in industrialized housing construction depends on developments in steel-based components and on the technical and economic preformance of such components.

2.3 Multi-storey buildings

Between 1955 and 1975, roughly, metal frameworks made a successful impact where the construction of some multi-storey buildings such as offices, schools, universities and hospitals was concerned.

A steel framework offers a whole range of advantages which do not always seem to have been fully exploited by planners. When the cost of the various competing options are compared, are all the factors which influence the erection and use of a structure taken into consideration?

We may list the following advantages :
- additional income. If using steel permits the work to be completed more quickly, return on investment is accelerated;
- the optimum ratio of useful area to the overall site area which can be achieved using steel;
- floors made of a mixture of steel and concrete are not so thick and permit more use to be made of the height available;
- the building can be easily adapted to take account of changes in purpose or layout;
- use can still be made of the building while extensions or improvements are being carried out, and finally,
- a steel framework can be dismantled easily in the event of relocation or demolition.

Comparisons of this kind help to prove that metal construction is truly competitive. Nor should we forget the advantages of composite structures combining steel and concrete, which should become of greater interest to architects.

Although metal frameworks have proved their worth in high-rise blocks, there has been a reduction in the number of such buildings. In some countries they are opposed in the name of the environment.

2.4 Buildings for social, cultural and sport activities

Considering the similar character of the purposes to which such public buildings are put, steel is not used in construction as widely as one might expect in all countries.

When steel has been used, it is most often found in lightweight, standardized buildings of turnkey construction of the type also offered by competitors using concrete and glu-lam.

2.5 Bridges and other civil structures

For bridges with a span of more than 500 metres, steel alone is used. Bridges with a span of between 100 and 500 metres employ either steel or prestressed concrete. It would however be incorrect to assume that steel is losing its competitive edge in this latter sector. Thorough and objective comparisons of all the relevant factors need to be made before steel is rejected as a viable solution.

In many cases too, a mixture of steel and concrete is chosen for construction in order to benefit from the advantages of both. Railway bridges, for which a variety of options is available, are a case in point.

Steel is not often used in the construction of small and medium-sized bridges (less than 100 m span). Attempts to erect bridges using steel modules in combination with a concrete slab which are assembled on the site have not been as successful as was expected. They do however provide an opportunity to reintroduce the use of steel into this relatively important sector.

Such solutions may also be considered when laying out new sections of railway and when modernizing the many bridges built in the last century.

3. WHAT IS THE OUTLOOK FOR STEEL CONSTRUCTION? - STRATEGIES AND CHOICES FOR THE FUTURE

This brief survey of the main markets for steel construction has revealed a number of weak points. Our next task is to analyse the situation while taking due account of changes in market outlets, of our competitors in the field at the present time, and of changes in the construction industry.

Indeed, if one of our market outlets is weakened - not to say threatened - this must inspire us to renewed efforts and imaginative thinking to ensure that the use of steel products in construction is extended.

An initial attempt has been made with the launching of a comparative study on metal construction throughout the world.

The proposal for this study came from the European steel industry and is unter the supervision of the Steel Information Centres and the European Commission.

We can only define the strategies we need to adopt if we bear in mind the requirements of users and the full potential of steel to meet these requirements.

The following three areas should have priority :
- the structure of the market and the way it can be approached,
- factors of structural design,
- information and promotion programmes.

3.1 Structure of the market and approaches to it

The traditional function of metal construction was above all to provide frameworks and for a long time steel had no technical competitors in this field.

The framework only accounts for a relatively small fraction of the total cost of a structure, however, except in the case of industrial buildings and steel bridges. For this reason metal framework constructors are generally confined to the role of subcontractor.

This state of affairs places metal construction in a precarious situation which is further aggravated by advances made in the technical capacities and competitivity of concrete and by the trend towards turnkey construction, which mainly benefits general contractors with the necessary expertise at their disposal to carry out all the works involved.

It is apparent therefore that the role of steel in construction can only be maintained or developed further if new approaches to the market are adopted. Changes will have to be made from the technical point of view and on the marketing and sales promotion side.

Let us consider the people traditionally associated with this market and examine whether our future task should not be to reassign some of the tasks performed. The design and manufacture of components and modules, for example, could be the responsibility of indsutrialists and manufacturers, while the marketing of structures in their entirety, erecting the structures and coordinating work could be entrusted to specialized general contractors. Members of these groups would be recruited and trained by manufacturers and would act as their agents.

Another possibility would be for metal constructors themselves to take on the role of general contractor.

Such a venture would be even more successful if close and durable relationships could be formed between individual metal constructors and civil engineering firms.

General contractors will continue to play a major role in the building industry. Their energy, their authority and their experience of turn-key construction, together with the trend towards composite methods, can all contribute in promoting a new relationship with experts in the steel industry.

The steel makers and the manufacturers of metal frameworks for buildings must find ways to collaborate more closely in the light of technical and structural developments in the construction industry generally.

While it is incontestable that concrete, thanks to steel, has made such great progress that it rivals a steel framework, nevertheless steel's unique features give it significant technical and economic advantages. We must therefore explore every possible opportunity for further expansion and seek out highly qualified partners to help us promote steel.

3.2 Structural design factors

As steel construction is faced with keen competition, careful research needs to be carried out into structural design and the rational use of steel.

- First of all, it is to be hoped that full use can at last be made of computers when analysing all types of structures. When studying plans for structures, greater use should be made of the analysis of finished components in order to take full advantage of the properties of steel. In particular, greater advantage could be taken of the extra margin of strength of any steel construction, which is a result of steel's ductility limit, one of its salient features.

- The use of a computer also makes for spectacular improvements in general and final designs. From now on, computer-assisted design techniques should be used for frameworks, boiler making and mechanical engineering. In order to make the most of this new technique, it is also necessary to feed into the computer directly usable data on the characteristics of steel sections.

- All these innovations are preparing the way for integrated data processing. The principle of such systems is that the initial parameters entered at the beginning are retained throughout the process of construction. In this way, there is much less scope for human error during the successive stages of design, structural analysis, execution of drawings, manufacture and construction.

- Special efforts need to be made to collate the findings of the research which is being carried out throughout Europe and the world. For what use is all this mental effort unless competent and energetic people collect, test and sort research results in order to present the relevant facts in a practical way to steel users? Here again, there is a need to make such computer programs marketable in order to obtain the best possible return on research which has sometimes been financed with great difficulty.

- Innovation is of the utmost importance and we must learn to welcome it and not to discourage it, no matter what the source or its degree of development. Innovations must be encouraged, analysed and developed before they can be critically examined. What is more, it is really only through such encouragement that marketable patents can be produced.

  In this context, we may mention the use of steel for partitions and finishing elements, the standardization of construction elements, the development of construction techniques using compatible components, standardized modules, streamlining of types of sections and, finally, simplification of the manufacturing and erection process.

- Particular attention needs to be given to composite construction, where steel can be combined with any other complementary material, the aim being to make optimum use of the properties of each material. Combining materials can reap benefits not only from the point of view of structural dependability but also where thermal insulation, fireproofing and steel corrosion are concerned.

The outcome of the courses of action outlined above would be to give steel construction a better competitive edge and would also have a direct impact on the design of structures, leading to changes in their form and their appearance.

3.3 Information and promotion campaigns

Generally speaking, people involved in construction are not sufficiently aware of steel's potential and important assets. As a result, steel's image is often adversely affected.

It is therefore vital to continue with information, demonstration and training activities. A number of different campaigns must be pursued and stepped up. These focus mainly on the following areas :

3.3.1 Regulations

The regulations vary in their degree of severity regarding conditions for the use of steel; they therefore inhibit, and even penalize steel when the requirements are excessively strict.

In other cases, it is not so much a question of regulations as of certain traditions which allow no room for new techniques.

If we wish to replace excessive regulations with more realistic recommendations, if we wish to maintain the same requirements for competing materials, we must campaign strenuously to get more accurate information across to the authorities who draw up regulations and those responsible for public works contracts.

Such steps are particularly necessary where fire protection and corrosion are concerned, as more accurate information would help to eliminate certain prejudices.

The time has come to insist on the completion of procedures which will lead to a harmonization of regulations and codes of practice throughout Europe. Community legislation could clarify the conditions of entry to the European market while at the same time simplifying planning procedures for steel constructions.

3.3.2 Technical information and advice to users

Progressive industries concern themselves with solving their client's problems, do the necessary research to find competitive solutions, inform their customers of the possibilities offered by the results of such research, and assist in putting them into practice.

To what extent - and with what degree of success - can we say that industrialists involved in producing and processing steel have acquired the necessary resources and thrust to rise to the challenge of competition from other materials?

We need to develop a strategy which involves our entire profession, by pooling the initiatives of individual companies, of the Steel Information Centres, of metal construction professional associations and of research centres and with the support of the Community authorities.

3.3.3 Education and training in the profession

Professional hierarchies, and the customs and traditions of the construction trades in Europe have led to a situation where in many architecture and engineering courses instruction in the use of steel comes a very poor second to instruction in the use of concrete.

This situation bodes ill for the future, as students who have been thought that concrete is best will naturally be conditioned into using it and will reject steel out of ignorance.

It is therefore crucial to pursue campaigns already under way to devise other solutions for filling the gaps in students' knowledge. The trade associations of builders and steel manufacturers should provide adequate information to teaching staff which will enable them to improve their courses on steel and its use in metal construction.

Such courses should not only include structural analysis but should survey all aspects of construction problems, including those encountered in turnkey construction.

4. CONCLUSIONS

There are fundamental reasons for believing that steel can compete. Steel construction has proved its capabilities technologically, but competition forces it continually to improve on its achievements and to keep pace with market trends. From now on the race will depend not only on the materials themselves, which are constantly evolving, but also on the capabilities and aptitudes of the firms involved.

There is a great deal at stake. Only a coherent strategy, adopted by a consensus of the entire profession and by each individual firm will tip the scales in favour of steel construction.

STEEL IN THE MIDDLE EAST - A CHALLENGE

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Summary

The explosion in the Middle East construction market has also affected the steel construction market. This paper reports on where construction is taking place, how much of this is in steel and also who is awarding the contracts. In recent years the West European steek industry's strong position has been under strong attack. The problem is how to counter this.
It appears that there are opportunities for steel construction and for the West European steel construction industry. Individual undertakings must take a number of steps themselves. Other measures will have to be taken jointly, e.g. as regards innovation and promotion. Governement authorities could also do more to encourage exports.

1. INTRODUCTION

Ten years ago or more it is unlikely that this subject would have been on the agenda of a steel congress. Its inclusion now is not due to any new developments in steelmaking or steel construction, but to an enormous change in the world construction market. The market has changed because of the steep rise in oil prices and thus in the revenues of a number of Middle Eastern countries, which has led to an explosion in building. And this has happened precisely in an area where there was no local building capacity.

However, not all the countries which comprise the Middle East enjoy high oil revenues. They evidence great differences in incomes, the needs of the population density and the political situation.

The need to acquire a better knowledge of the market in the Middle East and the prospects of introducing our materials into this market, constitute a challenge to steel construction and to the West European steel construction industry.

2.1 GEOGRAPHICAL DEFINITION

In this paper the Middle East means the countries around the Arabian Gulf, those around the Red Sea and those which form the Eastern shores of the Mediterranean. Sometimes the countries forming the southern shores of the Mediterranean are also regarded as part of the Middle East because of their links with the Islamic world. In view of the nature of this paper we shall also include these countries in the Middle East.

2.2 MARKET SECTORS

The construction market, including the steel construction market, cannot be divided into geographical areas. The market in a given country depends to a much greater extent on the country's oil revenues and the size of its population. Countries with small populations utilize their oil revenues differently from countries with large populations. This gives us four different groups of countries.

Firstly, the countries with large oil revenues and a small population. These countries invest their revenues in high-cost projects which require only small workforces to keep them operational. These investments are funded out of oil revenues by the government authorities concerned. Saudi Arabia is the main country to invest in this way, carrying one or two other Gulf states with it. These large industrial investments are often located in centres wchich are almost completely new, such as Jubail and Yanbu in Saudi Arabia, Mina Jebel Ali and Ruwais in the United Arab Emirates, and Raslanuf and Misurata in Libya.

To complete these projects much work had to be done to create an infrastructure, i.e. roads, airports, seaports, new residential areas, office accomodation and hotels. In Saudi Arabia this preparatory phase is practically complete. There are practically no more delays in the ports. The residential accomodation, offices and hotels are hard to fill.

Saudi Arabia's third five-year plan also includes the construction of large industries and community facilities such as schools, universities, hospitals, government buildings etc. Great efforts are being made to encourage small industries by offering subsidies, tax concessions, favoured treatment in the awarding of contracts and other measures.

The second category of countries comprises those with large oil revenues and large populations. These countries are less interested in large-scale projects and spend more on the needs of their own people, i.e. roads, power stations, residential accomodation etc. This category includes Algeria, Iran and Iraq.

Unlike the countries in the first category, these countries do not have a large foreign workforce, but materials are certainly obtained from overseas.

A third group of countries, with practically no oil revenues but with one or two other sources of income, have the greatest difficulty in funding larger capital projects. These are therefore confined to the most essential infrastructure projects such as roads, power stations and port improvements.

In Egypt, Jordan, Morocco and Turkey help is given by governments and overseas aid is obtained in the form of credits, loans under favourable conditions and grants in aid to establish small industries and take measures in the agricultural processing sector.

Lastly, Ethiopia, Somalia and the Sudan form a group of countries with persistent balance of payments deficit. These countries are completely dependent on overseas aid to finance and complete a small number of projects, mainly port improvements, road construction, irrigation systems and similar works.

3. POLITICAL INFLUENCES

When it comes to market research, the financial situation of a country is not the only consideration. The past few years have shown that the political situation is also a most important factor. Changes in the political power structure can have a great effect on government policy and consequently in investment. I shall confine myself to a brief review of recent years, and gladly leave future prospects to the specialists in this field. The changes in the power structure in Iran have caused an abrupt decline in investment and even a complete standstill on a number of current projects. This has had serious consequences for overseas undertakings, and has demonstrated the importance of insuring against political risks.

The policy pursued by Egypt has allowed this country to start to think about development, following several years of vast spending on defence. This has produced a cautious policy of investment in industrial and agricultural processing projects, construction of power stations and port improvements. Oil companies are beginning to take more interest in Egypt. New prospects are opening for the tourist industry.

Next comes Libya, a country without direct experience of sudden changes, and which has a cautious policy as regards its foreign business relationships. There is some capital expenditure on fairly large-scale projects. The country is rich because of its oil revenues and the population is small. The country is therefore very dependent on overseas undertakings for construction and project operation. However, fear of excess foreign influence has produced a policy of strict control. It is always difficult to obtain official approval for phases of a project, and this often militates against the rapid and economical completion.

4.1 CONTRACTS IN THE CONSTRUCTION MARKET

In most countries the major projects in the construction sector are initiated and the contract let by the government. In most of these cases the contracts are awarded by a number of ministries in conjunction with a number of bodies set up by the governement; in Saudi Arabia, for example, the Ports Authorities, the Royal Commission for Jubail and Yanbu, the US Army Corps of Engineers, acting on behalf of the Ministry of Defense and Aviation, and the Saudi Basic Industries Corp. (SABIC).

The contracts for many projects are let by national oil companies which control completely, or nearly completely, various industrial companies, e.g. Adnoc, in the United Arab Emirates, Q.G.P.C. (Qatar General Petroleum Corporation) in Qatar, Aramco and Petromin in Saudi Arabia, Sonatrach in Algeria and E.G.P.C. (Egyptian General Petroleum Corporation) in Egypt.

In some countries there are a number of organizations to help the medium-sized and small industries in the initial stages. Saudi Arabia and Egypt have organized this particularly well. These bodies usually operate in a consultative capacity, but sometimes they also let contracts for projects themselves. In Saudi Arabia the Saudi Industrial Development Fund (S.I.D.F.) and the Industrial Studies and Development Centre (I.S.D.C.) operate in this way. In Egypt there is the General Authority for Investmenets and Free Zones and the General Organization for Industrialization. Under Egypt's open-door policy these organizations are responsible for investment guidance, arranging facilities, etc. In addition, there are a number of sectoral organizations which are responsible for developing industry, the agricultural sector, the cotton industry, bakeries, etc. In some cases the bodies for developing the medium-sized and small industries award contracts themselves, in others they merely provide assistance and facilities for investment in this sector, which is becoming a potential market for steel construction.

4.2 CONTRACTS IN THE STEEL CONSTRUCTION MARKET

Most construction projects or part-projects which become part of the steel construction market do so in a somewhat roundabout way. A steel construction is not a self-contained project. Steel construction modules in the form of load-bearing structures or façade units, roof membres, silo plant, greenhouses, prefabricated dwellings, etc. are supplied by specialist undertakings and incorporated into a larger project, large production units or a building project.

Sometimes the authority awarding the contract is in a position to determine the amount of steel in a project and offer a separate contract for it. In the less industrialized countries, such as those in the Middle East, the countries with construction industries which have not yet achieved stability, this practice of awarding separate contracts is not very usual. Usually the steel is a sub-lot of the whole project and is subcontracted.

In this case steel construction firms look for contracts from the large processing industries and the industries which are concerned with producing energy, desalination and communications. Customers of this group are mainly situated in Japan, the United States and Western Europe, and often order their steel construction requirements in their own country, and from steel processing undertakings which they own themselves.

A further large group of customers is the building industry. Unum quid contracts are often awarded for such projects as ports, airports, roads, bridges, and buildings, which often use large quantities of steel. Each main contractor obtains quotations in turn for the steel items from steel processing undertakings. The competition for this kind of project is very severe, and often there is a further round of tendering for the steel items after the main contract has been awarded. If the quantity of steel required for the project warrants it, sometimes a joint venture association or consortium is formed.

A third group of customers is formed by medium-sized and small industry. These industries often need some load-bearing structure or a roof over their heads. The preparatory work for these projects is often lengthy and detailed. In many cases, once the money for the expenditure is released construction must be completed quickly so that production can start as soon as possible. Cheep standard structures are usually the answer in these cases, of which steel offers a wide range. Often price is not the only consideration, and factors such as communications, prompt execution of orders, shipping dates etc. are also important.

5. THE WEST EUROPEAN STEEL PROCESSING INDUSTRY

The West European steel processing industry is the oldest in the world and therefore has the greatest experience, beginning with bridge building when the railways were being developed and the construction of industrial premises for the new industries in the last century. In the United States the development was more or less parallel. Japan followed. Tower buildings and steel frameworks for them developed mainly in America in the closing years of last century. Europe built high-rise buildings in concrete, and after the second world war high-rise buildings in Japan were constructed of steel because of the danger of earthquakes. The United States produced its own requirements and exported little. Western Europe, was committed to exports, since the markets in the individual countries were often too small, and did much building abroad. For a number of years the Japanese construction market was strictly confined to that country. When the market for steel construction in the Middle East developed Western Europe had a lead, with its technical and financial experience and also its business experience. In many cases business relations were good and of long standing.

More recently this situation has changed in one respect. Japan has developed a keen interest in the Middle East, because of its needs for oil and for security of oil supplies, and also because it needs to export not only watches and motor cars but also construction projects, and particularly steel construction. This has produced stiff competition from Japan in the Middle East, particularly on projects for the major process industries. While this market is still open to Western Europe, the Japanese Sogo Shosha system - an all-in package - offers the customer very considerable advantages. This is particularly true when the deal includes not only design and delivery but also finance, operation and management.

For projects in the second group, where subcontracts are awarded, competition is simply a matter of quoting the lowest price for an identical product. The product required is usually fairly well-defined and requires little design work, and the undertaking with the lowest wage costs stands the best chance. At the beginning of the construction boom the large construction contractors mainly came from Western Europe, falling back on their established contacts for subcontractors, which themselves were mainly in Western Europe. Competition among building contractors has become much fiercer, undertakings outside Western Europe are improving considerably. The fast growing number of construction contractors from the Far East are no longer tied in any way to Western Europe. This means that Western Europe now faces competition from the Far Eastern countries such as Japan in the first instance, but also from Korea, Malaysia, the Philippines and Taiwan.

The situation regarding the third group, medium-sized and small industry, is much more favourable. Very often turnkey construction is required for these projects, including processing know-how, process equipment and construction of the main and ancillary structures. Western Europe still has a good market share in this sector. Better mutual communications are such an advantage in these projects that West European undertakings are in a favourable position.

The situation facing the West European steel processing industry is not simple, particularly when seen against the background of reduced activity in the domestic market. The need to find and keep other markets is therefore all the greater. The challenge is to find ways of holding on to the Middle East market and to expand it as far as possible.

6. TECHNICAL OUTLETS FOR STEEL CONSTRUCTION

Steel offers many possibilities. Naturally there are many pros and cons in using steel. However, the question is whether the various advantages and disadvantages each carry the same weight in the Middle East as in the domestic market of Western Europe.

6.1 LABOUR MARKET

One of the main considerations is the labour market. A number of Middle Eastern countries have little or no indigenous labour force. These countries have no choice but bring in labour from overseas. In some countries this has been done to such an extent that it has caused problems. At present in Saudi Arabia, which has a total population of approximately 5.5 million, there are 1.6 million foreigners. In the smaller Gulf states there are more foreigners than nationals. In these countries steel construction, in the form of prefabricated structures, offers considerable advantages since the work on the site can be done by a much smaller labour force. For example, a steel frame building can require fewer workmen (by a factor of 4 - 6) than a concrete building.

When this kind of building is clad with precast units, the floors constructed of steel plate and concrete, and prefabricated ceiling panels used, etc, the workforce on the site can be drastically reduced.

Intensive prefabrication allows modular construction in the offshore industries. This is an advantage for quite different reasons, viz the severely restricted site area and the short assembly times available.
The construction of industrial complexes in the form of compact transportable units is particularly suited to the large industrial cities in the Middle East, which are all adjacent to good seaports. Construction time is limited to a minimum and the installation can be completed with a very small workforce. Besides the saving in manpower, there are further advantages in the form of lower expenditure on temporary working accomodation on the site, less expense on time spent waiting for supplies, and a smoother commissioning phase. However, it is essential that the decision to use this building method should be taken at an early stage.

6.2 TRAINING

Another consideration is the quality of the labour force. All the components of a steel structure are prepared in advance. A few people who are familiar with the system of marking components, assembly work and measuring, and who will mainly work as supervisors, are adequate to direct untrained workers in erecting a structure. It cannot go wrong, as it were. The likelihood of untrained personnel affecting the final quality of the structure is practically negligible. This is not the case with concrete, which is prepared and placed on site, and which calls for some care, and workmen who can follow detailed instructions. Heat, language problems and working methods also affect the final product. And demolishing concrete is expensive and time-consuming.

6.3 BUILDING SITE

In urban areas building sites are often very restricted. Often there is no cement works, so that sand, gravel and cement must be stored on the site.

Sometimes half of the road is used as storage space, in many cases for long periods. In the hot and windy conditions which are most usual everything in the area becomes covered with dust and there are frequent traffic jams. A steel structure causes far less inconvenience and for a much shorter time.

Some towns solve their traffic problems by accepting an aggravation of the problem over a period. A bridge, viaduct or fly-over is needed to absorb increasing traffic densities. These are often constructed of concrete which is poured in situ. There are many examples of traffic disruption which has lasted for years because the proposal which was accepted appeared to be somewhat cheaper. Even in Europe a traffic jam is not very pleasant, certainly not in summer when one is surrounded by perspiring travellers, exhaust gases and cars which stall. In the Middle East it is usually somewhat hotter and the cars of somewhat poorer quality. Even though the local population is less sensitive to these inconveniences than we aren it is possible that this state of affairs may also change.

Building these structures in steel can reduce disruption and costs which are not directly related to the construction, because of the greatly reduced construction time and the much smaller storage areas at the construction site.

6.4 QUALITY

Another consideration which gives steel an advantage is that of quality. The basic material is prepared under the most favourable conditions and is constantly checked in the laboratory. In general processing is subjected to good quality control. Material is checked for dimensions, and the welding and paintwork are inspected. Quality does not come into on-site assembly under supervision. All these factors represent disadvantages for concrete. The ingredients of concrete are not always of the same quality, the gravel comes from different sources, as does the sand. The water used must be of good quality. Not every building site has a good concrete laboratory. Concrete must be placed under favourable conditions and is very sensitive to temperatures and water. Good quality concrete can be made only by a skilled workforce under expert supervision.

It also happens that concrete which was of good quality initially appears less good at a later stage. It is a recognized fact that in a certain area the reinforcement will rust after a number of years because the sand contains too much residual salt. The effect of the climate should not be underestimated either. The coastline along the Arabian Gulf has a very corrosive climate, with high humidity and severe changes in temperature over a 24-hour period. It is known that steel must be painted well to withstand these conditions, and in fact this is done. However, it is still not usual to paint concrete, and certainly not in that part of the world, with the inevitable consequences.

6.5 RE-USE

Another consideration which in the Middle East is possibly at least as important as in Western Europe is the re-use of material. In countries which are expanding rapidly it is inevitable that not all the plans are right first time. A change of plan, a course of development that has not been anticipated - there are more reasons for discontinuing projects there than in Western Europe. In Western Europe we are glad to make use of the fact that a steel structure can be dismantled and reconstructed. Steel is used not only for temporary steel bridges for traffic diversions, of which there are some good examples, but also for permanent structures. A very well known example is the replacement and reconstruction of the Moerdijk Bridge in the Netherlands. Even factories can be transported wholesale.

It is worth considering the possibility of re-using the Bahrain Causeway if it is decided to construct it in steel. The steel deck could be used for any bridge. The box girders, slightly adapted, could be used for a number of bridges. The residual value of 120 000 tonnes of steel, valued at $ 1 000/tonne, is $ 120 million. This is a significant factor in evaluating a tender of this kind.

7. FINANCIAL RESOURCES FOR STEEL CONSTRUCTION

7.1 OVERSEAS AID

Practically all the Middle East countries have to import steel from overseas. This means that payment must be in foreign currency. For the richer countries this is no problem. For countries with persitent deficits it is naturally an immense barrier to the use of steel for construction. However, it is noteworthy that a country which is one of the so-called developing countries finds it easier to obtain financial assistance for a project which requires supplies from overseas than for one which does not. When a country provides aid obviously it is also thinking of its own industry. This provides quite a few opportunities for exporting steel structures, and it is certain that more use could be made of them.

7.2 TRENDS IN RAW MATERIAL PRICES

The difference between the raw material costs for steel and concrete is an important criterion when deciding whether to construct in steel. Factors influencing the price of steel are the winning costs for ore and coal, the investment expenditure required for processing these, the processing itself and wages. It must be remembered that all these costs are rising. Wages are probably rising most steeply, while processing costs can possibly be kept down reasonably well be improving the bulk transport of coal and ore.

Factors influencing the price of concrete are the cost of cement, winning and movement of sand and gravel, the quantities involved and wages. Increased wage costs are also pushing up the price of cement, but the main factors are the cost of winning and moving sand and gravel. Lorries are almost the only possible means for the bulk transport of sand and gravel. These costs are largely determined by wage and fuel costs, in this case oil. It is not impossible that raw material costs are increasing slightly faster for concrete than for steel.

7.3 PROCESSING COSTS

The costs of processing steel for steel construction components are governed by general overheads for investment and management and also by wage costs. There is still room for investment to increase productivity in individual enterprises, e.g. by providing drilling machines, improving shearing and welding equipment, improving internal transport, standardisation etc. Wage costs in Western Europe are high, even higher than in North America, much higher than in the Middle East and approximately the same as in Japan.

Processing costs for concrete mainly arise on the site. In countries with few labour resources, the Gulf states, use is made of so-called "cheap labour" from abroad, under the day-to-day management of West Europeans or management recruited to some extent from the countries which provide the labour. In countries with greater labour resources the level of incomes is much lower, e.g. in Egypt and Turkey. Even though wage costs for making concrete will rise, concrete construction will still retain a great advantage in this respect.

It is certain that processing steel on site, in the same way as concrete, will never be attractive. This work still belongs in the steelworks.

However, in steel construction it is quite possible to transfer some of the production process to low-wage areas, as in the case of other industries. The investment required need not be particularly great, compared with that required for the motor car or textile industry. It is possible that training and management require more attention than in highly automated industries. Design, construction and procurement can be carried out by the undertaking's own management in the parent country.

8. ORGANIZATION

In the steel construction industry production centres are spread over the regions and tied to their area. It is practically impossible to bring them together. The formation of large companies with centralized offices is not always an attractive proposition. Steel construction is easier with good cooperation between individual units, a group of different production centres or diverse undertakings in association.

The great variety in Western Europe is difficult to rationalize, however, because of the differences from one country to another in language, legislation, export regulations etc. It is practically impossible to set up closely knit and strong export organizations such as exist in Japan.

More effort could be made to undertake joint economic curveys. In the technical sphere joint research is now firmly established, and incorporates scientific training and the use of laboratories. As the economic factors become more important than the technical factors emphasis will inevitably move away from research activities.

Another factor which must be noted is the great variety of technical standards in Western Europe. All the standards are excellent in themselves, but they differ from each other. The technical advisory bureau lays down which standards must be applied for a particular project. In most cases the country of the bureau can be deduced from this information. However, the purpose of the continued existence of differing standards can hardly be to ensure preferential treatment for industries in particular countries. In addition there is the danger that the European position will be weakened. Why should a customer go into the pros and cons of English, French or German standards? He lets the American standards be specified in the knowledge that Japan follows them for all practical purposes, and this solves all his problems. European industry is left with the problems and its competitive situation is weakened.

9. CONCLUSIONS

If the West European steel construction industry wants to continue to export and retain a presence in the Middle East a number of steps must be taken.

Firstly individual undertakings must reduce their costs by improving productivity and reducing overheads. Their sales organizations must also be improved in order to secure those contracts which are more difficult to win. Left to themselves they will find that in many cases this is no longer possible. However, by making a joint effort, and with help from the steel producing industry and the governments concerned, the position can be improved. Joint innovation, sales drives and measures to encourage exports are urgently needed.

There are a few measures which could have an effect on the steel market in the Middle East to varying degrees. Well documented information for customers, designers and advisory bureaux is essential, as well as information at schools and universities.

This information must not be restricted to our domestic markets but must extend to customers in the Middle East.

STEEL CONSTRUCTION IN THE DEVELOPING COUNTRIES

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Summary

The population of the developing countries currently represents almost three-quarters of the world population. These countries are characterized by a low per capita GNP but also by very rapid population growth and runaway urbanization, with the result that in less than 20 years eight of the 10 largest cities in the world will be in developing countries.

In ordre to satisfy their enormous requirements, the developing countries must create a proper building industry. Steel construction is one of the well-known technologies in a number of such countries : Iran, Venezuela, Mexico, and China. Steel may thus be a means of meeting these countries' needs and the advantages of the steel option are fully appreciated. This technology cannot develop in isolation but only in conjunction with the production of compatible building components. It must also be combined with a new, original and local style of architecture appropriate to the requirements, customs and climate of the countries concerned.

There are several possible approaches to these markets : exportation of the complete package, which will be possible only in very special cases; cooperation associated with transfer of technology and local investment; self-build arrangements.

In conclusion, it is necessary in order to satisfy these enormous requirements, to exploit the effectiveness of steel construction and the associated techniques in a very open spirit of cooperation and innovation.

1.0 INTRODUCTION

I should like to thank the Chairman and the organizers of this conference for entrusting me with the rather formidable task of speaking to you on this subject, which is a large one, too large to be dealt with in detail. There are many differences between the various developing countries. This term, which I shall try to define more closely, in fact covers three-quarters of the human race. The world population in 1979 may be estimated at about 4 300 million, the population of the developed countries, including the Communist bloc; being 1 072 million, i.e. exactly a quarter of the total. If one deducts the population of the Middle Eastern countries, whose building sector has been discussed by Mr. KINGMA, the population with which the present paper is concerned is in the region of 3 000 million.

The countries in question are to be found in a wide variety of regions including Central and Southern America, Africa, South-East Asia and Oceania, excluding Australia.

It is thus clear that there are considerable differences in the levels of development, requirements, characteristics and problems of these countries and it is quite wrong to lump them together as we do every day when we describe them as "The developing countries".

At the same time, I am obviously familiar with only a small number of these countries, which I have visited in the course of study or exploratory trips. Studies based on the literature are also very unreliable, given the difficulties we encounter in obtaining accurate information on these countries, even when on the spot.

My coverage of the subject will therefore be incomplete, but I shall state the geographical zones on which it is based and those to which it can be extrapolated.

With these reservations, I now propose to consider the common characteristics of those countries, which constitute the vast majority of the human race.

2.0 DEFINITION AND CHARACTERISTICS OF THE DEVELOPING COUNTRIES

What is meant by the term "developing country"? About 10 years ago, it quickly replaced the expression "underdeveloped country", which distinguished between two classes of hûman beings - those living in the prosperous countries and the rest - on the basis of ratios, of which the most instructive and the most readily ascertained is the per capita gross national product.

2.1 The GNP

In 1979 vitually all the "developed countries" had a per capita GNP in excess of FF 15 000 per year. This criterion, however, is not satisfactory in itself since it includes three Middle Eastern countries along with others among the developed countries as a result of their oil production and excludes other countries, in particular those of the Communist bloc.

It does, however, remain a useful guide, as in 1979 524 million human beings, i.e. half the population of the developed countries, lived in states with a per capita GNP in excess of FF 36 000 per year, while more than 3 000 million, or virtually the entire population of the developing countries, achieved a per capita GNP of less than FF 8 000 and 2 500 million fell short of FF 2 700 per year and head of population.

2.2 Other criteria

Three sets of criteria are used in a study by Elias Gannagé to characterize these countries.

Human factors :
- Rapid population growth as a result of a declining death rate and a continuing high birthrate
- Nutritional inadequacies and deficiencies
- Primitive hygiene conditions
- Very often a large rural population.

Economic factors :
- Predominance of the primary sector

- Low capital investment per head of population
- Limited volume of domestic and foreign trade

Social and cultural factors :
- Class structure frequently highly stratified and unbalanced
- Adherence to traditional values which do not encourage individual effort.

The position in these countries thus cannot be compared with that which existed a century ago in what are now the developed countries. There are basic differences, in particular the population explosion and the international environment, which has been transformed by the existence of the developed countries.

2.3 Urbanization

Rapid population growth in conjunction with the industrialization of the developing countries leads in all such countries to very rapid urbanization, which is often unregulated and therefore running rampant.

75 % of domestic and foreign investment in Brazil between 1955 and 1960 was concentrated on Sao Paulo. The population of Dakar quadrupled between 1945 and 1965.

At a meeting at the beginning of this month in Rome, the United Nations Fund for Population Activities (U.N.F.P.A.) released the following figures : the world urban population, which was 14 % of total population in 1920, has now reached 41 % and will increase to 50 % by the year 2000.

In 1950, only 10 conurbations had a population of more than 5 million and they were located in the developed countries. There are currently 26 such conurbations, and it is predicted that in 20 years there will be 60, of which 45 will be located in developing countries. The future megalopolises are listed below with their population as predicted for the year 2000.

- Mexico District	31 million, 8.7 in 1970
- Sao Paulo	25 million, 6.3 in 1970
- Rio de Janeiro	19 million, 4.4 in 1970
- Shanghai	23 million, 7.0 in 1966

- Peking	20 million, 8.0 in 1975
- Bombay	17 million, 5.5 in 1971
- Calcutta	16 million, 3.1 in 1971
- Djakarta	16 million, 5.0 in 1970

Together with New York and Tokyo, these will be the 10 largest cities.

This frantic urbanization under squalid conditions is one of the major problems of the developing countries, for the needs are enormous while at the same time it is impossible to provide employment, services and decent accomodation for an extremely poor population. The practical effects of urbanization may be seen in the ranchitos around Mexico City, the favellas around Caracas, or the strange combination of enormous low-cost housing blocks and of floating slums on a sea which is oil-smooth in more senses than one at Hong Kong.

Massive assistance is necessary : internal assistance when the community, i.e. the state, has the requisite means, generally obtained by large-scale exploitation of natural resources, and foreign aid in countries which do not possess such resources or are currently unable to make use of them.

This rapid, over-simplified analysis reveals two categories of country :

- those possessing and exploiting natural resources, whose economies have taken off or are in the process of doing so;
- those whose economies are stagnating (zero growth or decline in the GNP).

The trend in this second category of country could conceivably be reversed in the long term only as a result of the development of world food requirements in conjunction with effective aid.

In the first category, which includes most of the world population, the GNP is increasing rapidly as a result of an industrialization process which has either been accomplished or is in progress : Brazil 7.0 % in 1978, Mexico 8 % in 1979, Algeria 10 % in 1979, China 10 % in 1978 and 7 % in 1979 and India 7 % in 1978 and 1979.

3.0 THE CONSTRUCTION INDUSTRY

What is required in these countries which are in the process of industrialization is mass construction. As already mentioned, population figures are soaring, urganization is proceeding at an unprecedented rate and the rise in living standards creates needs of a new type at community level.

For all these countries, speed of construction thus appears to be a prime consideration. As shown by Jean Monnet in France in 1946, however, mass construction or reconstruction requires steel and cement and hence coal, railways and an industrial base. Progress can best be achieved by setting up industries capable of providing the country with the processed building materials which it requires.

This necessary preparatory phase prior to expansion of building activity is very apparent in countries with planned economies, where priority is given at this stage to industrial investment.

It then remains for the productive capacity of the industries set up to be applied to the problem of building.

Here too, a parallel may be drawn with the period of European reconstruction beginning in 1946, of which only European firms have any experience. What is required is to standardize and industrializethe construction sector and to introduce industrial methods to the building trades in order to satisfy the needs of the greatest number at the minimum cost and in the minimum time.

Steel construction has not merely adjusted to these methods, but as it is itself an offshoot of industry, forming a link between industry and building, it has played an innovative rôle, providing an area for experiment in industrialized building.

4.0 STEEL CONSTRUCTION IN THE DEVELOPING COUNTRIES

Steel construction is already employed locally in many countries to meet requirements outside the purely industrial field and thus has a range of applications extending from apartment blocks or individual houses to administrative buildings or community facilities.

4.1 Iran

I cannot but mention the very original example set by Iran in this field.

Steel construction is used there at the small-scale level for individual houses. Here a house in the vicinity of Teheran is being built using castellated beams and terracotta. A further example of small-scale application is this extension to an administrative building, which is itself of steel construction. Technological expertise, however, is demonstrated by the construction of apartment blocks, also in Teheran. The skeleton is of course of steel and the infilling of terracotta.

4.2 Venezuela

As a steel producer, Venezuela has a dynamic steel construction industry. The output of the largest company in the sector is 70 000 tonnes per year, and it has completed spectacular projects such as the framework of these 54-storey blocks in the Central Park at Caracas. The methods and equipment employed are of a high standard and are comparable with our own : computerization of design, manufacturing plant and inspection systems are extremely advanced.

Here the Instituto National de la Vivienda (INAVI) has cooperated with the building firms to develop methods of industrialized or prefabricated construction on the basis of a modular system using both steel and concrete.

The combination of a steel skeleton and concrete panels, which involves a prefabricated and an artisanal element, is suitable for the construction of houses in rural areas; steel and concrete blocks for country schools; steel skeleton, concrete floors laid on steel troughs and roofs of dry construction for an apartment block system. The Caracas school of architecture has developed an industrialized building system of steel-frame construction which is particularly flexible, and meets various types of requirement.

4.3 Mexico

Mexico is often regarded as the trail-blazer among the Central American countries. Its construction sector is very active. Its building contractors, which are the largest in this region, export throughout Central America and in the last two years have begun to operate in Africa and the Middle East.

Steel construction is used for office buildings in the centre of Mexico City, in combination with curtain walls of local design and execution. Here, the steel structure makes it possible to use the brise-soleil of the façade as a load-bearing and stabilizing element. Steel-based technology and architecture are well known here and are widely used.

The steelworks of the Monterrey region are in production.

4.4 China

In China, too, the steel industry achieves remarkably high quality and reliability, but the steel produced is reserved for heavy industry or for the capital goods sector. There is no systematic use of steel for building and one sees very few steel-frame structures of Chinese origin.

This exhibition hall in Shanghai, which forms one wing of the industrial exhibition centre, appears to be of Chinese design and execution. On the other hand, this steelwork under construction in the steel-making quarter on the outskirts of Shanghai has been designed and executed by Japanese, Japan being China's main economic partner.

China is, however, carrying out a substantial programme of all kinds of construction.

Sheds, like this one, completed entirely within the space of one month, the whole skeleton being of lashed bamboo with spans of about 20 metres; blocks of flats in Peking, like these, built with a concrete framework and brick infilling, as is this hotel in Shanghai, on which a labour force of 1 500 worked for almost two years, only the façades being of steel. Here are other blocks, built using a conventional heavy prefabrication method.

In Hong Kong concrete seems to predominate both in the city and in the New Territories, although a very fine example of steel construction is provided by this remarkable post office.

5.0 PROBABLE DEVELOPMENTS

5.1 The steel option

All these countries are tempted by steel construction as a complement or as an alternative to building in concrete. The advantages of this option are well known and fully appreciated :

- genuine industrialization, hence high production capacity and reliability;
- ease of transport;
- requisite investment in steel framework production slight and of a type readily integrated into rural areas, avoiding the concentration of population in urban zones, which is vigorously opposed for the reasons previously mentioned;
- creation of more skilled jobs for the workforce involved, hence upgrading of labour.

In addition, only 35 to 40 kg of steel per m^2 of overall surface area are required for the erection of conventional apartment blocks of steel construction, while 20 to 30 kg/m^2 are required for blocks of concrete construction with cross walls.

There is therefore no great difference in the volume of imports or the steel-making capacity required to attain the same objective by the two methods.

Steel construction is thus in a strong position and there is a demand for this advanced technology, but there are many pitfalls to be avoided.

5.2 The need to create a new architecture

We must realize from the start that it is pointless to seek to transpose European building methods and adápt them to local conditions.

This easy way out would result in superimposing the sociological and climatic constraints in the country concerned on those existing in our own countries.

As a result of our temperate climates, our main concern is protection against cold and rain and our entire technology, the whole art of building in our countries, is implicitly based on these climatic factors. Our way of life and the sociological constraints to which we are subject have made us delicate and unable to tolerate many of the variations in weather conditions which our parents tolerated and indeed considered to be much more acceptable than what had gone before. Our per capita consumption of water, for example, is growing disproportionately from generation to generation and these standards of comfort cannot be attained in many of the developing countries for several decades to come.

Such a transposition of our methods leads to the construction of buildings which in practice are unusable and whose high cost is increased by the necessary modifications : solar shading or air conditioning.

In order to succeed it is necessary to take the local way of life and climatic conditions fully into consideration.

For example, average temperatures in the city of Caracas vary from 14° C mean winter temperature at night to 27° C mean summer temperature in the daytime. Modest thermal insulation will thus be adequate and the complete lack of such insulation is perfectly tolerable. A number of luxury villas which I was able to visit were not insulated, and the front of one of them, looking on to magnificent grounds, was completely open, being protected from intruders at night only by an arrangement of grilles.

The vast majority of the population with which this paper is concerned lives in the tropics, where the traditional building style ensures efficient protection from the sun by roofs with wide overhanging eaves and efficient natural ventilation.

Many European firms will remember the problem of the Nigerian barracks, for which European-style designs proved less satisfactory than a design which was very primitive and perhaps no less expensive but which was more compatible with the way of life of the population. The population of the developing countries does not necessarily admire or seek to imitate our manner of living. We too often assume that these peoples must in the long term move closer to our criteria of civilization.

We must therefore recreate an appropriate style of architecture on a cooperative basis, taking account of real needs, resources and deep-seated aspirations.

A further example of the inappropriateness of our techniques is that of the lecture rooms at the Algiers school of architecture. Although they were designed by an architect of world-wide reputation, their air-conditioning system proved insufficiently robust and broke down, and there was only a single door providing very slight ventilation. A simple solution would have been to replace the enormous flat concrete slab which forms the roof by a light metal framework which would create a draught effect to provide efficient and permanent natural ventilation requiring no maintenance or power.

Great humility is therefore required in tackling these problems and we must constantly re-examine what we assumed to be established truths and be prepared to serve our apprenticeships over and over again.

5.3 Steel construction is a method of building

A steel skeleton on its own does not satisfy a need but only makes its satisfaction possible. The need can be satisfied by a building, and steel construction is one of the methods of executing the structure.

If steel construction is to be practised, it is thus essential that the materials, or rather components, associated with the structure should form a whole permitting the construction of a building. If there are no such compatible materials, or if it is impossible to import them, steel construction will not be practicable, whatever its merits.

It is therefore necessary to establish that such materials are available and, if they are not, to have them produced or involve the appropriate manufacturers in a parallel venture. The "industrialized" systems using concrete employ concrete for the structural and infilling components and this technique does not presuppose production of complementary infilling materials.

6.0 POSSIBLE APPROACHES TO THESE MARKETS

There are various possible approaches to these markets.

6.1 Exportation of the entire package

The most obvious is to export entire buildings. This involves carrying out the design work, calculations and manufacture of the necessary components in Europe, transporting the components and carrying out only the assembly work on site.

It is possible to export in this manner only to countries which have plenty of foreign currency; these are not very numerous and are at present located in the Middle East. However, in certain specific cases, various countries employ such methods either to solve a political problem, when an important deadline has to be met, or to satisfy an urgent requirement which could not be met by the methods more usually employed.

This type of contracts is particularly advantageous for our economies since it in practice enables us to export up to 80 % of the contract value from Europe, the labour force on the site being small and mainly European.

Here, for example, is an office building constructed at Jedda. All the components were produced in France, and assembly on site was carried out by a team of 50 Europeans in about one year.

6.2 Cooperation

This form of project, which costs the purchasing country large quantities of foreign currency, thus makes no contribution to the training of local labour. It is carried out in isolation from the local market and is thus not subject to disruption by external factors.

For all the countries in the process of industrialization imports must be an investment, and not merely a material investment at a given point in time but an educational investment with a long-term effect. This direct form of importation is thus generally rejected.

A concrete structure, for which the ratio of exported to local work is the inverse of that for a steel structure, will thus, for a given price, cost only a quarter as much in terms of foreign currency but will also fail to meet the real requirements of such states.

It is necessary to adopt a cooperative approach, i.e. to transfer knowledge of working methods, to pursue joint development of new technologies and then to invest in local production units. In countries which are short of currency the contractor will also be required to re-export from the production units set up in order to ensure a return on the investment and services provided.

In addition to the obvious balance-of-trade considerations, these rules are designed
- to ensure training of the labour force;
- to speed up to progress of industrialization;
- to utilize indigenous resources;
- to promote or maintain independence.

Exporting of buildings must therefore be seen in terms of collaboration and exchange and not simply in terms of sales.

6.3 Self-build arrangements

Whether locally manufactured or imported, the basic components must be assembled on site with or without infilling materials of diverse origin.

One of the approaches developed is self-build construction.

This involves supplying the population with the necessary means for erection of fairly small buildings, mainly for housing purposes. The components supplied must obviously be fairly light so that they can be assembled without means of handling other than the user's physical strength, hence the name "self-build".

The methods developed thus employ frames generally of metal but sometimes timber, used in conjunction with infilling materials which range from strictly local materials such as cob or adobe to industrial components :

sheet metal, asbestos cement slabs, fibre-board or other wood which can be easily handled without sophisticated equipment or training in complicated motions.

7.0 CONCLUSION

In conclusion, I should like to point out that the building requirements of the developing countries represent the largest market in the history of mankind. The population explosion in conjunction with urbanization is creating enormous needs.

Steel construction is a logical and effective answer to the problem arising out of the enormous scale of this development. If it is to be used, however, the European steel construction firms and the associated industries will have to work together to export the techniques which they had to invent and perfect in order to meet the requirements of the immediate post-war era.

It is necessary not only to produce and sell but to provide cooperation and training above all to ensure that what we offer corresponds to real needs and not to our preconceived ideas of the form to be taken by steel construction in this whole group of countries.

Every people has its own individuality : it is for us not only to respect that individuality but to realize its potential.

SUMMARY OF THE SESSION AND DISCUSSION

P. BORCHGRAEVE, Chairman

In organizing this conference the Commission of the European Communities is following a long tradition, since the first Steel Congress was organized in 1964 in Luxembourg by the Coal and Steel High Authority.

In the context of the present economic crisis the theme chosen for this conference takes on particular significance. Steel and construction, two key sectors, cannot exist without each other. In the Community, the construction industry accounts for 25 to 30 % of final steel use in all its forms : it is the steel industry's customer. Steel construction alone (structures + finishings) represents approximately 12.5 %.

There are numerous potential outlets in the construction industry. The opportunities for steel are there, but major efforts of innovation and adaptation are required if its technical and economic advantages are to be fully exploited.

However, although construction is largely determined by economic and technical factors, it must not be forgotten that first and foremost it means constantly adapting to the needs of man. It is therefore fitting that the significance of "construction on a human scale" should be considered in the introduction to the work of the conference.

The papers on the role and prospects for steel construction in the major economic zones afford the opportunity for a comprehensive study of the situation with regard to steel construction. They highlight the opportunities which exist, the methods used to exploit them, the obstacles which need to be eliminated and the successes achieved.

In the United States the construction industry used 29 million tonnes of steel in 1979, i.e. 26 % of the total steel market. To meet the challenge from concrete some American steel companies have successfully devised technical assistance programmes for architects and consulting engineers; the assistance often involves the drawing up of a preliminary structural study and an estimated bill of quantities. Initiatives are also taken by the steel industry as a whole, in conjunction with other organizations, to inform and educate steel users. Since concrete can now match steel in structural performance, the future of steel construction depends on more dynamic and aggressive marketing methods.

In Japan, construction still represents 50 % of total steel demand. Steel structures occupy an important position, with an index figure of 738 in 1977 (1960 = 100) compared with 397 for concrete structures and 538 for composite structures. The reason is that the Japanese steel industry invests heavily in researching and developing new products and technologies.

An organization with a strong hierarchical structure is responsible for developing new markets for the whole of the steel industry. Its initiative usually take the form of publicity designed to promote wider and better use of steel.

Finally, the Japanese steel industry cooperates with other industries in the execution of very large construction projects, in which overall steel consumption is measured in millions of tonnes.

The prospects for steel construction remain good as long as the steel industry continues to endeavour to meet new demands and to enable users to make the most rational and economic use of the best products.

In Western Europe, steel needs to reestablish itself in the construction industry. Changing demand, the increasing versatility of concrete and changes in the construction sector call for determined efforts to adapt and improve the services offered and to find new ways of penetrating the market. If steel construction is to be more competitive, greater attention needs to be given to research on structure design and the rational use of steel, in particular by integrated computer processing. Finally, if the potential uses and important advantages of steel are to be sufficiently recognized, it is essential to continue to inform, to demonstrate and to educate.

The industry as a whole and each individual entreprise must adopt a voluntary strategy and a dynamic consensus if the role of steel in construction is to be maintained and developed.

The construction requirements of the Middle East countries are enormous. The bulk of the steel construction market goes to subcontractors. The greatest opportunities lie in turn-key construction projects for small and medium-sized industries.

Steel construction carries a number of specific advantages in these countries. With steel, a smaller work force needs to be imported (local labour is practically non-existant).

Transport in compact units reduces disruption to urban traffic; the site, often in an urban area, is not cluttered with dusty, heavy products.

An unevitable consequence of the rapid expansion in these countries is that buildings are frequently demolished and reconstructed elsewhere; here again, steel offers considerable advantages.

These countries also have problems relating to the lack of harmonization of standards and procedures for awarding contracts. To maintain and develop steel construction, joint action should be taken to educate the local authorities and decision-makers.

The developing countries, undergoing very rapid and often uncontrolled urbanization, are tempted by steel construction; the advantages are generally clearly recognized.

We must avoid transposing European construction techniques based on our own constraints, which would result in buildings which were unusable in the light of local restrictions.

The need in these countries for imported buildings should not be seen simply as a once-for-all material investment; it should be the starting point for cooperation with them, with the aim of jointly developing new technologies adapted to their specific needs and leading to local investment.

DISCUSSION OF THE SESSION

Mr. CARPENA, Secretary-General of the European Convention for Structural Steelwork (CECM), referring to the remarks made by Mr. METZ on the significance of composite steel-concrete structures and the need to harmonize regulations at European level, mentioned the document "Recommandations pour le calcul des constructions mixtes" (Model Code for composite structures).

This Code had been prepared by a joint committee chaired by the CECM and including representatives of the International Prestressed Federation (IPF), the European-International Committee of Concrete (CEB) and the International Association for Bridge and Structural Engineering (IABSE). The English version would be published by the end of 1980, the French version having been published in the journal "Construction Métallique" in March 1980.

The steel and concrete aspects of these recommendations for composite structures were based respectively on the "Recommendations for steel Structures" published by the CECM in 1978 and the recommendations of the CEB. They would be included in the future European regulations "Eurocodes" which the Commission of the European Communities was preparing for the various construction materials.

Mr. THOMAS, Directorate-General III - Construction Division, CEC, asked Mr. KINGMA whether it was possible to specify which construction code should be applied by a European contractor when building in a Third World country.

In his reply, Mr. KINGMA pointed out that the specifications usually laid down the standards which would apply, often with the remark "approved similar". Consequently, the contractor tried to apply the standards most favourable to himself. The European standards DIN, BS and AFNOR were in common use on the international market. In practice the contractor had a certain amount of latitude which allowed him to refer to one standard for certain aspects of the construction and another standard for other aspects, depending on which he found most advantageous.

Mr. RORET mentioned the French experiment from 1973 to 1978 with the agency Assistance Technique Acier (ATAC), whose methods were very similar to those described by Mr. CHEHI and Mr. HORI and which was roughly in line with the proposals made by Mr. METZ.

This agency, which was jointly financed by the metal construction and steel industries, gave advice and prepared preliminary solutions to steel problems for architects and contractors from the very beginning of a construction project. The ATAC often sought advice from research or engineering consultancies and was thus not setting itself up in sterile competition with these agencies - on the contrary, it situmulated them to develop the metal construction aspect of their work.

Mr. RORET said that Mr. METZ was right to want metal constructors to take on the role of general contractors.

If a metal construction works manufactured not only the structure but also the façades, its direct share in the project could amount to 25 to 30 % of the cost.

In contrast, when, as often happened, a general concrete contractor subcontracted the implementation studies, the earthworks, the preparation of metal frameworks and even the concreting, his own share of the cost was a mere 5 to 10 %. The metal constructor was therefore in a better position and this viewpoint, if well presented, was often understood very clearly by the client.

In remply, Mr. METZ mentioned an example which supported this thesis : the turn-key construction of the new European Parliament hemicycle in Luxembourg had been awarded in its entirety to a metal constructor, who had completed the work in a record time.

Mr. METZ also thought that the system of preliminary studies and estimated bills of quantities outlined by Mr. CHEHI on the basis of Bethlehem Steel's experiment was a sound approach from which Europeans could learn.

Mr. DE MARTINO, Italsider, asked Mr. HORI whether construction in Japan, which was prone to frequent and severe earthquakes, was governed by regulations which favoured or advocated steel construction as opposed to other solutions.

Mr. HORI replied that Japanese constructors took stringent precautions against the risk of earthquakes. In this repect, some types of concrete structures were not satisfactory and were consequently less in demand. Mr. HORI would provide further information at a later stage.

MEETING THE CHALLENGE FOR STEEL IN CONSTRUCTION

Chairman: J. RORET, Director, Compagnie Française
d'Entreprises Métalliques, Paris

I. Steel meets new technico-economic requirements

- Observations of human aspects of architecture
- Steel in housing architecture
- Thermal Insulation of single storey steel clad buildings
- Mixed steel and concrete construction with improved fire resistance
- Railway bridges: a challenge for steel construction
- Light steel bridges to facilitate traffic and pedestrian movement

II. Steel in the restoration, conversion and adaptation of buildings

- The Maltings concert hall, Buxton opera house and York Minster: a reconstruction and two restorations
- Steel: a bonus in the restoration, conversion and adaptation of real-estate heritage
- Steel for restoration, rebuilding and conversion of real estate
- European Parliament hemicycle in Luxembourg
- Summary of the discussions

OBSERVATIONS ON HUMAN ASPECTS OF ARCHITECTURE

J. BRANDI

Brandi + Partner, Göttingen

Summary

1. Physical pressures have, in the past, almost always driven men into homogeneous and unified forms of settlement.
2. The living conditions in social ordering under circumstances of vertical family grouping and
3. the development of today's small family group
4. The present-day threats, mainly to man's psyche and
5. the challenge to man in the post-industrial society.
6. The type of the mature builder who is involved in planning
7. and the material steel as a primary building tool.
8. The argument for the building bricks principle and the challenge to the creativity of the dweller.
9. The research project at the ECSC experimental station
10. and the first data to emerge from the cooperative work with tenants. The promise of new living concepts.
11. Effort towards optimal interlocking of living, working and leisure time, illustrated by examples of actual steel buildings and future drafts for the urban housing ideas at the International Building Exhibition, Berlin, 1984.
12. Flexibility, adaptability, portability and built-in obsolescence in architecture for humans.

1. HOUSING AS 'THE PEOPLE'S ARCHITECTURE '

Physical pressures on man, like natural and climatic conditions and the likelihood of military action, as well as the limited availability of materials for building and of means of transport, have almost always led, in the past, to a certain kind of structure and settlement. Housing began as the architecture of the people, i.e. architecture without architect or in which the architect is anonymous. The unity of working and living, the need for protection within settlement walls, all combined to press people closely together. The sure knowledge of unchangeable fact, the necessarily modest demands which could be made on place and space, and the handing down of experience of working and living conditions, brought about the development of multi-purpose buildings.

2. SOCIAL CONDITIONS IN THE VERTICALLY ORGANISED FAMILY GROUP

The inhabitants of these buildings were organised in the socially secure structure of the large family group which was assumed by the dominant agricultural societies. In this group, which conventionally comprised three to four generations, labour and role distribution developed naturally in response to the age-determined capability and the needs of the members of the group. In agrarian society, the vertical family system provided a guarantee of social stability for the individual from the day of his birth to the day of his death. It was a social contract of the generations in miniature, from which sensible agreements and appropriate modes of living could be derived. (1)

3. THE DEVELOPMENT OF THE SMALL FAMILY UNIT

The large family group of agrarian man no longer exists, having been replaced by the small family unit of two, three, or four members. In the Federal Republic of Germany, communities of two to four persons are formed in 60% of all private housing. Single person households and experiments in alternative living are on the increase.

However, the small family is unstable. It is frequently threatened by marital and generation conflict. In it, the woman who is only a housewife often feels unfulfilled and frustrated, her children grow up with little contact or approach from working parents. The grandparents' generation is increasingly isolated and put away in old people's homes. With a falling population, the need in the Republic for kindergartens and schools diminishes, while the deficit in housing for the elderly grows worse. From the large population of children which once existed, there is now threat in 30 or 40 years time of a mountain of pensioners and elderly. The growing increase in the average age of the population, the age-determined disintegration of the industrial society, are bringing as yet unforeseen problems of a social, financial and political nature. (1)

4. PRESENT THREATS TO MAN

The present threats, which are psychological rather than physical, are inadequately described by the vocabulary of fashion and the jargon: 'Isolation and narcism, suburban neuroses and middle life crisis, commitment anxiety and family egotism, material well-being and loss of soul' . A really generally applicable awareness for the psychological threats of the present time in terms of supposed economic security is not yet available.

'Saxa loquuntur' - our housing is a demonstration of this truth. The confusion of our times is reflected in our architecture - as an illustration of perplexity (2) - in the destruction of the fabric of the town, in the cancerous growth at the edges of cities, and in the depopulation of the countryside. There is also the disastrous separation of living and working to question the human world - here a world of private experience, there the crowded workplace.

5. THE INHABITANTS OF POST-INDUSTRIAL SOCIETY

The number of these threats and challenges is forcing man to seek the answers in the so-called 'post-industrial society' with its capacity for modesty in material demands on the one hand and the satisfaction of reasonable claims on the other. Will the prognosis put forward in this congress hold true, that in the future **' less emphasis will be placed on driving, and more attention will be given to the living environment' ?**

Against the background of the likelihood of shorter working hours and a larger amount of free time, this trend will have the effect that in the future, the desire to own a private car will fall in significance and self-determining arrangements within one's own four walls will gain in significance.

6. THE NEW BUILDERS

A greater involvement on the part of the dweller in his surroundings presupposes a new type of master builder:

- with understanding of how to realise his own vital needs in terms of living forms and how to adapt constantly to changing conditions
- with insight into how the general and public good is to be brought into balance with his own individual requirements
- with a capacity for dispensing with the material and maintaining a constant learning and playing ability

The building components available to him must, therefore, be divisible and elementary. The components would, on economic grounds alone, be very largely industrially produced, with industrial methods providing the solutions to the energy problems of the future. 'The problem is to fit the industrial form and quantity to the needs of people and not - as in functionalism - to require a modified man who accepts a standardised machine as a dwelling or a town.' (2)

The above premises provide a powerful argument for steel, which should be developed through ideas, proposals and examples from a long-term research and development activity.

7. MODULAR BUILDING USING STEEL

We have come to steel through wood. The airy framework is a structure which can be transposed to building with a material whose properties open up new possibilities. Its load-bearing capability permits smaller cross-sections, greater spans, freer planning. Steel design and smaller transport volumes permit disassembly and reuse to meet changing requirements or the needs of urban modification. The materials characteristics of steel led our working group to the old idea of children's building bricks or construction sets.(3)

8. THE PRINCIPLE OF THE CONSTRUCTION SET AS A TOOL FOR LIVING

The principle is based on the idea of being able to use a number of elements of a few different forms in a wide variety of ways. In order to transfer this basic idea to actual building, it means that industrially standard units will no longer be used to build a standardised structure conceived and planned by architects and engineers, but to provide an open-ended system within which the occupant himself is able to produce multi-variable space enclosures.

The system proposed here takes into account equally the differing requirements of new occupants and the changing requirements of long-term occupants - the latter's marked requirement for change in the early years as well as the need for stability in later years when the environment has been identified with. The occupant is no longer excluded from the business of planning his own four walls. He experiences in practice that even a living programme finds its measure in the needs of men and is available for modification in his interests. In this way, the building of dwellings can no longer be seen as an alien sphere or as a preordained regulation, but as a vehicle for the expression of own ideas, free decisions and conscious self-determination. (3)

9. RESEARCH WORK AT THE ECSC EXPERIMENTAL STATION IN BERLIN

The ECSC provides research subsidies at its Experimental Station in Berlin. Using the demonstration building in the international experimental park in the commercial quarter of Berlin, on the banks of the Spree, a European cooperative research undertaking tests new building components and carries out applications trials, and examines and proposes new forms of building and living. In this way a testbed is provided not only for the production and assembly of components and of their suitability and of their alliance with steel, and of their application possibilities, but also under examination are the socio-psychological and the socio-educational consequences of a building method which puts structures at the disposal of the occupant or user in a new way. (3)

10. FIRST DATA ON LIVING FROM THE ECSC EXPERIMENTAL STATION IN BERLIN

The ECSC research order provides the opportunity to gain experience of new building methods in depth and in collaboration with the tenants. In accordance with the development directives of the Land Berlin, the ECSC experimental station has built 45 appartments ranging from single-person flats to family dwellings.

On the ground floor are the offices of the Forschungsgesellschaft für industrielle Bausysteme mbH which operates a running consultancy in connexion with the new, occupier-modifyable method of living.

The preliminary data available on this research activity confirm the concept and function of living in steel which is based on the first prize awarded in the international architectural competition by the then Montanunion in 1967.

The small scale and the vigour of the external steel architecture was, at first, regarded as rather alien by the occupants whose attitudes were conditioned by the monotony of the usual post-war block of flats. The spatial opportunities in the flats were soon appreciated by the occupants. Using a simple kit of steel shelving, wooden grating, lawns, plants, sand and water containers, the terraces, loggias and balconies were transformed into gardens. In the interior of the six living floors, the spatial subdivisions are entirely tailored to fit the requirements of the occupants; within limits, the walls are freely movable on steel tracks. Since 1976, the occupants have identified very strongly with the new style of accommodation and the involvement in planning has led to some very individual ground plans. A marked characteristic of the requirements of the occupants was the wish for the maximum possible space for the family room. It was felt to be a disadvantage that the conventional development guidelines and building recommendations were only oriented towards the conventional forms and severely limited elbow room.

The building has hardly any disadvantages in terms of noise and heat insulation, and all are agreed on it. One can be seen, but one is not disturbed. The wide terraces running round the building invite contact, like a landing on the outside. Each appartment is connected with the terraces by room-height sliding glass doors. In the summer, many families keep these doors open day and night. The children play unrestricted on their neighbour's terrace and this form of communication has become quite normal. The atmosphere among the occupants is quite unlike that normally found in blocks of flats. According to the occupants, who consider themselves to be something of pioneers of new living, it is simply 'more human'. (4)

11. HUMAN LIVING AND A WORKPLACE FIT FOR HUMANS

After decent home conditions, a human workplace is of enormous importance. A few examples from industrial building are provided here in connexion with the efforts towards optimum interlocking of areas for living, working, and recreation. The Täfler-Metallwarenfabrik, Dransfeld, and Adams and Refratechnik, Göttingen, represent further efforts of our group to make the workplace more attractive and human.

Town housing prototypes will be prepared in connexion with the International Building Exhibition in Berlin in 1984; these will be a further development of our ECSC work on building for concentrated habitation. Terraced houses are coming into being on the Lützow bank in 6.5 m parcel widths and with a ground area of about 200 m^2. Within a unit, 150 m^2 is planned for a family of five and 50 m^2 for single occupancy. The townhouse project is based on a judicious sequence of public, semi-public, semi-private and private zoning. The idea attempts to gain the advantages of individual single-family houses accompanied by the economic and spatial exigencies of inner-city planning and living. The 6.5 m fronted terraced houses will be placed beside each other mirror-image and thus form a ground unit. Above the street or alleyway space will be opened up an associated covered entrance area making a covered play space for children and which can also serve as a covered parking place. The single-occupancy appartment is in this entrance area so that it can readily be adapted as office, studio, workshop, or shop.

The communicating area of the family appartment, with living, dining, cooking, and utility spaces are on a main level and have a terrace onto the street and a loggia onto the garden. The loggia is inspired by the old wintergarden idea: in a further development of steel equipment, canopies will be hung in summer and additional glass screens in winter in order to provide a buffer between the appartment and the outside world in the interests of energy conservation. The metal component principle enables the occupant to make varying use of the area in response to the seasons.

On an upper level are the sleeping accommodation and bathroom. The partly projecting roof level contains a protected roof garden offering the feeling of a private courtyard which is not overlooked. The pergola-like construction is in hot-dip galvanised steel and it extends down to ground level as a trellice for plants.

12. FLEXIBILITY, ADAPTABILITY, PORTABILITY AND BUILT-IN OBSOLESCENCE IN HUMANISED ARCHITECTURE

The beginnings of structural steelwork principles of this kind go back through wood frames to the tent, which offered flexibility, adaptability, portability, and disposability. Steel is the only building material which fulfills the same criteria.

In its simplicity and striking appearance, the bedouin tent of the North Yemen demonstrates an irreducible piece of people's architecture serving simultaneously as home and workplace. It is the expression of the life of men in danger of their very existence. The plan of this dwelling is the most impressive and economical ground usage I have ever seen: two central posts provide the headroom in which one can stoop; two further supports stand at the ends. Under the ridge on the right is the simple bed of the man, on the left that of the woman. Near the man is a fireplace and beside it a tool - and the jewel case. And this jewel case is the only item of value which might help in case of need. Near the mother's bed, the children lie on the floor with the young lambs. At night it is very cold in that part of the world. So the children and the lambs keep each other warm. During the day, the temperature reaches 45°C and the tent provides shade for all that need it. The poultry do not need it.

The tent is protected by a canine alarm system; to one side is the camel of the nomadic tent-dweller. For a few days, the family occupies itself in this piece of the savanna. Then the tent is struck and they move on. A sandstorm blows over the spot and the earth is as it was in the first place.

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3. from 'Stahl und Form'; Jochen Brandi und Partner
4. Extracts from the Research Reports of the Forschungsgesellschaft für industrielle Bausysteme mbH, Berlin

Fig. 1
"Building is one of the oldest creative activities of mankind. Throughout history man has striven to make use of the most recent scientific and technical knowledge to satisfy his vital needs. In no other sphere are form and technology so directly interwoven in our lives as in architecture, which should be both utilitarian and beatiful, In this research project supported financially by the European Coal and Steel Community, the aim has been to use steel as a material for building. The modular building system proposed here gives everyone the opportunity to decide of himself on the interior layout and design of his home and to adapt it to his changing needs."
(Wilhelm Haferkamp, Vice-President of the Commission of the European Communities)
Photograph : A view of the façade of the project/West side

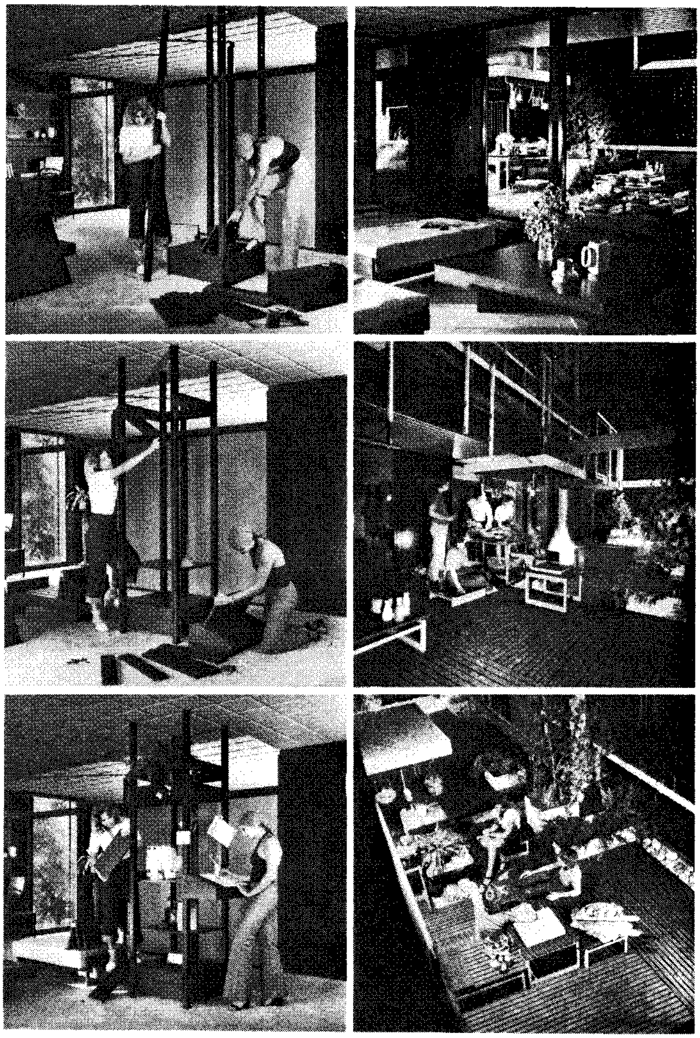


Fig 2

The baukasten system is a practical, economical and functional "open system", it accords with international dimensions. Components from different manufacturers can be integrated and combined, and the whole structure affords a broad range of uses. The freedom of choice in final layout offered by the system as presented here takes into acount not only the different requirements of changing users but also the changing tastes and needs of long-term residents - their greater need for variety and change when younger, and for stability and order when they are older and have identified with their self-made surroundings, which they no longer wish to alter.

Photograph : Stages of alterations by residents

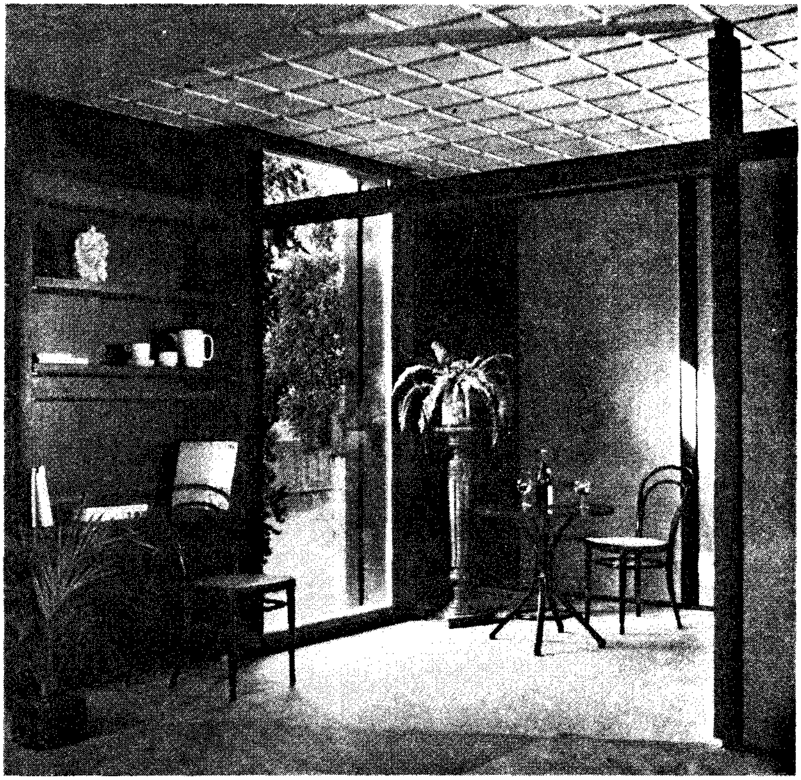


Fig. 3

The primary structure is filled out by non-loadbearing, space-enclosing wall elements, the connecting parts of which have simplified in such a way that residents can themselves alter the position of the walls. Within the area allotted to the secondary structure, vertical steel struts can be fitted when and where desired, to which wall or furniture elements can be attached. The various possibilities offered enable the resident to create a "spatial integration of walls and furniture" without any danger of clashing with the technicaql and supply systems located in the floor.
Photograph : Interior layout using elements / Dining area

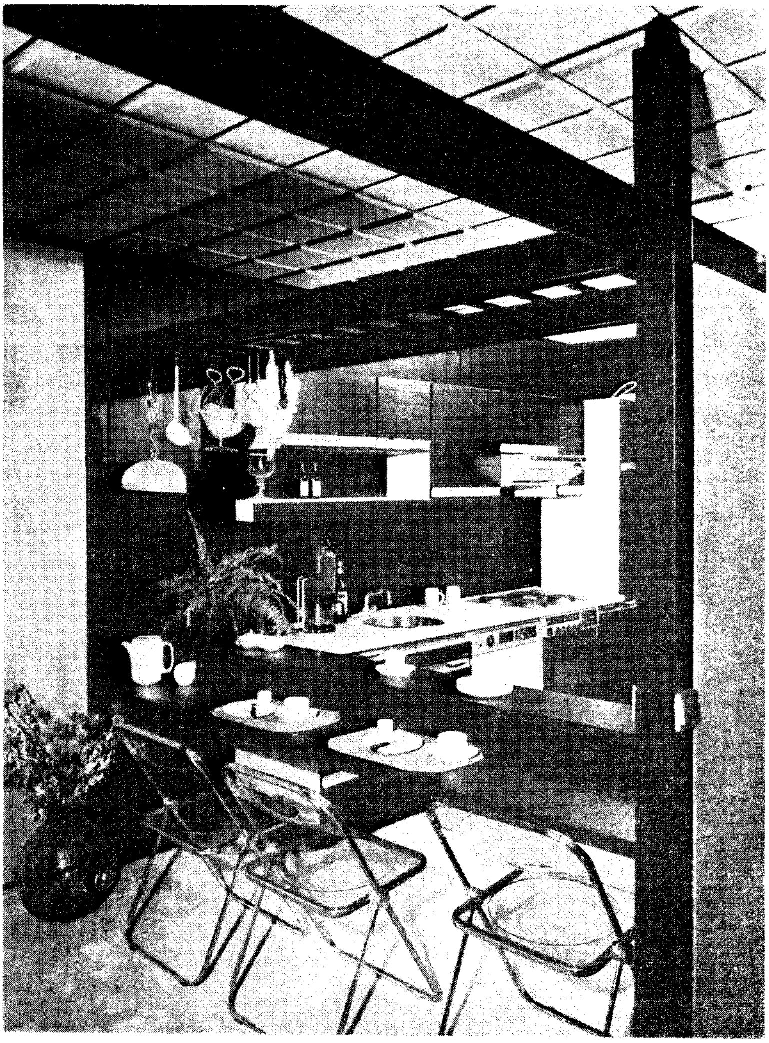


Fig. 4

In view of the necessary rationalisation and industrialisation of production and erection processes, new methods of steel frame construction and of general subcontracting have been developed. The attempt to relate support members and supply system to each other from the very beginning, and to incorporate them into an optimal system, has led to the combination of several functions within the same building component – for example the combination of sanitary, heating and ventilation installations within the framework itself.

Photograph : Kitchen with breakfast counter which can be installed anywhere at all in the living unit

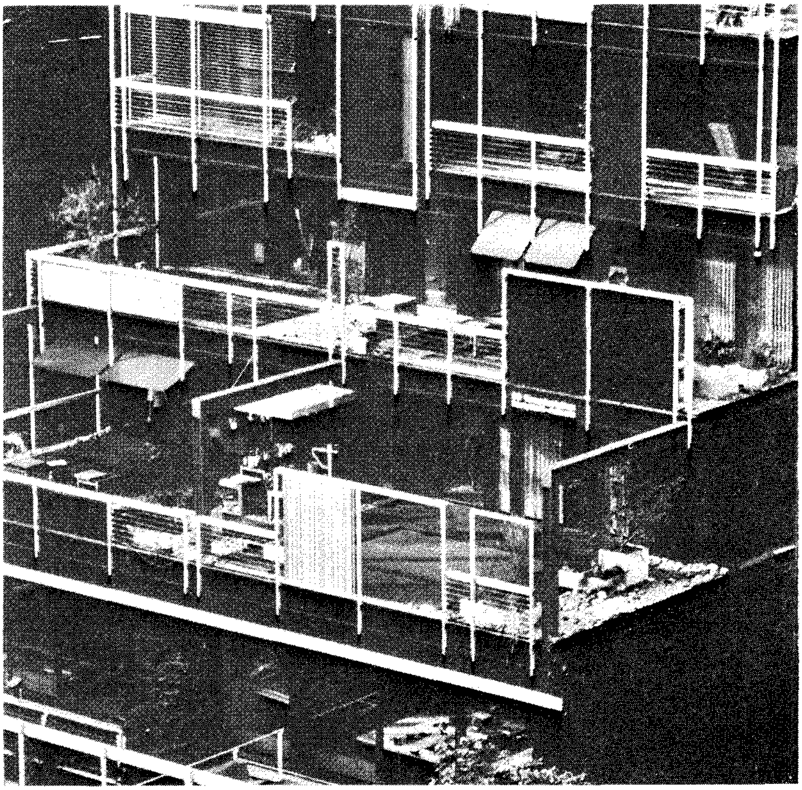


Fig. 5
The clean-cut appearance of timber frame houses seemed to the research group to be something that could be carried over construction to with steel. Its high load-bearing capacity means that slimmer cross-sections, wider spans and more freedom in final layout are possible. Steel components are easy to move and can thus be dismantled and reassembled - "Baukasten system" - as individual requirements or town-planning projects vary. In the place of isolated monuments, building forms would appear which represent the spirit of our time.
Photograph : View of the terrace landscape

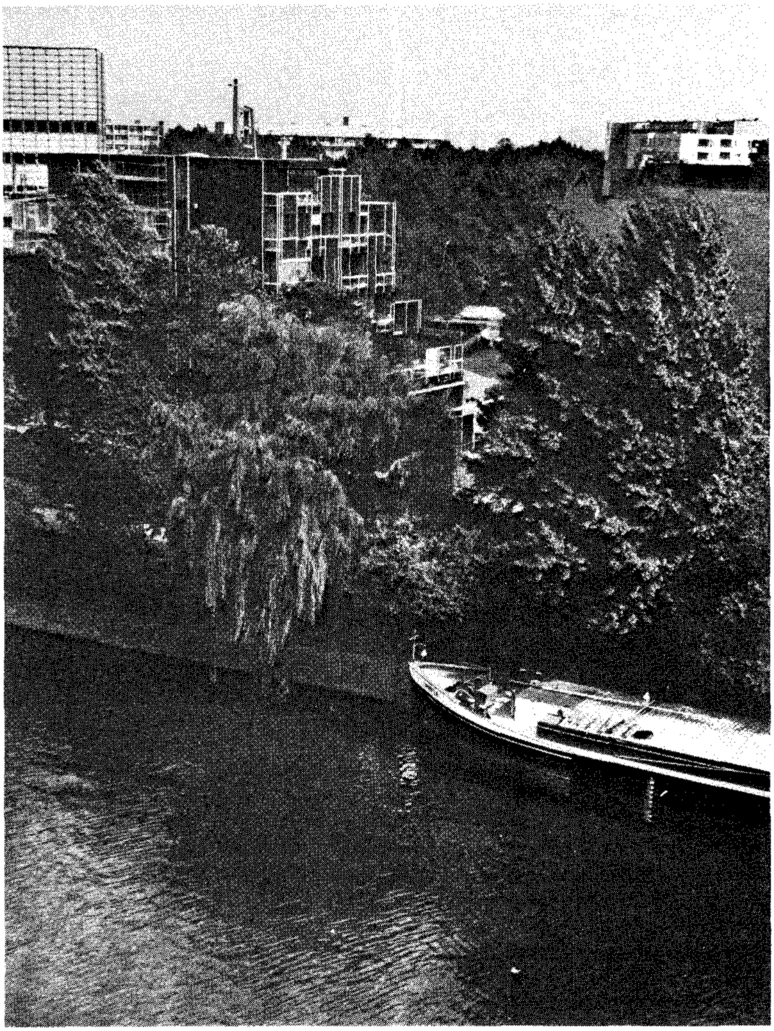


Fig. 6
Close to the banks of the river Spree, a transnational European Cooperative research project tests and demonstrates new construction elements and their possible applications as well as new methods of construction and living. In this demonstration building in the international experimental area of Berlin's "Hansa-Viertel", it is not only the production and assembly of building components, and their suitability and practicability that are exposed to critical appraisal, but also the implications for future development and the social consequences of a building method that opens up new possibilities for the resident or user.
Photograph : View across the Spree

STEEL IN HOUSING ARCHITECTURE

Marcel V. F. van Wetter

Director, SPRL Bureau d'Etudes M. van Wetter

Summary

The construction of 518 dwellings has been carried out at Tubize on behalf of the Société du Logement. Steel has been extensively used in the frame, flooring and facades. Standards of convenience received very great attention and the results were measured. Rapidity of execution exceeded all the predictions. The total weight of the frame, sheeting and trellising was about 2800 t.

1. INTRODUCTION

The example I have chosen to illustrate the subject with which I have been provided is that of an assembly of 518 dwellings, built using steel at Tubize by the Société Nationale du Logement.

To begin with, that organisation had at its disposal an undulating site of 30 ha, free of any building and capable of taking about a thousand dwellings. The director of works, well versed in the building of similar projects in Europe and particularly in France (notably the GEAI system of the architect Lods) wanted to begin with a first phase of 500 dwellings sited on an area of 15 ha.

The drawing up of a call for tenders, involving a large group, was entrusted to the ABEI Group (Association de Bureaux d'Etudes Intégrés), of which I was the head. The Group consisted of:

- the architectural office Tekhne, headed by M Delatte
- the architects Delferiere and Lepoivre
- the M. Hanquet consultancy for special techniques
- the M. van Wetter consultancy for structural stability

Our task was exhaustive. It comprised development of the site, architecture, heating, sanitation and electrical services, communications, the waste water processing plant, storm drains, street lighting, telecommunications, etc.

The basic directives issued by SNL were:

- to make as much use of steel as possible for the housing of the workers of the region largely employed in an important local steelworks (Clabecq)
- develop the site with as much exploitation of the shape of the terrain as possible
- design the buildings and their siting so as to create an urban environment compatible with its positioning
- use electricity as the sole source of energy to protect the inhabitants from atmospheric pollution
- arrange the building site itself to allow for the convenient and clean delivery of metal structures, panels and other 'finished' products
- draw up an invitation to tender giving the tendering organisations the opportunity to offer a choice of construction systems to aid the director of works. The document thus set out standards which

had to be met while leaving as wide as possible the selection of possible solutions

The invitation to tender, as drawn up by ABEI, comprised 29 buildings:

- 5 buildings 'G + 7' (ground plus seven floors)
- 24 buildings 'G + 2' (ground plus two floors)

containing an assortment of appartments:

- 32 appartments with 4 bedrooms (109 m^2)
- 128 appartments with 3 bedrooms (94 m^2)
- 288 appartments with 2 bedrooms (79 m^2)
- 70 studio appartments (51 m^2)

making a total of 518 dwellings.

2. FRAMEWORK

The nature of the soil reuired the use of cast piles. Each building required a foundation of reinforced concrete, poured on site, with shoes and beams on piles, peripheral load-bearing membranes, a network of columns and beams supporting the paved ground floor area. Everything to be constructed above that paved area was to be steel-frame: columns, main and secondary beams, shuttering not including the reinforced concrete items cast in place and surfaced by means of machines called 'helicopters'.

The framework formed by the beams and columns was designed to make use of reinforced concrete screens projecting 2.40 m between beam axes. The screen is reinforced with mesh ans is concreted on a corrugated steel sheet of 55 mm depth of curvature, and presenting 45 mm thickness above the grooves. The screen is joined to the load-bearing beams by 5/8" pins welded into place.

The load-bearing beams, associated with the compression-loaded floor, are of asymmetrical section of type YA 240 (more height utilised), and of PN and PE shape of smaller section.

The columns are HEA and all the exterior columns are set in front of the plane of the facade on aesthetic grounds.

The wind bracings are placed near the staircases and lifts, or in the gable ends. They are of K beams or in the form of St Andrew's cross.

The basic module is 1.20 m, permitting extensive repetition of similar elements.

All prefabricated units were mounted by the classical method, ie. by columns, main beams, secondary beams, wind braces, formers, then screens.

All the components are secured by bolts. The staircase steps are concrete bolted onto open metal stringers.

Because of the small amount of space occupied by the floor joists and of a careful survey of the items in the false ceiling, the total depth between the ceiling and the floor above was limited to 50 cm. The headroom was limited to 2.50 m so that the floors rose in 3 m intervals.

The project outlined above was as in the original plan, with the exception of the asymmetrical YA 240 item which was proposed by the adjudicator and accepted by us.

Few different systems were proposed by the organisations submitting tenders, except for a survey inspired by the GEAI system, whose application at Rouen and Elancourt were known to us. The scheme was not retained by the director of works.

The majority of the companies submitted prices based on our initial survey, with detailed modifications. It was evident that the more elaborate systems (channel sections, composite sections, special sections, high-strength steels, rigid ties, three-dimensional floor frames) did not conform to the requirements for ease of assembly, avoidance of delay, or cost reductions.

In this connexion, it should be pointed out that the budgetary limitations which we were set unfortunately meant the simplification of some of the details of our basic plan. We abandoned the external terraces and the detachable facades. Some intermediate buildings were lowered by about a metre because of the natural curvature of the ground: they had to be put on a common base on economic grounds. Some of the interior fittings were simplified.

3. FACADES

The exterior walling was considered in the light of maximum insulation due to the need to economise on the electricity for heating. They were made of factory-assembled panels composed of:

- an outer steel skin plate of 1 mm thickness
- 98 mm of poly iso cyanurate insulator
- an interior steel skin 1 mm thick and anti-corrosion painted.

The K coefficient of the panels is less than 0.3. Double glazing is used throughout. The external colour (predominantly white) reduces radiant heat problems in summer to a minimum. In the living rooms, the outer shutters, which are of the sliding type and are made of sectioned steel sheet, permit a layer of air between themselves and the glazing.

4. ROOFING

The initial project assumed a cold roof. Implementation, with the builder and SNL, led us to adopt the following solution:

on the outside, 0.8 mm aluminium foil with an anti-drumming coating, forming the rainproofing and allowing air circulation underneath; this was followed by a layer of fibreglass 100 mm thick, condensation trap, fibrous plaster panels with aluminium foil on the hidden face, all mounted on visible slideways.

Temperature and relative humidity under the outer foil are controlled by mechanical ventilation fed by the undulations in the roof sheeting and running behind the slideways.

In this way, roof overheating can be avoided during periods of strong sun.

5. HEATING AND VENTILATION

The equipment had to allow for the small thermal inertia of the frame, the walls and the roof.

The solution adopted is to use individual heating by appartment by means of ducted hot air from a night storage system controlled by external thermocouple and topped up two hours in the middle of the day.

The fresh air/extracted air balancing is carried out at the storage accumulator for fresh (filtred) air taken in. Extraction is effected at 60 m^3/h at bathroom level and 55 m^3/h at wc level. In the kitchen, a carbon-filled recycling hood limits the calorific losses due to air renewal. The concentration of carbon dioxide is kept below 0.5% within the appartment and the range of fresh air per person is 10 to 25 m^3 for the elimination of odour.

6. ACOUSTIC INSULATION

The interior partitioning is plaster board. Some of the partitions are double, notably those between appartments. Those partitions which are required to be fire resistant are in metal stud with steel frame 12 cm thick. Ceiling tiles are in Gyproc with aluminium foil on the hidden face and mounted on visible slideways. All the air ducting is located in the false ceiling. All the floor coverings (plain nylon felt carpets or vinyl carpet tiles) are mounted directly onto the 'helicopter' treated concrete partitioning. The bathroom and kitchen walls are covered in vinyl papers.

The combination yields good sound insulation properties. The general attenuation of airborne noise is:

- simple partition walls:	34 dBA
- double party walls:	47 dBA
- floors	54 dBA
- roofs	55 dBA

The heating equipment is particularly quiet and is situated at level NR 30.

7. ELECTRICITY

The twin supply system (day and night current) is carried by busbars in metal boxing to the appartments.

In order to avoid wall piercing, which would be detrimental to acoustic, thermal, or fire stopping qualities, the wiring has been grouped in special skirtings.

8. LIFTS

Each of the G + 7 buildings, consisting of 46 dwellings, has two lifts, one of which is a larger, service machine.

9. FIRE REGULATIONS

Standards 713-010 and 713-020 which should only apply to buildings over 30 m were imposed by the fire brigade, even though our buildings were under that limit. The result was considerable extra expense on the fire protection of the outer walls, doors and internal walls, among other expensive items.

Since the facade columns were external, an asbestos cement projection isolates the metal beams of the outer belt (on the inside of the false ceilings) as well as the interior face of the screening (metal beams and sectioned sheet).

10. SHOW FLAT

From the time work on the site began, a full-scale model of an appartment was built. The inspection model was an identical model in large-scale detail and from the viewpoint of finish. A series of laboratory tests was carried out by specialists, notably thermography (detection of spots), thermal, acoustic, stability etc. Moreover, the appartment has been occupied for more than a year to the satisfaction of those living in it.

The feedback of information confirmed the selection of materials made at the planning stage.

11. CONDUCT OF THE WORK

The general undertaking, including site preparation, building and equipment was awarded by SNL to the company 'Entreprises et Travaux - EGTA Contractors'.

We cannot list all the subcontractors but within the framework of a paper dealing with metal structures, we should mention Steyaert for the frame and Chamebel for the facade material.

Close collaboration was established from the beginning between the works director, the planners and the builders. Numerous meetings took place, first of all to make the selection from the initial submissions, then to agree on construction details, assembly, agreements with various national bodies, and the work scheduling.

12. CONCLUSION

In order to bring to fruition an essentially creative and original scheme, collaboration, both imaginative and technical, was put to the test in respect of the interests of the clerk of the works and all the other parties involved. The final cost of the work amounted to more than a thousand million Belgian francs, and it is easy to imagine the number of difficulties which had to be faced from many points of view. It is pleasant to record that the assembly of individuals assigned to the work rapidly became a team, in the sporting sense of the word.

It is especially worthy of note that there were no tolerance problems, the frame and the panelling all slotting together without difficulty.

The human problems, by no means the least important, were all solved with good humour. Each one of us is proud to have been associated with the project.

The end result of this excellent collaboration was a saving of 12 months on the original planning.

We should point out that a number of the appartments are already occupied, to the satisfaction of those in them.

AUDACES FORTUNA JUVAT
LABOR OMNIA VINCIT IMPROBUS

THERMAL INSULATION OF SINGLE STOREY STEEL CLAD BUILDINGS

V.M. DEMPSEY

Director - R.M. Douglas Roofing Limited - U.K.

Summary

For many years European attitudes regarding the extent to which the industrial single storey building had a need to be insulated varied to a great extent according to the geophysical and climatic conditions pertinent to particular countries the extremes being Scandinavian arctic to Italian riviera.

The oil crisis has changed all attitudes and polarised criteria for insulation away from concepts of health and comfort or individual designer's approach towards the more urgent need, that of conservation of energy; until the oil crisis there was no definitive attempt by the European communities to standardise an acceptable method of measuring energy conservation or even having a common approach to standards required.

In order to encourage some sort of exchange within the community the following paper illustrates as a case-history of what happened and is happening to the U.K. Roofing and Cladding Industry in order to meet the need created by the necessity for conservation of energy; the particular example chosen is single storey Industrial buildings which in the U.K. were previously not examined for significant sources of energy losses.

I INTRODUCTION

Environmental comfort and safety in dwellings has been accepted as a dictate that a building should be insulated closely related to particular climes of different European countries; to countries with a severely cold climate it was more obvious that efficient use of insulation possessed economic benefit of great significance.

The oil crisis highlighted the alarming prospect that energy sources are limited, conservation was of paramount importance and that insulation of buildings was a prime factor in energy conservation.

Various E.E.C. countries adopted differing stances towards energy conservation.

Upgrading the insulation of existing buildings gained first attention but governments adopted inconsistent schemes which can be loosely described as incentives incorporating attractive loan schemes at reduced interest rates or long-period repayments linked to upgrading of insulation of existing buildings; sometimes these incentives were linked to requirements for improving the efficiency of heating equipment.

Where new buildings are concerned most governments have begun to direct firmer legislation directly aimed at incorporating energy conservation measures in the design of buildings.

In Europe more consistency between nations' thermal standards is required on the degree of energy conservation and the basis of design. An examination of the case-history in the U.K. related to the rising awareness of the need to conserve energy and the effects of this concept on the design of new industrial single-storey buildings can be used to promote co-ordination of a reasonably consistent European code of practice on insulation design and practice relating to energy conservation.

In Europe there is no doubt that various countries by the nature of their differing geophysical and climatic conditions have already adopted solutions which can be usefully applied to energy conservation elsewhere but no single country can provide the complete solution to another country's energy conservation insulation technique; therefore a central information exchange of all existing or proposed solutions would be beneficial within the community so that members may obtain benefits from other members' experience without necessarily adopting in toto any particular solution.

In the following pages the U.K. experience of the effects of new concepts in Thermal Insulation may provide the beginning of a larger exchange throughout the community.

II INSULATION OF SINGLE-STOREY STEEL-CLAD BUILDINGS IN U.K.

Single storey steel-clad buildings consist mainly of a steel frame with lightweight roof purlins and sheeting rails; because of the need to eliminate energy-consuming volume of buildings shapes are now tending towards low-rise and low-pitch; therefore the percentage of surface area of fabric of the roof is increasing relative to area of walls; roofs become a major source of energy waste if not designed properly, although walls cannot be ignored in Thermal design; Thermal design solutions of roofs usually can be adapted to wall situations.

Increased efficiency of Thermal performance of roofs and walls generates a significant change in designers' attitudes to the energy-economical-advantages of a low-heat-capacity lightweight roof and wall which is immediately compatible with the economic use of the now popular intermittent heating systems installed in modern industrial buildings.

The building envelope is increasingly considered separately as a design principle, consequently the Thermal performance of the building fabric based on energy saving principles is being rapidly re-designed encompassing a revised examination of the methods of installation.

The energy design of roofing and cladding involving insulation is being accepted by designers as a specialised building discipline within the overall design of the basic shell. To relate the change in attitudes we have chosen to offer the effects of energy conservation on roofs and walls separately but solutions are sometimes common to both. The solutions we are providing in the U.K. should be compared directly with solutions other countries have produced; the co-ordination of all solutions will in the end provide correct design for energy conservation of single storey buildings and encourage the free movement of thought and products throughout the community.

III ROOFING IN U.K. 1980

The trend away from lightweight warm roofs (fig. 1) to lightweight cold roofs (figs 3 - 9) is already evident in the U.K. and is primarily identified as a reaction to the problematical effects of slightly increasing

Thermal Insulation efficiency prior to 1973 by the introduction of a new generation high thermal value insulation material placed beneath the available weatherproof membranes; this slight increase in thermal efficiency led to the exposure of the limitations of existing waterproof membranes which were then standard in the U.K. (such as bitumen roofing felt or asphalt) the design of which had not been substantially improved for many years

The necessary improvement and introduction of high-performance membranes in answer to the problems of laying directly on to plastic or mineral high thermal boards was engendered; unfortunately, this improvement brought about a significant escalation in the cost of an efficient warm roof because the majority of the components of warm roofs to-day are derived from the petro-chemical industry (felt, bitumen, plastic insulations etc) with certain exceptions such as the mineral type of insulation material.

Insulation or weatherproofing material derived from the oil-based products are continuing to escalate in tandem with oil price rises; the conservation of energy value of warm roof constructions is therefore beginning to compare unfavourably with the cost of equally efficient cold roofs (figs 3-10).

The attractive economies of the high-thermal cold roof construction now bear the main design attraction; therefore it is the cold roof construction that is rapidly being updated and re-designed to cater for increased thermal efficiency.

The examination is centred on the effects of changes in a construction which now incorporate cold roofs where previously warm roofs would have been employed.

The debate on the new approach to cold roof design now that warm roofs are beginning to price themselves out in reaching their optimum performance concerns what the manufacturers are offering to meet the new requirement and how the installer is beginning to appreciate the necessary changes in techniques brought about by the influx of new products or significant changes in existing available products; the designers' responsibility is having to bring both together under the design umbrella in order to produce an economic energy-conserving building design.

IV THE PHYSICAL EFFECTS CAUSED BY THE INCREASED THERMAL EFFICIENCY IN COLD ROOF STRUCTURES

Uneven temperature distribution between the outer and inner surfaces of the roof fabric can lead to differential movement between the skins particularly on sandwich panels which have already known to produce failure in the interface bonding of components.

Individual components as well as complete systems will operate under more extreme environmental conditions where outer surfaces will be more vulnerable because of longer exposures to the effects of winter conditions without the relief of escaping energy to reduce the effects whilst also operating at lower pitches than previously considered for profiled steel sheets where membrane roofs would have previously been employed; inner skins will be expected to sustain the effects of longer periods at constant higher temperatures again with no escape of the heat energy through the construction due to the efficiency of the insulation above the inner skins.

Because of the increase in the extremes in the temperature difference the change in the temperature gradient through the construction of the roof fabric will necessitate a certain amount of re-design in cold roofs to prevent interstitial condensation.

A much closer consideration will also be desirable in the choice and use of glazing or translucent areas forming cool-areas within the system (which act as local condensation collection areas) bearing in mind that profiled translucent roofing sheeting of a GRP or similar material is normally incorporated to-day instead of traditional patent glazing system using glass and metal bars; translucent sheets can be installed in runs, chequerboard or strips-depending on designers' quirks (fig. 2); on low-slope roofs providing the fire regulations are complied with the neatest and most suitable solution is in ridge-to-eaves strips which prevent an unnecessary amount of end laps undesirable in low roof-pitches and stiffens the sidelap of the translucent sheeting which is of a more flexible material than steel; the strip method concentrates dissimilar materials (GRP/steel) in semi-isolation rather than in an unsatisfactory mixture; it also controls condensation effects by deliberately placing the condensation risk in a position that the designer is aware of and will cater for in his design and detailing.

The U.K. experience on industrial projects is that buildings are already being designed towards low-volume energy-saving shapes and which incorporate reduced-slope construction; this leads to a revised approach to cold roof construction which previously were laid quite effectively at reasonable pitches such as 10° but where pitches reduce down to 4° or 5° a new approach is required to improving the detail and insulation techniques to combat their vulnerability when installed at such very low pitches.

This design of flashings and ancillary components in a cold roof - such as eaves, valley gutters, ridge and gable treatments should ensure the elimination of cold-bridge effects that can occur in careless designs which on first inspection may appear well insulated in general.

Perforations in the cold roof which employs steel profiled sheets for instance are much more difficult to weather than in warm roof systems where the flexible membranes can be dressed and torched to provide watertight penetrations; in cold roof systems where the roof vents or pipes, chimneys etc have to perforate the profiled steel sheet improvements are already taking place in the detailing of the soaker flashings with particular awareness when installed at the mid-slope on large-low-slope roofs.

V FABRIC DESIGN AMENDMENTS TO INCREASE THERMAL EFFICIENCY

The most economical existing site-assembled system in use (figs 3 & 4) easily accommodates any necessary increase in thickness of mineral insulation components. It will also be easy to incorporate a vapour barrier directly laid between the insulation on the warm side and the lining board.

Where plastic insulation board replaces a lining board in the system (fig 5) eliminating the quilt or mineral wool construction the plastic insulations available can without difficulty be increased to comply with an improvement in thermal efficiency but there are difficulties in incorporating a suitable vapour barrier with this system.

The energy crisis has brought an upsurge in the U.K. of factory-made two-part assembly glued-on (bonded panel) (fig 6), and already an improvement in this system in the form of a factory-made composite panel (fig. 7) is on the market. In this latter type the corrugations of the profiled sheets are completely filled with the plastic insulation (which has now been increased to meet the energy requirement); the side-laps of these panels will have to be carefully re-designed or improved to obviate the possible incidence of condensation at the side joints, although some panels are already improved by incorporating a flexible type of vapour check in the form of a plastic extrusion which runs the full length of the side lap of each panel (figs 8 & 9). Composite panels available at this time are provided with an alternative of inner surface made of lightly profiled decorative steel or a faced decorative asbestos paper; whereas the former is more robust the latter is usually sufficient to overcome normal constructional handling, and is quite acceptable on an industrial building.

Investigations are now going on to examine more closely the type of coatings available on steel sheets, particularly to be used in roof systems where a certain amount of post-installation trafficking may take place without knowledge of the installer, and there are several European committees in existence and meeting to provide the specifier and installer with more advice on suitability and coatings for different situations.

VI AMENDMENTS REQUIRED TO EXISTING INSTALLATION TECHNIQUES WHEN INCREASED INSULATION THICKNESSES ARE REQUIRED.

The increase in thickness of a mineral slab or quilt insulation in a system (detailed in fig 3 or 4) naturally increases the depth required of the metal or timber spacer and as a result the screw utilised to attach the outer profiled sheet to the main support system is becoming excessive, lengthy and difficult to apply.

A metal spacer which can be primarily fixed to the main steelwork with short screws prior to the attachment of the outer sheet to the spacer is being increasingly used but produces a significant cold-bridging effect which is difficult to counter by the strategic application of cold-bridging insulation in a roof system due to the necessity to prevent compressibility of fasteners over support systems.

A deeper timber spacer if provided, has an advantage of being a useful drilling guide for extra long screw fixings.

A further alternative is to apply a superior grade of timber adequate to accept the outer sheet fixing; this super grade timber is fixed to the primary supports before the main sheeting is applied.

To suit new low-slope situations a significant increase in good workmanship when drilling for main fixing and secondary fixings such as seam stitching is essential; this will apply to any perimeter details involving flashings or any internal detailing where soakers are applied to the external sheet.

The end laps of sheets on low-pitched roofs which are one of the most vulnerable positions for water ingress will have to be reduced to an absolute minimum; this will lead to an increase in the length of the sheets supplied to sites and there will be more on-site difficulties in handling the increased length in sheets; no doubt this will reduce efficiency in installation.

It should be realised that the site assembled construction of cold roofs (such as in fig 3 or 4) can adapt the flexibility of each component part to overcome or compensate for excess tolerances in building erection without being obviously visible. The installer has to realise that factory bonded or composite panels (such as figs 6-9) are supplied in one plank and as such will reflect any discrepancy in the building structure and designers will have to accept that it is not possible to compensate for framework deficiencies when using composite or bonded panels.

Site assembled panels (such as figs 3 & 4) allow that all the components can be readily removed, replaced or exchanged positions which is an advantage over factory assembled panels where replacements or removals or re-positioning of sheets can be difficult due to the overlap detail both at the side and end of the sheets, which are dictated by the direction at which such panels can be removed or replaced.

The incorporation of plastic rooflights or other types of openings in the site-assembled panel is less problematical than in a factory assembled panel where unsightly cutting of factory assembled panels and in particular the foam filling will occur unless the on-site penetrations are designed more intimately to fit into the module of the composite panel systems and provide reasonable soaker flashing details. On-site cutting and adjustment of pressed metal flashing sheets and other fitments is quite simple using systems 3 and 4 but is slightly more difficult when using factory system 6 - 7 because the plastic foam has to be removed on site to allow flashings to be inserted in a regular and satisfactory manner.

These are just some of the problems that are being examined with regard to changes in systems and which no doubt different European countries will either have experienced or about to experience.

VII THE EFFECTS OF THE INTRODUCTION OF NEW COLD ROOF SYSTEMS ON LABOUR COSTS AND CONSTRUCTION TIMES

It is recognised that the existing site-assembled, five part cold roof construction (system 3 or 4) has always and will remain labour-intensive but that the required increase in insulation thickness or the introduction of vapour barriers to meet new energy requirements will not significantly escalate either the existing labour intensity or the erection time. Bonded or composite panels (systems 6 & 7) are much less site-labour intensive because it is recognised most of the labour in assembly is already carried out off-site in ideal factory conditions not dependent upon ambient weather conditions.

Assuming that for the reasons stated previously the trend will be to supply composite panels in lengths as long as possible to avoid end lapping etc it evolves that these panels require an additional and significant cost of plant-assisted site installation. The factory assembled panels, however, can be erected on site approximately two to three times faster than site-assembled constructions but the full time-saving effect has to be tempered by the knowledge that the pattern of building construction dictates the pace at which the other elements are erected or other trades operate and will detract from some of the advantages of rapid roof panel installation.

VIII COST EFFECTS OF INCREASED INSULATION EFFICIENCY IN THE MATERIALS COMPRISING THE ROOF FABRIC

To meet increased energy saving requirements the on-site assembled system of construction (as in 3 or 4) do not significantly increase in price with the exception of an acceptable escalation in the cost of quilt or matt insulation and possibly the cost of the inclusion of a vapour barrier; cost increases are kept to an acceptable minimum.

Bonded panels or composite panels (system 6 or 7) using mostly petrochemical orientated plastic boards or filling are increasingly expensive as the price of oil escalates. These bonded or composite panels, because of their bulk, their poor nesting shape cost more to transport and require more on-site storage space. The waste of the materials in the composite panels because of the way they are fabricated can prove costly where with few exceptions on-site damage usually entails a new whole-panel replacement; it should be noted that a site assembled system could be replaced with individual components if required, without a large cost implication.

IX DEVELOPMENT OF NEW PRODUCTS AND SYSTEMS IN COLD ROOFS

Insulation thicknesses will no doubt increase in the foreseeable future and a possibility of composite or bonded panels becoming less cost-efficient leads to the consideration of further changes in construction.

An example is such as on fig 10 where a structural profiled steel sheet is provided as the main support bed for installing an outer weathering of a second lightweight profiled steel sheet roof with quilt or matt insulation, and the introduction of lattice metal spacers in lieu of timber spacers to reduce cold-bridging and to cut down the unsatisfactory length of fixing screws; the most suitable type of metal sheet to be utilised as a weathering sheet in this construction on very low slopes will eliminate any external fixings and preferably make use of an internal semi-clip arrangement within a sealed standing-seam to allow for movement within the length of the sheet; this construction is now competitive in both price and effectiveness, with a familiar warm roof weathered by a site-installed membrane system and is quite close in cost terms to that of a composite metal system (such as system 8).

Other countries may produce different solutions or evolution of new roof systems to meet increased insulation requirements.

X WALL CONSTRUCTIONS

The U.K. experience is that most of the parameters governing thermal redesign of building roof fabrics by increasing insulation efficiency or thickness can be applied almost directly to lightweight wall constructions the major difference being that walls will not be trafficked and do not attract wind or imposed loads in the same manner as roof systems.

Wall systems built up as roofs (similar to system 3 or 4) are still the most popular and economic type of lightweight wall; the new plastic lining boards with decorative foil faces are also used to replace plasterboard in some situations but attract adverse criticism relating to the fire risk attributed to Urethane or other plastics; with the site-assembled systems (figs 3,4, and 5) however there is a growing requirement to check the fire performance of the system because of the flue effect of open corrugations the bonded panel (system 6) will not prove acceptable as it was six months ago.

A relatively recent innovation is of structural steel-planks or trays (filled with mineral insulation) fully supporting the outer profiled sheet but being currently used with more frequency. These trays provide one of the most economical forms of quick construction with the special attraction that they can be used as temporary protection to the inside of the building and that the vertical or horizontal sheeting rails are virtually eliminated. This system is easily dismantled if for instance additional doors or other openings are required at a later date.

The factory assembled composite system (similar to systems 6 & 7 on a roof) is proving extremely useful when adjusted to walls particularly with the new low-rise buildings where one plank 7 - 8 metres long is sufficient without any end laps to fill in the whole of the side of the building; problems experienced with this system in a low-slope roof are virtually eliminated in walls. Similar to roof systems the wall systems can be obtained with either steel or soft backed materials to form a robust, washable and decorative inner face; doors, windows and louvres can be easily incorporated in these systems.

The coatings as in roofs are still under the examination of various bodies but the smooth coatings with long-life colour retention characteristics are used more on walls than roofs due to the reduction in the risk of mechanical damage.

XI SOME PHYSICAL EFFECTS OF THE INCREASE IN INSULATION PERFORMANCE REQUIREMENT OF LIGHTWEIGHT WALL CONSTRUCTION.

Traditional site- assembled wall systems are not significantly affected by the increase in insulation other than the expected increase in length of fasteners or the introduction of a different type of fastening system either through metal or timber spacers.

Where structural trays are employed and totally support the outer cladding designers should bear in mind that for economy and convenience the longer spans are used; the amounts of allowable deflection that have been previously acceptable should be considered more carefully and in our opinion should not be less than $\frac{L}{150}$ for long span trays up to say 6 metre span otherwise the deflection will be aesthetically unacceptable and may place greater stress on the fixing of the trays; horizontal cladding is often used with this system and because of the direction of the span, excessively long continuous elevations (as much as 90-100 metres) have to allow for expansion and contraction of even a steel sheet.

Bonded or composite panels which rely on mechanical or structural increase in strength and span performance by the contribution to the profiled sheet properties by the addition of insulation should be treated with caution. There is no clear proof that the strength of the glue line in the case of bonded panels, or the natural bond of the composite panel to the outer sheet is permanent. There have already been isolated failures in the bond between glue line or composite foam to the outer sheet.

X11 TRENDS

The use of profiled steel sheets as the outer weathering skin of cold roofs has been on the increase in the U.K. since 1973 and is continuing to increase its share of the market at the expense of flat "warm roof" constructions as the problems of weathering cold roof sheets around fixings and penetrations has been solved.

The increase in the use of bonded or composite plastic foam panels incorporating steel outer sheets will continue although the more economical site-assembled panels will hold their share in the same way as asbestos sheeted roofs are still utilised for economy despite the overall advantages of metal sheeting in comparative situations.

No real investigation has been undertaken of the possible effects of involuntary stiffening of roof purlin produced by roof systems in causing higher stresses on the increasing length of fastener now being employed.

At the same time the integrity of fasteners fixed through a steel sheet over a semi-rigid plastic roofboard has not been entirely successful, particularly in cases where low-slope roofs have been employed and where there is no scope for human error because every fixing must give 100% integrity for the roof to succeed.

In particular, where soft backed infill foam or bonded panel is used over-tightening of screws may cause surface cell collapse over the purlin which, depending on the friability of the insulation material, will not be visible at the time of placing the fastener but can reduce significantly the integrity of the washer-seal leading to leaks around fasteners.

With thicknesses of foam reaching 30mm upwards and mineral quilts or matts 60mm upwards, any lateral restraint previously given or by roof sheeting will be difficult to justify as the plane of the sheet and the length of the screws will be incompatible with lateral restraint or stressed-skin design.

Solutions incorporating the full mechanical and section properties of site-assembled tray and sheet constructions producing a monocoque system are being investigated and may make all-steel lightweight walls even more competitive.

The new wave of products and systems for roof and wall fabrics brought out in the U.K. to meet increased insulation requirements has not yet produced the satisfactory standard solution or a final firm basis for designers to utilise and, at this moment, there is a scramble by manufacturers to impose their own solution. In the end the solution will, by necessity, be decided by the flair of designers in conjunction with the on-site practical experience of installers and a constant exchange between European nations.

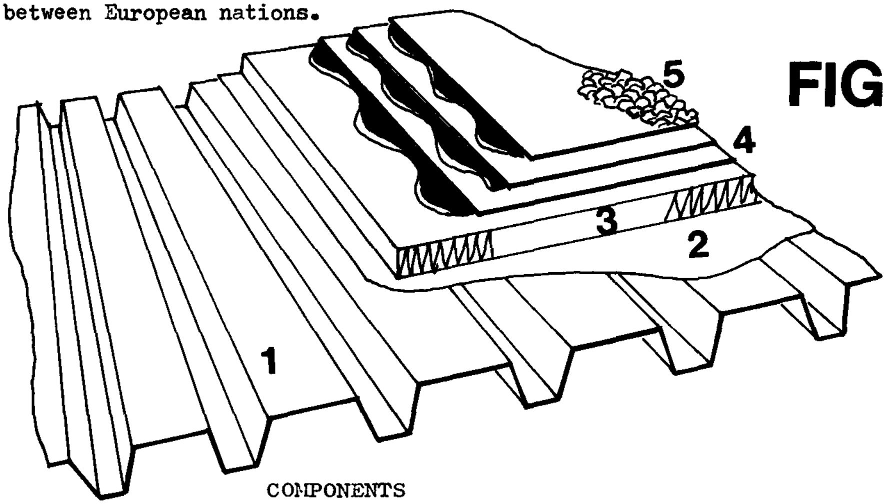
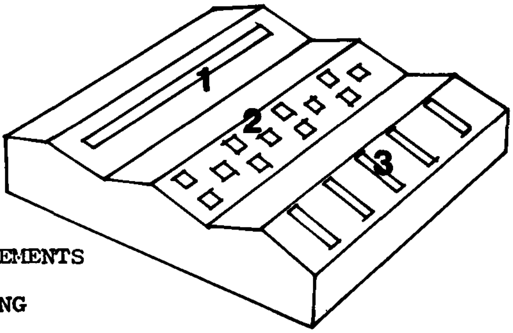


FIG.1

COMPONENTS

1. Galvanized steel profiled decking with spans from 2 - 6 metres.
2. Bitumenized or fire retardant foil faced Sisalkraft vapour barrier.
3. Rigid insulation material in board form.
4. Built-up bituminous weatherproofing system with standard or high performance layers.
5. Reflective stone chippings or reflective aluminium paint or fine granule mineral finish.

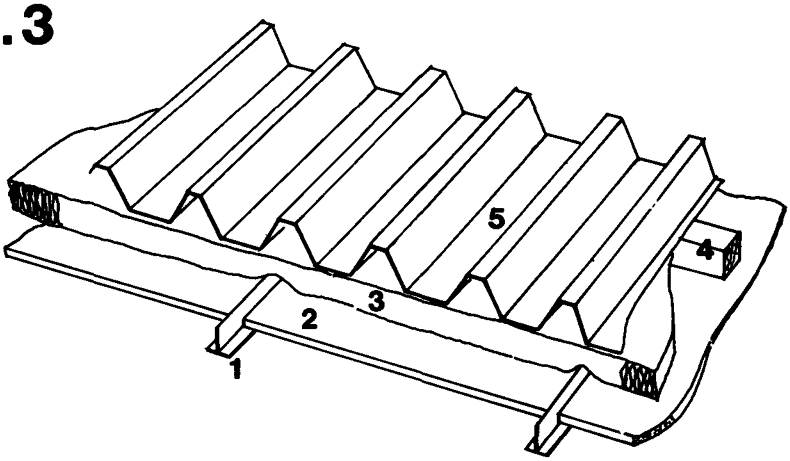
FIG. 2



TYPICAL AVAILABLE ARRANGEMENTS
OF
TRANSLUCENT SHEETING

1. Profiled translucent sheeting installed in continuous run across width of building.
2. Profiled translucent sheeting installed in a random or chequer-board pattern.
3. Profiled translucent sheeting installed in strips from ridge to eaves parallel to span of profiled roof sheeting.

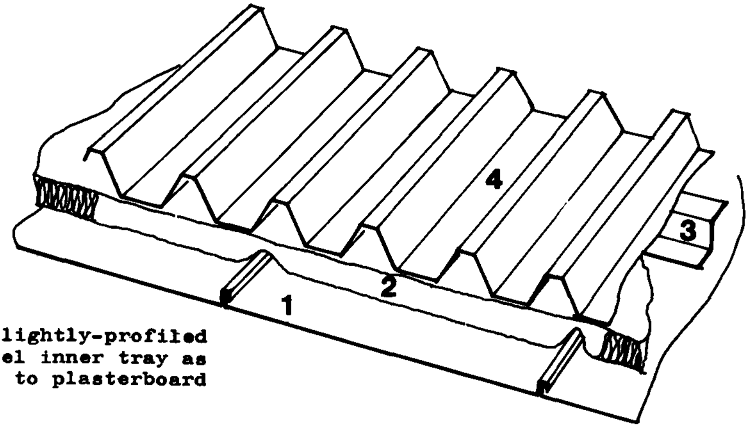
FIG. 3



COMPONENTS

1. Galvanized steel tee-section support system with optional white plastic face.
2. White-plastic-faced-aluminium-foil backed plasterboard lining.
3. Mineral insulation matt.
4. Treated timber spacer batten (or galvanized steel spacer profile).
5. Outer weathering sheet profiled colour coated steel.

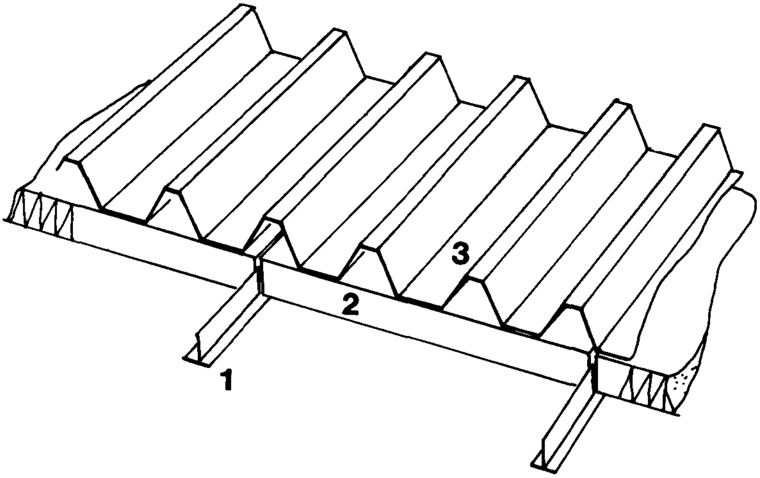
FIG. 4



COMPONENTS

1. Lightweight - lightly-profiled decorative steel inner tray as an alternative to plasterboard lining.
2. Mineral insulation matt.
3. Treated timber spacer batten (or galvanized steel spacer profile)
4. Outer weathering sheet profiled colour coated steel.

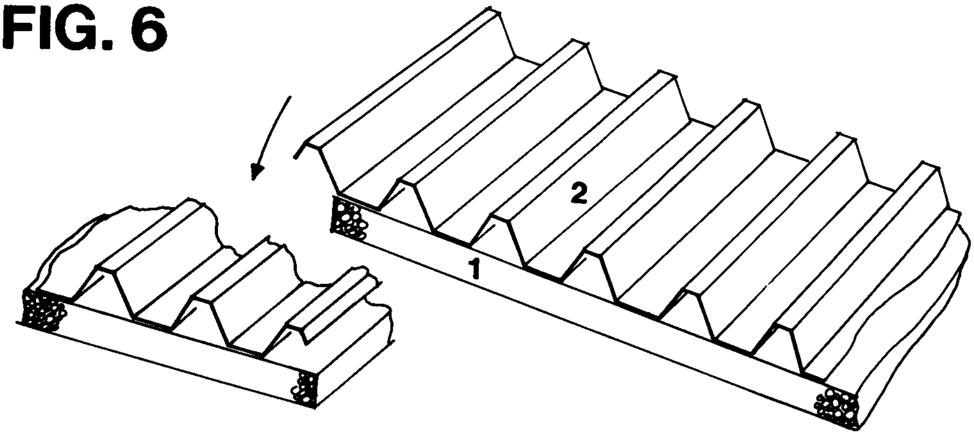
FIG. 5



COMPONENTS

1. Galvanized steel tee-section support system with optional white plastic face.
2. Rigid plastic insulation board with inner face decorative aluminium foil.
3. Outer weathering sheet profiled colour coated steel.

FIG. 6

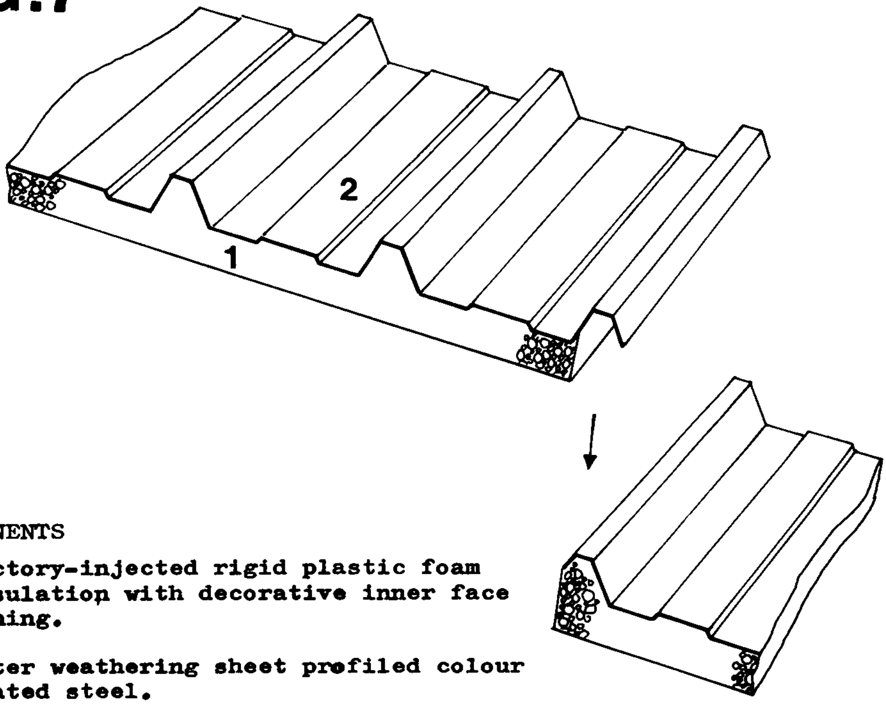


COMPONENTS

1. Factory-glued and applied rigid plastic insulation with inner face decorative aluminium foil.

2. Outer weathering sheet profiled colour coated steel

FIG.7

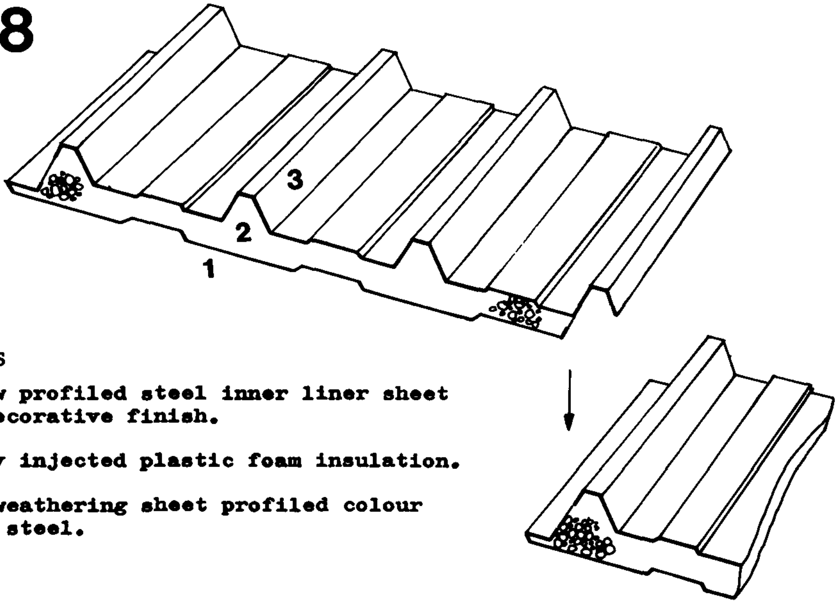


COMPONENTS

1. Factory-injected rigid plastic foam insulation with decorative inner face lining.

2. Outer weathering sheet profiled colour coated steel.

FIG.8



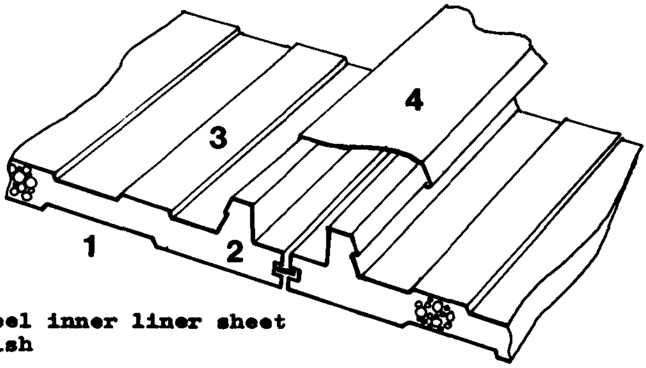
COMPONENTS

1. Shallow profiled steel inner liner sheet with decorative finish.

2. Factory injected plastic foam insulation.

3. Outer weathering sheet profiled colour coated steel.

FIG.9



COMPONENTS

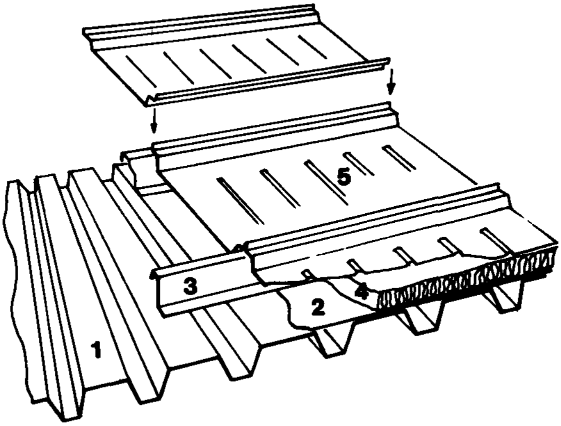
1. Shallow profiled steel inner liner sheet with decorative finish

2. Factory injected plastic foam insulation.

3. Outer weathering sheet profiled colour coated steel.

4. Colour coated steel interlocking cover plate.

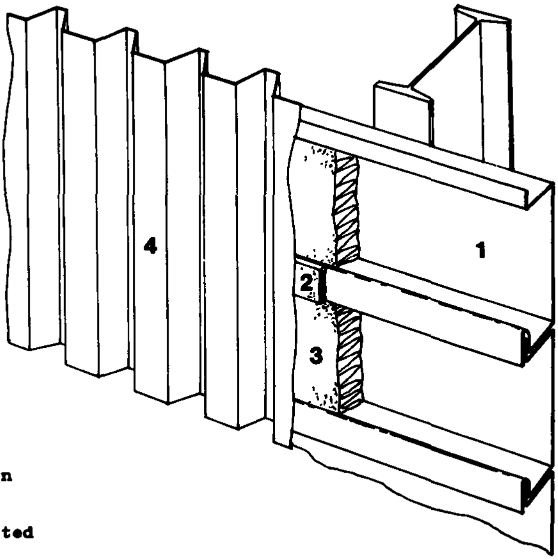
FIG.10



COMPONENTS

1. **Galvanized steel profiled decking spanning 3-10 metres.**
2. **Heavy gauge polythene vapour barrier.**
3. **Profiled galvanised steel support member attached to deck.**
4. **Mineral insulation matt.**
5. **Aluminized steel or aluminium secret-fix fully standing seamed profiled roof sheet for installation down to 2°.**

FIG.11



INSULATED METAL WALL CONSTRUCTION

1. **Galvanised steel structural plank to span 3 - 5 metres.**
2. **High-compressive-strength mineral thermal spacer on each plank-flange.**
3. **Matt or semi-rigid slab insulation infill to tray plank.**
4. **Outer galvanised steel colour-coated profiled sheet.**

MIXED STEEL AND CONCRETE CONSTRUCTION WITH IMPROVED FIRE RESISTANCE

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Summary

The AF90 system is a mixed construction of steel and concrete with 90 minutes fire resistance following heating according to the ISO curve. The system is suitable both for columns and braces of buildings and for metallic frames for industrial purposes. Columns in AF90 consist of broad - flange beams with the typical characteristic that the ratio of flange thickness to web thickness does not exceed 1. The valleys between the web and flanges are concrete filled around reinforcing bar welded to the web. By comparison with entirely metal columns, the composite column leads to economies in terms of total weight of steel. For floor bracings, the weight gain is small, but the mixed system increases the inertia of the beam to the effect that deformation under load is of less significance. The mixed system can be considered as a synthesis of steel and reinforced concrete construction. It receives the advantages of both principles and avoids their disadvantages. From the concrete viewpoint, it enables the concrete to be poured on site and without shuttering. From the metal viewpoint it guarantees fire resistance without supplementary protection. The system allows large loads to be carried on small sections.

1. IMPORTANCE OF FIRE RESISTANCE

Serious fires in buildings and industrial installations usually cause catastrophic damage, both bodily and material. In spite of the stringent measures taken to date with respect to protection against fire, the number and extent of fire damage in the German Federal Republic has practically trebled over the period 1970-1977. Figure 1 provides some fire damage statistics for several countries, excluding indirect damage (1). It is clear why the coming regulations such as the rules for industrial building and DIN 18230 'Fire protection measures in construction of industrial buildings' are more precise on this point in order to provide an enhanced level of safety. It is known that in the case of unprotected metal structures subjected to (ISO) standard fire test, collapse occurs after 10 to 12 minutes. The hope of achieving significantly better performance by resorting to massive sections, such as by using heavy square sections, has only been partly satisfied. The duration of fire resistance obtained with a laminated square section of 180 x 180 mm subjected to the admissible load was only 14 minutes (2). The residual stresses played an important role. This brings out the significance of the results of trials carried out under identical conditions on columns of this type using forging steel or on heat treated laminated sections. For these last sections, the resistance times exceeded 36.28 and 33 minutes.

Reinforced concrete columns subjected to standard fire tests attain a clearly superior level of resistance provided that the reinforcement is adequately covered. Nonetheless, class F 90 is not achieved in all cases, especially where the perimeter/section ratio (U/F) is large and where premature bursting of the outer layers of concrete occurs. Since the loss of mechanical properties in concrete containing quartz aggregates and in steel due to increase in temperature is not significantly different, the greater fire resistance of concrete with reinforcement is explained by the following:

1. the thermal conductivity of concrete (which varies with temperature, (Fig. 3), being only 1/10 that of steel, the mechanical strength of concrete, as a function of the depth of penetration of the heat, falls more slowly than it does in unprotected steel (Fig. 4).
2. Steel reinforcement is protected by the insulating effect of the concrete against rapid loss of mechanical strength.

It is, therefore, logical to make use of these properties of concrete to the benefit of the metal and to turn towards a mixed concrete/steel construction.

This aim is being pursued by the 'Studiengesellschaft für Anwndungstechnik von Eisen und Stahl eV', Düsseldorf, in a massive programme of research on the fire resistance of mixed columns being carried out at the Institute for building materials at the Technical University, Brunswick.

Independently of this work, ARBED, Luxemburg (4), also began, at the suggestion of Prof. Jungbluth, trials on fire resistance of HE beams in which the spaces between the web and the flanges were concrete filled; the remainder of this paper is devoted to a report on that work.

2. MIXED STEEL-CONCRETE CONSTRUCTION

Beams in which only the space delineated by the perimeter circumscribed is filled with concrete have the advantage of not requiring shuttering. In the event of fire, the maximum load to be supported is the useful load with no safety factor.

The beam dimensions are selected with the knowledge that the strength of steel and concrete at the perimeter of the section falls in proprtion as the safety factor of the remainder of the section reaches 1.0. This system dispensed with the need for non-load-bearing supplementary protection.

The selection of materials dimensions and grades enabled the structural elements to be dimensioned on the basis of fire resistance and load bearing derived from static calculations. The fire resistance attained according to DIN 4102 varied from class F 30 to class F120.

Instead of dimensioning according to the theory of elasticity, whereby for a given beam the greater part of the steel should be placed in the flanges, the optimum solution for fire protection is based on concentrating the greater part of the steel in the web, which is protected by the concrete.

That is why HE sections, open welded sections, and extruded sections lend themselves particularly well to these applications. The techniques of rolling, welding, and extrusion allow, in the case of a double T for example, relatively thicker webs to be produced.

In order to achieve a given class of fire resistance, a special U shape reinforcing bar, of which the longitudinal sections varied widely, was welded to the web, thus providing a junction between the beam and the concrete. In some cases, for example where the U/F ratio is unfavourable or where an especially high degree of fire resistance is required, the plate of the metal section can be protected using supplementary insulation (Fig. 6).

The properties of the composite construction of a metallic section combined with concrete may be described as follows:

1. Increased strength at room temperature
2. Choice of fire resistance performance from class F 30 to F 120
3. Greater rigidity for beams working in flexion and for rigid frames
4. Good surface appearance (washed concrete)
5. Elimination of anti-corrosion layer in the case shown in Fig. 6
6. No shuttering
7. Preservation of classical methods of joining by bolting or welding even if the non-concreted spaces have to be filled with a special mortar
8. Transport and assembly in a manner similar to that of conventional metallic components

From the materials viewpoint, in the majority of cases steel AE 24 was selected for the metal sections, B 420/500 for the reinforcement, and B 35 or B 45 for the concrete.

The U-shaped network forming the reinforcement is defined by the class of fire resistance and the intended function of the element as column, floor joist, or rigid frames for factory bays.

3. FACTORS AFFECTING FIRE RESISTANCE

Since the flanges and a part of the web in composite sections working as deflected beams or as columns rapidly lose mechanical strength due to the action of fire, the remainder of the section behaves as a reinforced concrete component.

1. Ratio $\frac{\text{perimeter}}{\text{area of cross section}}$ $\left(\frac{U}{F}\right)$	(large)
2. Elancement	(medium-large)
3. Concrete covering	(large)
4. Load	(large)
5. Percentage in reinforcement	(medium)
6. Mechanical strength of materials	(small)
7. Eccentricity	(small)

8. Geometric defects	(wide dispersion)
9. Support conditions	(low - medium)

These different factors are, of course, interdependent, which accounts for the very complex behaviour under fire conditions as well as for the difficulty of isolating the parameters experimentally in a selective manner.

4. RESISTANCE LIMIT

With the development of the theory of limiting states in metallic and reinforced concrete structures, it seemed logical to extend this theory, which explains rupture phenomena better than the classical theory, to the mixed steel and concrete constructions, on the assumption that the interface between the two materials, i.e. the metal section and the concrete covering, is continuous throughout its length.

In order to calculate exactly the fire resistance limit, thermal analysis is first necessary to determine the distribution of temperature along the cross-section. For this analysis to be made, it is necessary to take into account the non-linear thermal criteria affecting different materials and different sections. In the case of columns, apart from the two-dimensional system, account must also be taken of the axial direction in order to take account of the effect of deformation on equilibrium (second-order theory) (7). Iterative methods leading to determination of the time to failure of finished parts are the province of the larger hardware facilities.

4.1 CALCULATION OF FIRE RESISTANCE LIMIT

In practice, a simple calculation method is used which consists of assuming that a decreased section effectively resists forces until just before failure (Fig. 7). If the temperature distribution in the straight section is known experimentally for the fire classes F 30, F 60 and F 90, then differentially reduced strengths can be attributed to different elements in that section. If it is assumed that the section is completely plastic, the following hypotheses can be made concerning the dimensions and the elastic limits:

> For the flanges, one takes the reduced elastic limit (Table 1) which is determined by the flange temperature and by the curve showing its value as a function of temperature. For a fire of long duration, and for flanges of limited thickness, the elastic limit is zero.

Within the web, the hot spots (Table 1) showing temperatures higher than 500°C are ignored. The web temperatures are determined from the flange temperatures using a gradient of 90°C/cm, corresponding to values measured during tests.

The concrete, in the areas in contact with the fire or with the flanges, loses thickness s_b. One assumes for the remainder of the system a reduced resistance βRR which, like s_b is a function of the fire resistance class (Table 2).

As far as the reinforcement is concerned, which should be located a minimum distance from the exterior sides of 6 cm and 5 cm from the interior terminations of the flanges, an elastic limit of β_{SR} reduced is applied to the entire section (Table 2).

4.2 COMPOSITE STEEL-CONCRETE BEAM

The dimensioning of a composite steel-concrete beam subjected to deflection is carried out with reference to the plastic behaviour of the materials (cf. 'Richtlinien zur Bemessung von Verbundträgern'). One assumes that the neutral axis is located in the web in symmetrical metal sections.

$$\boxed{x' = \frac{h' \cdot t_S \cdot \sigma_F + Fe\ \beta_S}{2 \cdot t_S\ \sigma_F + b'\ \beta_R}}$$

The plastic moment is provided by the formula

$$\boxed{M_{pl} = t_F (h' + t_F)\ b\ \sigma_F + \frac{h'^2}{2}\ t_S\ \sigma_F + z'_e \cdot Fe\ \beta_S - x'^2 \left(t_S \cdot \sigma_F + \frac{1}{2}\ b'\ \beta_R \right)}$$

The dimensional change under the influence of fire is determined by means of the reduced section as in 4.1 above.

For a beam without protection of the footing, the expressions are:

$$\boxed{\begin{gathered} x' = \frac{h'\ t_S\ \sigma_F + Fe\ \beta_{SR} + s_b \cdot \bar{b}\ \beta_{RR}}{2\ t_S \cdot \sigma_F + \bar{b}\ \beta_{RR}} \\[1em] M^B_{pl} = (h' + t_F) \cdot t_F\ b\ \sigma_{RR} + \frac{1}{2}\left(s_s^2 + (h - s_S)^2\right) \cdot t_S\ \sigma_F + \frac{s_b^2}{2}\ \bar{b}\ \beta_{RR} \\ + z'_e \cdot Fe\ \beta_{SR} - x'^2 \left(t_S \cdot \sigma_F + \frac{1}{2} \cdot \bar{b}\ \beta_{RR} \right) \end{gathered}}$$

and for a beam with protection of the footing (e.g. an insulating layer):

see over..........

$$\boxed{\begin{aligned} x' &= \frac{h' \cdot t_S \cdot \sigma_F + Fe \cdot \beta_{SR} - b \cdot t_F (\sigma_F - \sigma_{RR}) - s_S \cdot t_S\, \sigma_F}{2\, t_S \cdot \sigma_F + \bar{b} \cdot \beta_{RR}} \\ M_{pl}^{B} &= \frac{1}{2}\, b\, t_F^2 \cdot (\sigma_F + \sigma_{RR}(1 + \frac{2h'}{t_F})) + \frac{1}{2}(h' - s_S)^2 \cdot t_S \cdot \sigma_F + z'_e \cdot Fe\ \beta_{SR} \\ &\quad - x'^2 \cdot (\frac{\bar{b}}{2} \cdot \beta_{RR} + t_S\, \sigma_F) \end{aligned}}$$

4.3 COMPOSITE STEEL-CONCRETE COLUMNS

Over and above the laws governing the non-linear thermal characteristics of materials, it is necessary to take account of the effects of deformation in the case of columns (second-order theory). It is clear that the proximation method used for mixed columns is applicable here (6) which is based on the use of European curves for exposure to flame in metallic components. Instead of consideration of the composite section as a whole, it is helpful in the case of dimensional change under fire conditions to use the reduced section corresponding to the class of fire resistance according to 4.1 above.

5. RESULTS OF PROXIMATION METHODS

5.1 COMPOSITE STEEL-CONCRETE BEAM

The equation yielding the plastic moment for certain sections showing a ratio s/t of 1 or 1.2. has been solved and the results are shown for the various fire resistance classes and for footings with and without protection in Fig. 8.

The abscissa shows the percentage of reinforcement Fe $\beta_s/\text{Fa}\ \sigma_f$ and the ordinate γ_B the ratio between the plastic moment in the event of fire and the permissible moment. Also shown is the relationship between the plastic moment of the composite column M_{pl} and that of the steel section $M_{pl,a}$.

With the aid of the diagrams, it is easy to verify whether or not a steel section is suitable or not for use in a composite section for any given fire resistance rating.

The relationship γ_B should, if possible, be equal to 1. At the same time, the required percentage of reinforcement is found. To make for simpler reading, absolute reinforcement values of 10, 20, and 30 cm^2 have been adopted. In the calculations, concrete B45 has been assumed, with steel AE24 for the metallic section and reinforcement in BSt 420/500. The reinforcement was at 5 cm from the termination at the upper end of the lower footing.

Values for γ_B were determined which were greater (γ_B = 0.85-0.95) for class F 90 in the case of composite beams associated with a reinforced concrete base. Load factors of 10 - 45% can be obtained in excess of those obtained without the composite system.

5.2 COMPOSITE COLUMNS

Figure 9 shows the computed results for a section HEL 600 x 460 x 211 as designed by computer. Using these aids, it is possible to determine the permissible loads as a function of duration of exposure to flame in the case of each section forming part of a composite at ambient temperature and for various fire resistance ratings.

The relationship between the permissible load under the influence of fire (F 90) and the permissible load for the composite column at ambient temperature increases in proportion to the fall in the ratio U/F, i.e. when the section and the percentage of reinforcement are large.

Where the flanges are protected (Fig. 6) the fire resistance is increased, especially for smaller sections.

6. EXPERIMENTAL WORK

6.1 RUPTURE TESTS

The composite section technique can be extended to rigid cage structures and space frames with advantage. Figure 10 shows a rupture mechanism based on the theory of plastic linkages of a gridded framework supported at the sides. The rupture tests carried out at ambient temperature with welded joints AF 90 have shown an increase in the load sustained by comparison with the section alone:

- composite beam - flooring	34%
- composite beam	110%
- composite beam and flooring	164%

Moreover, a very clear increase in inertia is evident in the composite system (8). As the fracture load can be calculated according to the German guidelines, trials at ambient temperature have not, to date, been carried out, but it is intended to conduct control tests.

6.2 FIRE RESISTANCE TESTS

Composite steel-concrete beam

Two identical fire tests have been carried out on sections as shown in Fig. 12 (9); in each case, a fire resistance time of 112 minutes was recorded. Figure 12 also shows the development of the temperature pattern in the section as a function of time. The load consisted of two forces of 36 kN applied in the middle of the span 1200 mm apart and corresponding to the permissible overload for the metal section alone.

Composite steel-concrete columns

Figure 13 shows the sections which were subjected to fire trials. The columns were 3.80 m long and were loaded at 2200kN, or 106% of the permissible load for the metal section; the fire resistance time obtained was 141 minutes. At a loading of 3000 kN, or 145% of the permissible, the time was 112 minutes (10). The curves for the temperature within the section as a function of time are analogous to those obtained for the beams. The tests may have given even better results if the covering on the reinforcement had been 60 mm on the outer and 55 mm on the inner edge of the flange instead of the 40 mm and 45 mm dimension actually used.

Trapezoidal plates for composite floors

Trials with floors cast on trapezoidal plates serving as lost falsework showed (11) that the plastic load can be reached on condition that the bonding of the concrete and the plate is assured. This means that the permissible moment for the composite structure can be two or three times that of the plate alone (Fig. 14). Moreover, two fire trials have shown (Fig. 15) that composite floors of this type can attain, without supplementary protection, fire resistance times of 93 and 122 minutes (Table 3). A flooring without the assistance of the plate but with the same reinforcement, representing a safety factor of 1.2, would have been clearly underdimensioned (12).

7. CONCLUSIONS

The results so far obtained await confirmation on the basis of other theoretical and experimental work. Other points of detail to consider are the joints, the limits of application for the system, the possibilities for rolling special sections, the economic making up of supplementary reinforcement netwroks. The approach to these problems provides the hope of complete systems of structural elements with good fire resistance, such as columns, stays, floors, and rigid frames, or in the form of purlins, all using composite construction. The scheme, in the majority of cases, gives guarantee of fire resistance to classes F 30 to F 120. Computer-aided dimensions for these structural elements could be placed at the disposal of the user in the form of tables and graphs.

Composite construction can be considered as a synthesis between metal and reinforced concrete methods. It combines the advantages of the two systems and eliminates their disadvantages.

From the reinforced concrete viewpoint, it offers on-site pouring without shuttering.

From the metal viewpoint, it offers guaranteed fire resistance without the need for supplementary protection.

The system withstands large loads using small sections.

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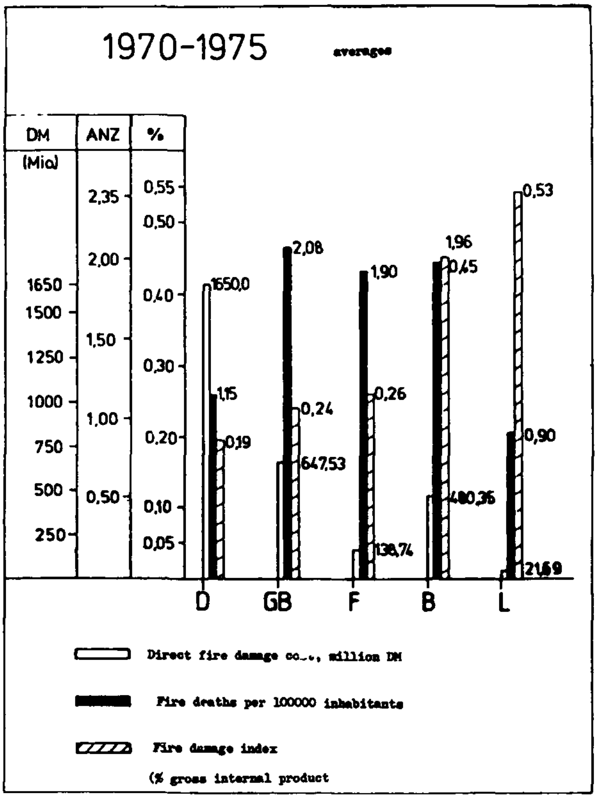


Fig. 1 Fire damage statistics

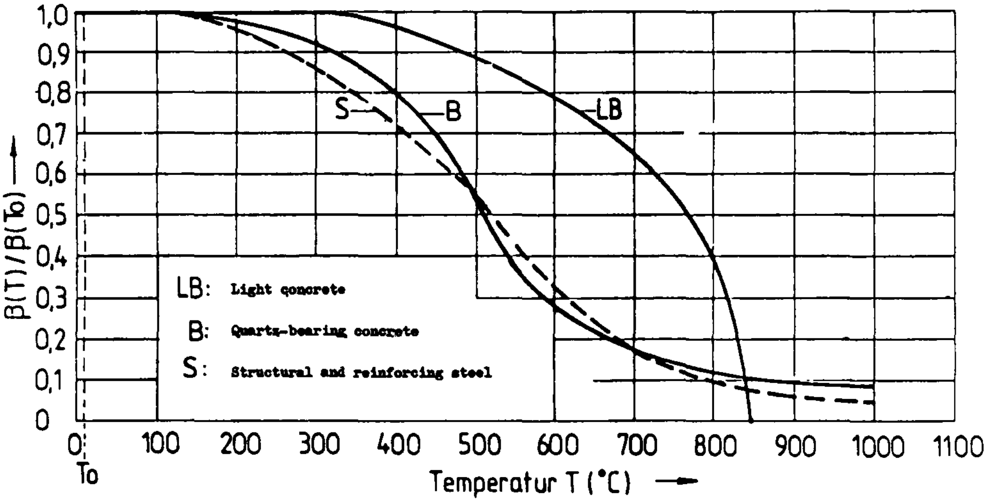


Fig. 2 Change in mechanical properties of steel and concrete with temperature

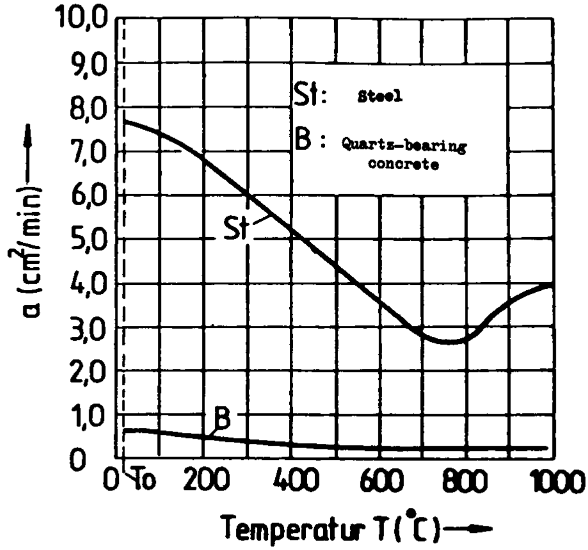


Fig. 3 Thermal conductivity of steel and concrete

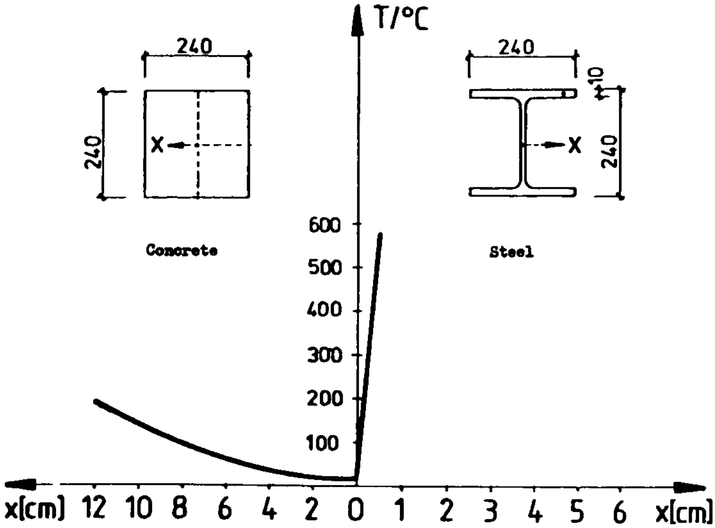


Fig. 4 Depth of heat penetration into steel and concrete after 15 minutes exposure, and according to temperature

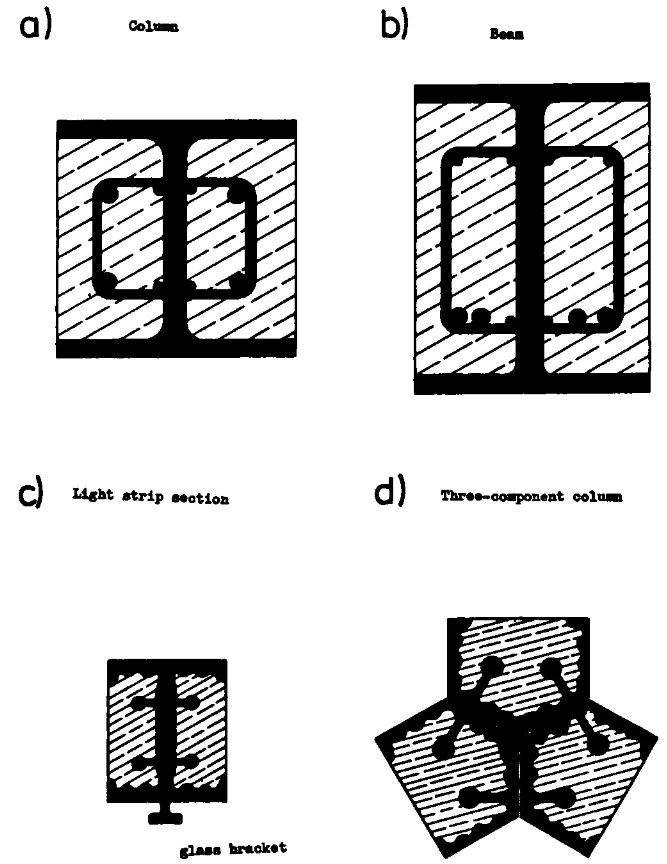


Fig. 5 Cross-sections of composite components

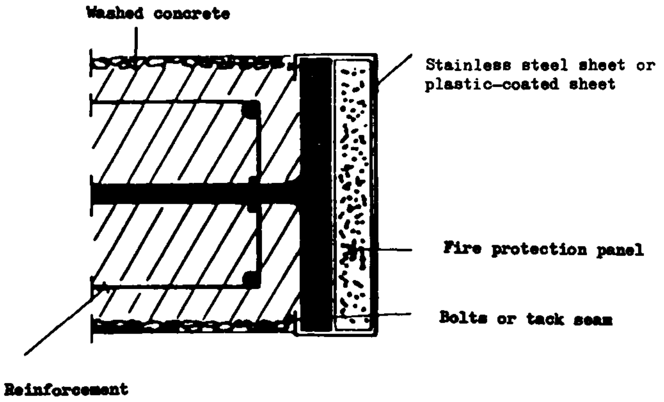


Fig. 6 AF 90, section showing supplementary fire protection

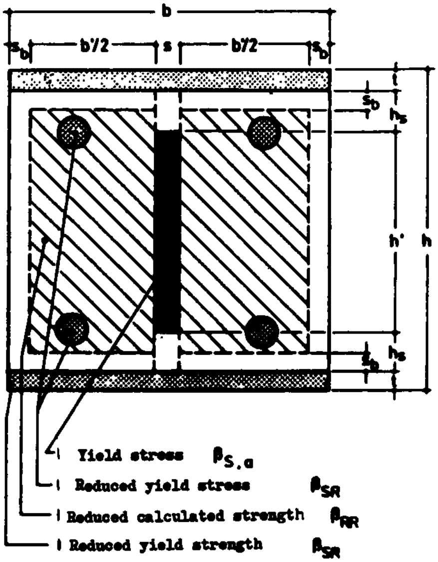


Fig. 7 Reduced 'fire' cross-section dependent on fire class

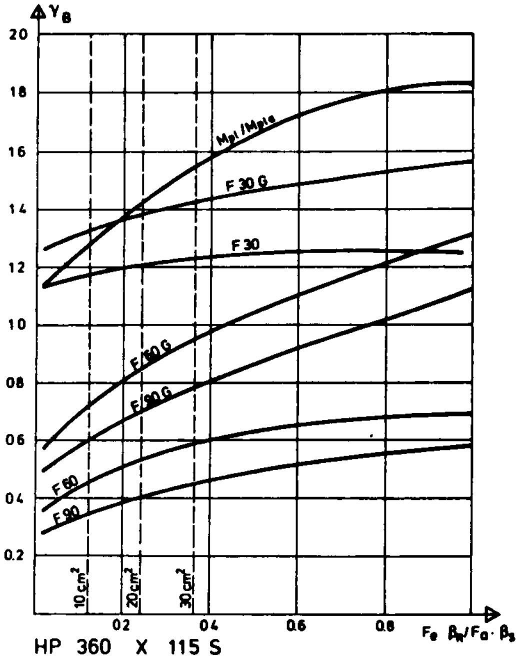
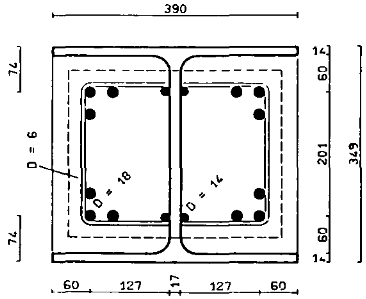


Fig. 8 Dimensioning diagram for composite beams

AF 90 | STUETZENQUERSCHNITT 1 : 5

ZUL. LAST (STAHLPROFIL) = 2061 kN
ZUL. LAST (VERBUND) = 4222 kN
ZUL. LAST ((F 30) = 5536 kN
ZUL. LAST ((F 60) = 3154 kN
ZUL. LAST ((F 90) = 2648 kN
ALFA = 0.48
MUE_L = 2.6 %



KRIECHERZEUGENDE
N-KRAFT = 50 %
KNICKLAENGE = 4000 MM

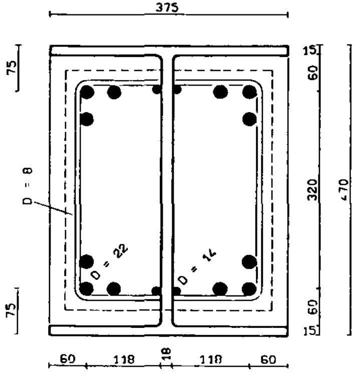
PROFIL HP 400*133 S
Fa = 12.4 %
Fb = 85.3 %
Fe = 2.2 %
WERKSTOFFE : U St 37-2
BSt 420/500
B 45

Bild 9

(PLOTTED BY I E Z TH DARMSTADT)

AF 90 | STUETZENQUERSCHNITT 1 : 5

ZUL. LAST (STAHLPROFIL) = 2269 kN
ZUL. LAST (VERBUND) = 5194 kN
ZUL. LAST ((F 30) = 6998 kN
ZUL. LAST ((F 60) = 4309 kN
ZUL. LAST ((F 90) = 3663 kN
ALFA = 0.43
MUE_L = 3.0 %



KRIECHERZEUGENDE
N-KRAFT = 50 %
KNICKLAENGE = 4000 MM

PROFIL : 470*375*15/18
Fa = 10.9 %
Fb = 86.5 %
Fe = 2.6 %
WERKSTOFFE . U St 37-2
BSt 420/500
B 45

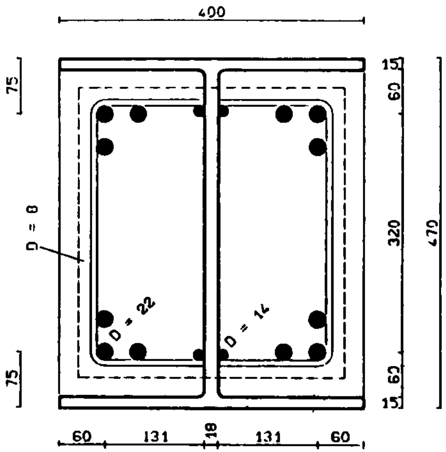
Bild 9 A

(PLOTTED BY I E Z TH DARMSTADT)

AF 90 STUETZENQUERSCHNITT 1 : 5

(1) ZUL. LAST (STAHLPROFIL) = 2423 kN
(2) ZUL. LAST (VERBUND) = 5557 kN
(3) ZUL. LAST ((F 30) = 7558 kN
(4) ZUL. LAST ((F 60) = 4744 kN
(5) ZUL. LAST ((F 90) = 4054 kN

ALFA = 0.43
MUE$_L$ = 2.8 %



(6) KRIECHERZEUGENDE
(7) N-KRAFT = 50 %
(8) KNICKLAENGE = 4000 MM

PROFIL : 470*400*15/18
Fa = 10.6 %
Fb = 86.9 %
Fe = 2.4 %
(9) WERKSTOFFE : U St 37-2
BSt 420/500
B 45

Fig 9b

(PL[illegible] BY I E Z TH DARMSTADT)

Column cross-section

(1) permissible load (steel)
(2) " " (composite)
(3) load F 30
(4) " F 60
(5) " F 90

(6) Creep inducing
(7) N force
(8) deflected length
(9) materials

Fig. 9,9a,9b: Computer-aided design for composite column

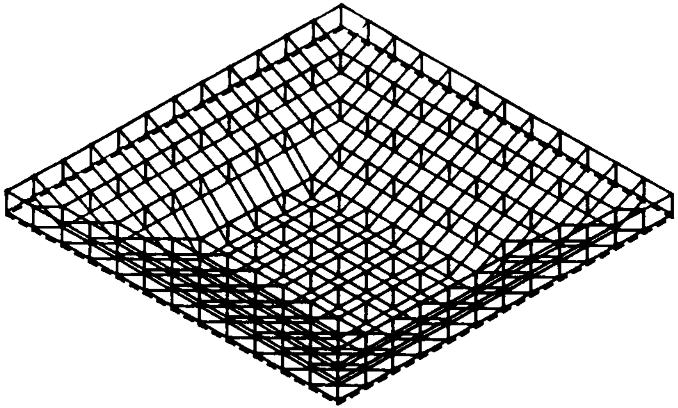


Fig. 10; Failure mechanism in edge-supported rigid framework according to elastic link theory

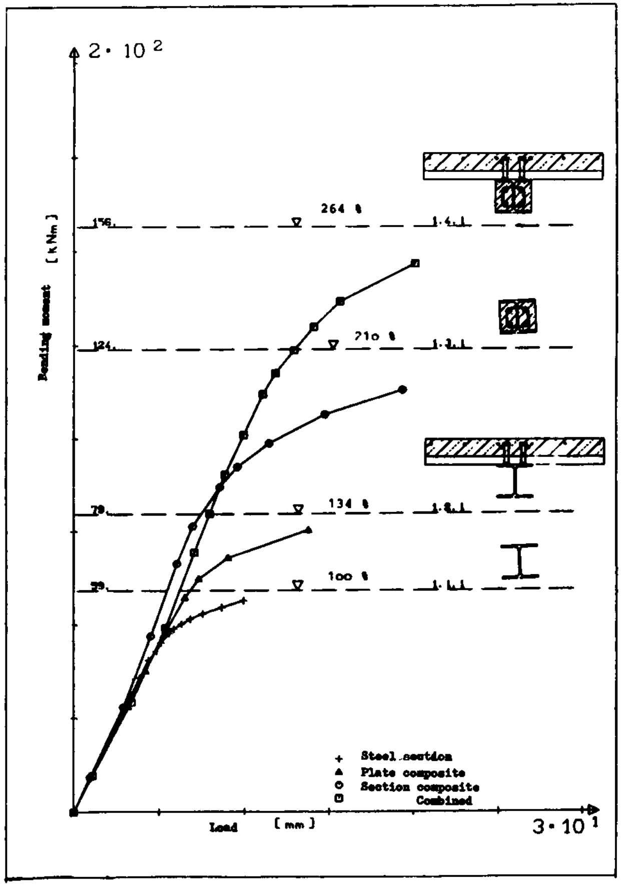


Fig. 11; Increased load-bearing capacity by use of composites

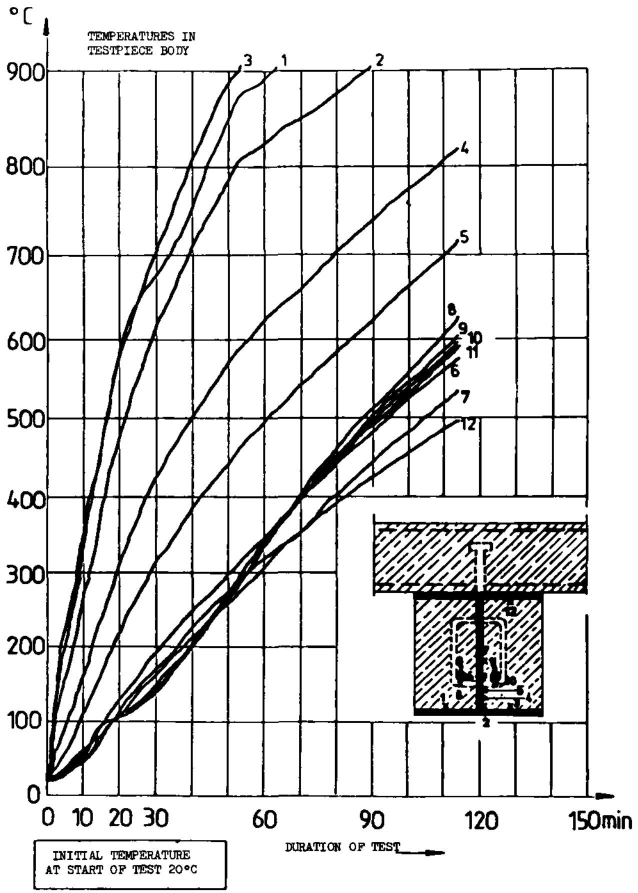


Fig. 12 Time-temperature curves for section under test

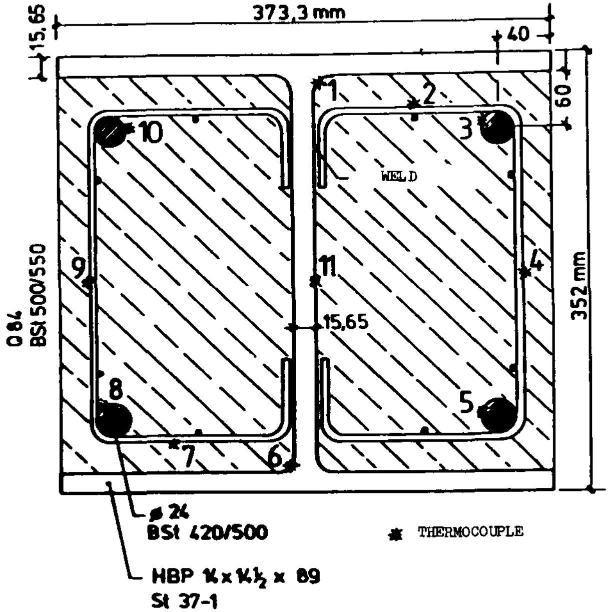


Fig. 13 Cross-section of trial composite column

SECTION	MIXED SYSTEM NOT USED M_{zul} [kNm/m] (SUPPLIER'S FIGURES)	USING MIXED SYSTEM $M_{zul} = \frac{M_{pl}}{1,75}$ [kNm/m]
	SCHEET THICKNESS t = 0,75/1,0/1,5 mm	SHEET THICKNESS t = 0,75/1,0/1,5 mm
Fi 70/200 	3,7/5,5/9,3 (100%)	12,6/17,0/25,8 (340/309/277%)
Fi 120/190 	6,5/11,0/20,1 (100%)	20,4/27,6/42,0 (314/251/209%)
Hoe 70/167 	-/4,7/9,0 (100%)	-/18,6/28,2 (-/396/313%)

Fig. 14 Resistance to deflection of trapezoidal steel sheeting with and withou use of composite system (11)

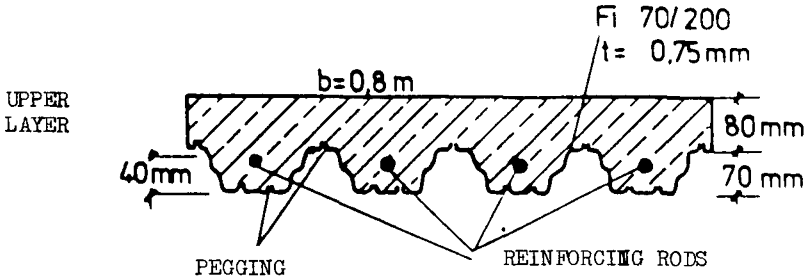


Fig. 15 Steel sheet composite flooring

t [mm]	F 30		F 60		F 90	
	h_s [cm]	σ_{fu}/σ_f	h_s [cm]	σ_{fu}/σ_f	h_s [cm]	σ_{fu}/σ_f
6	1.5	-	4.0	-	5.5	-
8	0.5	0.35	3.5	-	5.0	-
18	-	0.65	1.0	-	3.0	-
20	-	0.65	1.0	0.25	3.0	-
40	-	0.70	-	0.60	0.5	0.30

Table 1 Web dimensions and reduced elastic limit of flanges according to fire class

	F 30	F 60	F 90
s_L [cm]	1.0	2.0	2.5
β_{Ru}/β_R	0.95	0.90	0.85
β_{su}/β_s	0.95	0.80	0.60

Table 2 Concrete dimensions and reduced strength according to fire class

TEST		1	2
STEEL CROSS-SECT. [cm^2] IN RELATION TO 1 m WIDTH		Fi 70/200 : 10,8 + 5 ϕ 12 : 3,9	Fi 70/200 : 10,8 + 5 ϕ 14 : 5,7
LOADING DURING TEST		4 x P = 3,1 kN	4 x P = 3,6 kN
AS ABOVE CORRESPONDING TO EVENLY DISTRIBUTED WORKING LOAD		p = 3,25 kN/m^2	p = 3,75 kN/m^2
FIRE RESISTANCE TIME		93 Minuten	122 Minuten
MAX. TEMP. IN FIRE TEST °C	IN THE FIRE CHAMBER	988	1030
	AT THE STEEL SHEET	850 - 920	790 - 960
	AT THE RE-ROD	460	500
	AT CONCRETE SURFACE	150	160

Table 3 **Trapezoidal sheet in composite flooring; test loads and results**

RAILWAY BRIDGES: A CHALLENGE FOR STEEL CONSTRUCTION

Prof. H. SIEBKE

Deutsche Bundesbahn

Summary

The railway is a constant and integral part of modern technology. Bridge building technology has moved from a craft to the application of mathematical and scientific techniques.

Where an intuitive approach to the load-bearing properties of a design was at one time enough, computation and price now loom large. Confident and far-sighted engineers and architects have recognised the aesthetics of engineered structures and have developed them further.

Present-day bridge building is dominated by the large bridges of motorways. This makes it difficult for new railway bridges, or those to be renewed, to adopt a suitable mode of construction, the more so since older structures have advantages as far as the public is concerned in terms of noise as opposed to steel bridges. The noise reflected is forced down through the ballast layer to the extent of the free section of track.

Even so, a precise understanding of the immission problems remains a research task in steel construction.

Materials quantities no longer play the decisive role in cost calculations. The further development of railway bridges in terms of important matters such as manufacture, assembly, maintenance, suitability, and life are of great urgency for the survival of steel construction. The challenges to today's steel bridge building are the simplification of dimensions down to those which are actually necessary, the engineering prediction of sound reflection values, design in keeping with the times, and comprehensive public education.

1. THE BASIC SITUATION

The railway is a constant and integral part of modern technology. With the aid of the railway, large volumes can be transported over great distances. The railway itself requires vast quantities of earth, ballast, wood, and steel by way of materials. Bridge building technique, which, in the Middle Ages, had made hardly any advance on the Roman arch, was first timidly then ever more boldly revolutionised by the coming of the railways. It is fascinating to trace the way in which the sequences and complexes of the curves of viaducts have been pushed aside by the finer lines of iron lattices. There are simple and ridiculous forms; the progressive mastering of structural techniques, moving from craft to mathematical and scientific methods, has, in many phases, been foolish.

2. ENVIRONMENTAL PROBLEMS

Railway bridge building is a form of civil engineering. The ever increasing railway loads have meant the replacement of many of the impressive pieces of engineering of the past. Construction did not, thereby, improve from the aesthetic viewpoint. If an intuitive approach and the quality of the craftsmanship were once the determining factors in the structure, the need for calculation and price considerations later came to the fore. The design was seen as being tacked on to architecture. Certainly it called for confident and far-sighted engineers to recognise beauty in a functional construction and to develop it consciously. A new mode of transport, the car, required new kinds of roads to run on and bridge architecture adequate for highway engineering came about. The railway bridge was pushed into the background and new ones were hardly necessary. At the moment, new stretches of railway line exist. Furthermore, many of the longer railway bridges are aging seriously and must be replaced in the near future.

3. PROBLEMS OF OPINION FORMATION

Where does railway bridge building stand today? There are still some impressive early examples of steel bridge construction about. They have, with time, become an integral part of the surrounding scenery. On the other hand, these old bridges rumble when a train passes over them. At one time, the rumble was hailed as a signal of the new age. Then it became a comfortable and homely feeling, and today it is a burdensome noise. This has led the general public to jump to the conclusion that steel railway bridges equal insupportable noise. Therefore, all possible measures are taken to prevent the construction of new steel railway bridges. This is unfortunate. Since not only in design, but also in terms of cost, steel railway bridges are a preferable alternative to bridges of prestressed concrete, the more so since rail traffic on modern steel, massive, bridges, makes no more noise than it does on the open track.

4. THE THINKING OF DEUTSCHE BUNDESBAHN

Deutsche Bundesbahn intends to place great emphasis in the coming years on the replacement of old bridges. A requirements plan has been devised which has needed considerable expertise. In many cases, the dimensions and the general structural condition of the substructure is satisfactory and only the superstructure deficiencies need replacement. The frequency of the span widths of the bridges requiring renewal has a somewhat Poisson character, i.e. most have relatively short spans between supports and only a few reach any considerable length in so far as they can be spoken of in connexion with steel bridges. Many of the small and very small steel superstructures will be replaced by very economical rolled steel beams in concrete. There is no doubt about their robustness and simplicity. Their small structural height means that the ballast can be organised largely without gradients.

5. TECHNICAL PROBLEMS

Installation during normal operation, with the frequently very difficult working conditions, is nonetheless seen as desirable and competitive even for relatively small spans. Significant problems arise in two areas: the physical and technical, and the economic. It is at present still common to calculate the tender price on the basis of the weight of steel. In this method all the expenditure which affects the total price, such as labour or any local constructional difficulties, will be proportional to the steel weight, so that even a small volume change will grossly distort the related circumstances.

More than ever before, it is necessary to divide the tender price into two components (fixed and current costs). This is not so much intended to produce the 'right' price, which defies definition, but to get away from the severity of linking the steel quantity to the price.

6. DETERMINATION OF SOUND REFLECTION

Noise immission is a severe handicap to steel construction. The aim of at all costs keeping down the height of the structure has led steel bridge construction into folly. The cross-sections interesting and compact from the design viewpoint have not been fully proven. Above all, the high level of noise has led to protests from adjoining owners and others affected. If the DB decision to, in future, take the ballast over the frame, thus making a major contribution to noise reduction, the question still remains as to whether a proper engineering solution to sound immission can be found.

7. THE CHALLENGE FOR THE FUTURE

The decades old practice of paying for steel structures by weight has led civil engineers and designers away from the technological optimum approach. The attempt, as a result of competition, to keep the weight of a structure down, has brought about a disproportionate effect on

- dimensioning
- labour cost
- deformation
- vibration tendency
- operational strength problems
- corrosion susceptibility
- accessibility
- ease of maintenance
- strengthening possibilities

The associated expense and risk have not always worked to the advantage of steel construction. In order better to balance expenditure and return, predictability and risk, a common solution must be found as a task for the future. The need to approach the problem in common applies to cooperation among competing interests as much as to international harmonisation and to exchange of experience between supplier and customer. Herein lies a challenge for constructing in steel. It will be a turning point for the further development of modern steel railway bridge building when design, construction, assembly and maintenance are brought into line, above all keeping durability in mind. Satisfactory construction is based on:

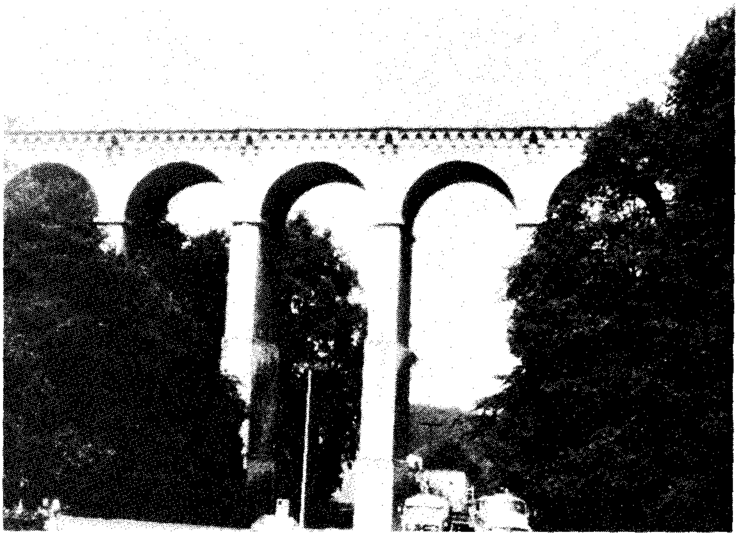
- planning for using automatic equipment for welded joints
- reduction of hand welding
- good welding positions

- good access to the seam
- correct welding sequence
- structural elasticity for the avoidance of shrinkage stresses

Steel superstructures for short and medium span widths resemble each other in the sense that negligible local differences should not absorb the whole attention through maximum suitable plate thickness variations, but that with each project, more experience on executed designs of the same type should be fed back for purposes of improvement. These improvements are often unimportant in themselves, but in some they are of immense value. BD is attempting to carry out a systematic evaluation of all test data so that in the course of time a set of design rules can be worked out. Cooperation with the steel industry would be very much welcomed. The correctly built, accessible, and low-maintenance structure is to a very great extent affected by the operational strength criteria. The extent of the fund of knowledge of the parameters involved has been increased both nationally and internationally in recent years. Nonetheless, a number of important questions remain unanswered. It is of great significance that design rules previously considered reasonably plausible have been shown to be unsatisfactory. Behaviour under multiaxial load is still very much a dark area. Furthermore, the load-bearing capabilities of large structural components can no longer be extrapolated from work with small testpieces. The diversity of design makes it impossible to carry out tests on large-scale specimens for all constructional ends. However, the degree of similarity that does exist in railway bridges leaves the hope that extrapolations from test data for all important large components will be possible. The prerequisite here, apart from the tests themselves, is the ability to transform the test data into usable regulations. The extraordinarily wide spread of such simple items as types of joint in relation to durability should be a warning of great complexity to come.

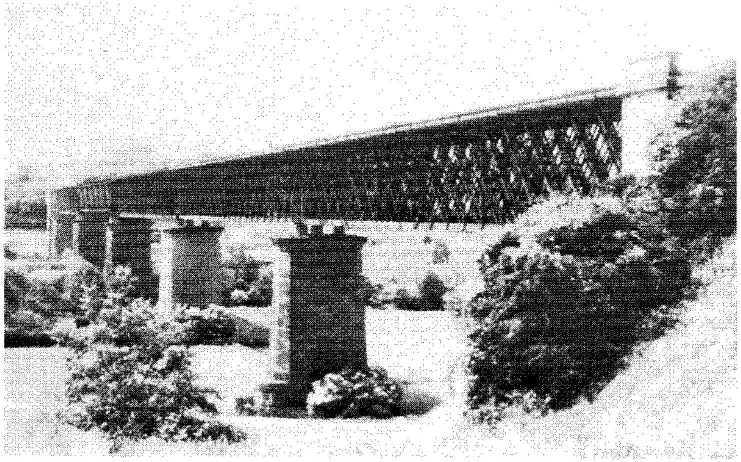
As far as sound immission is concerned, a great deal of important knowledge is missing on the various interdependent factors, and it will take some time before a given steel construction project can be measured against some limiting value for sound reflection. But why? In spite of the fact that certainly the regulations will be difficult, we still lack the punch necessary to approach them firmly. Railway bridges, with their frequently changing design characteristics, offer a unified area in which to get to grips with the problem. Box or lattice construction with running track on the top, parallel ribbed frames with upper or lower running track and curved supports are all so predictable, design-wise, that it must be possible to influence the sound reflection behaviour. A great danger is that research will be biassed towards noise elimination, so that the other components of manufacture, accessibility and durability will be ignored.

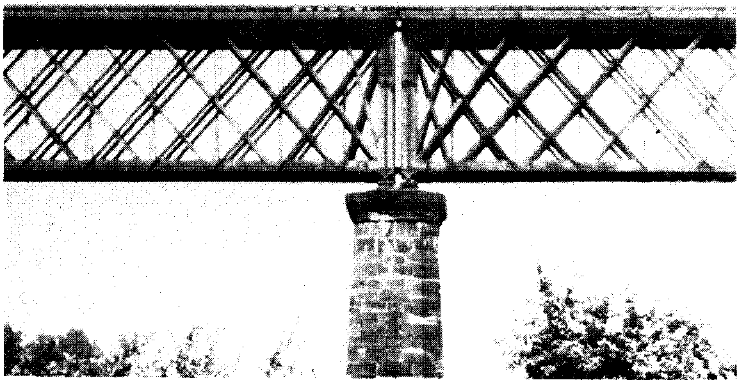
As well as investigation of technological and purely physical problems, matters of a commercial nature must be got to grips with. The relationships here are incomparably more difficult, since the problems are more extensive and less familiar. So far, only the consumer goods industry has made any move towards influencing public opinion. Whether or not organisations of similar type in the capital investment area regard such matters as being within their purview is one of the challenges affecting the survival of constructing in steel.



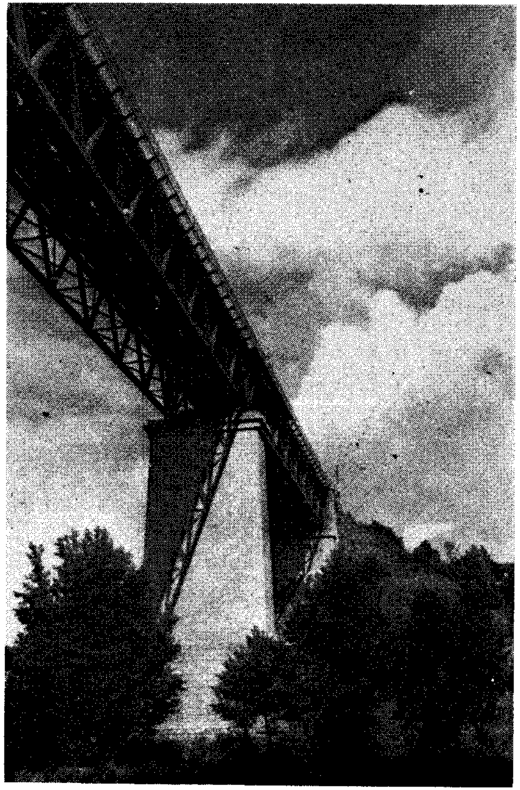
1. Railway viaduct

2. Parallel strut framework



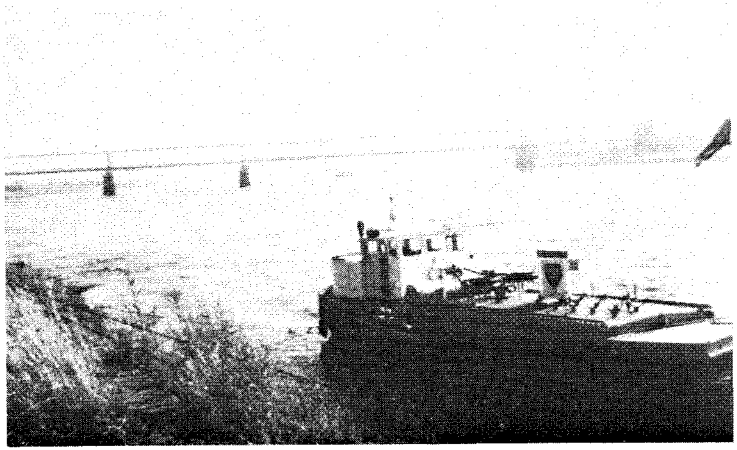


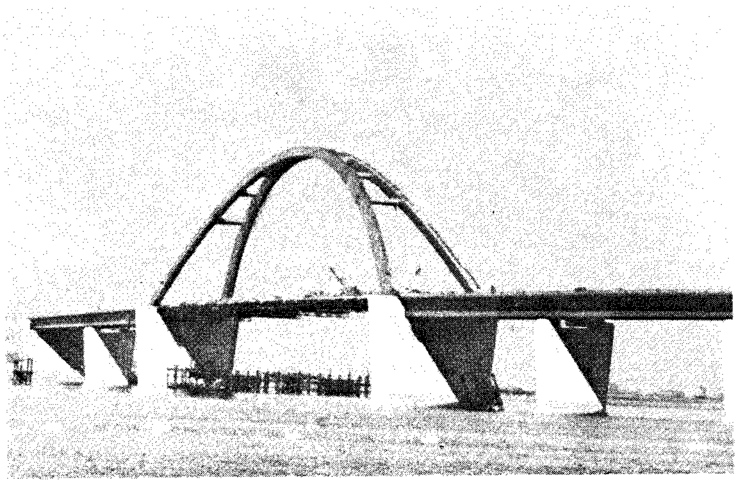
3. Balance of form and method

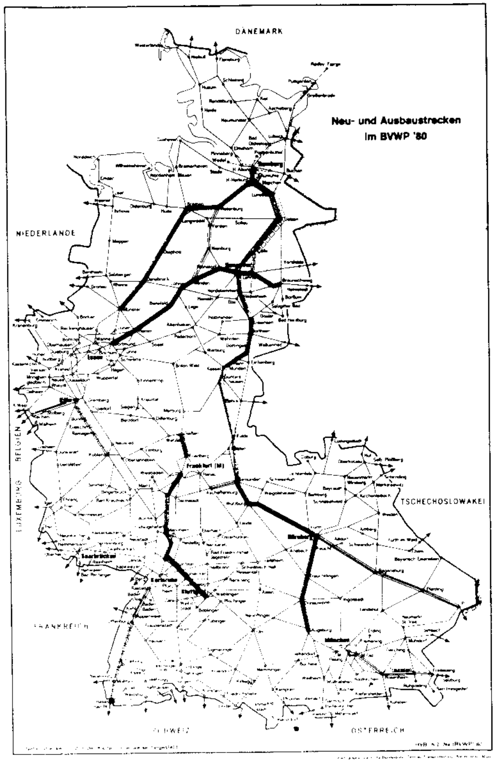


4. Modern frame bridge on old piles and abutments

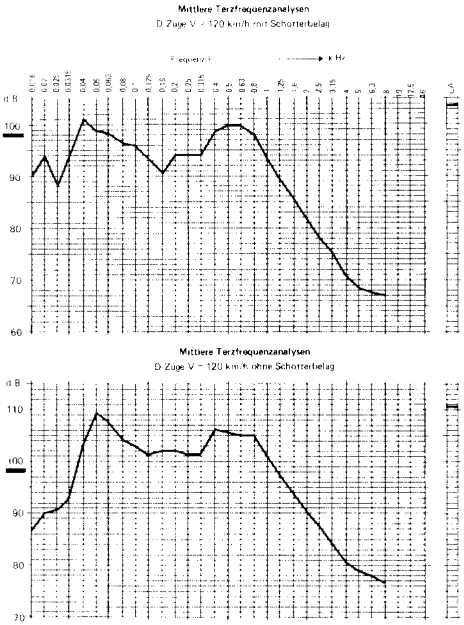
5. A convincing concept with traditional influences

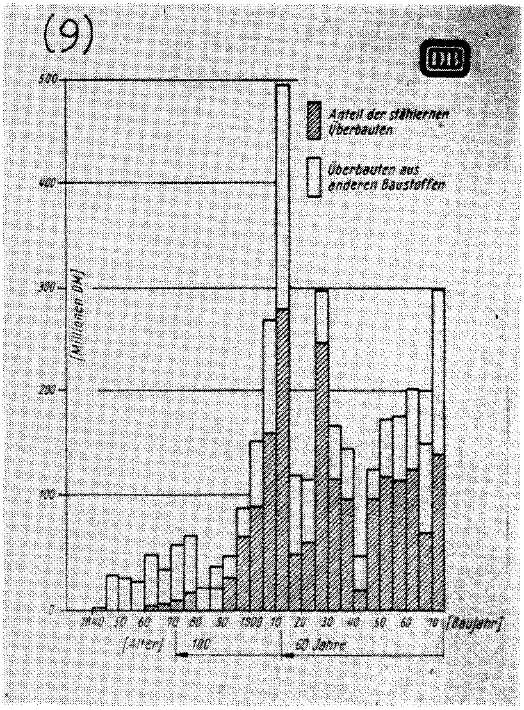






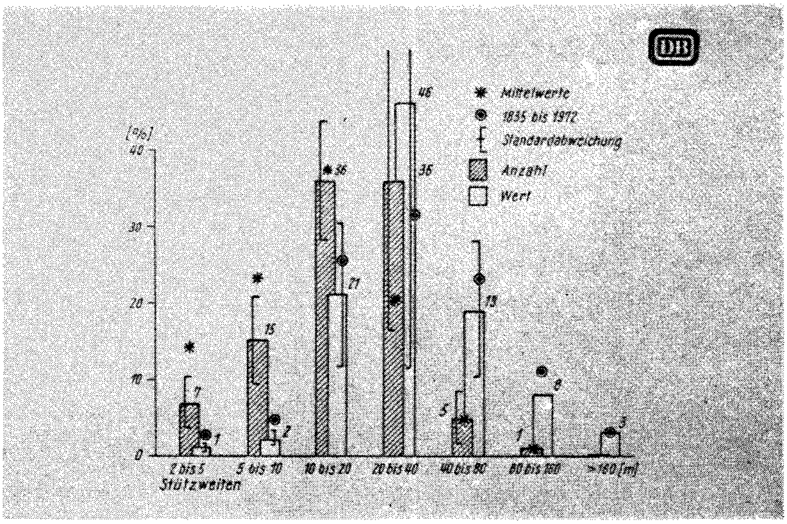
7. New and renewed DB rail tracks





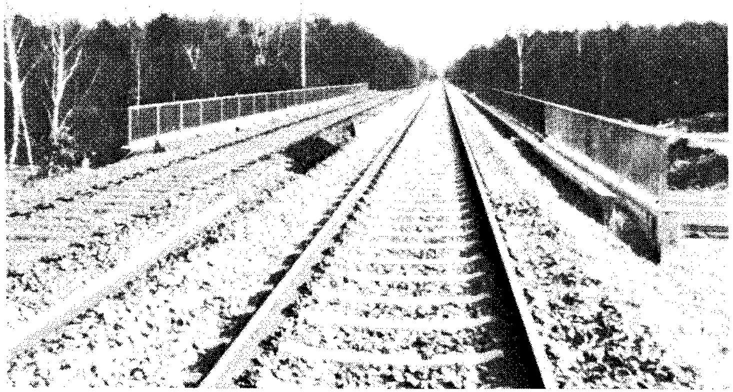
8. Ballast significantly reduces noise reflection

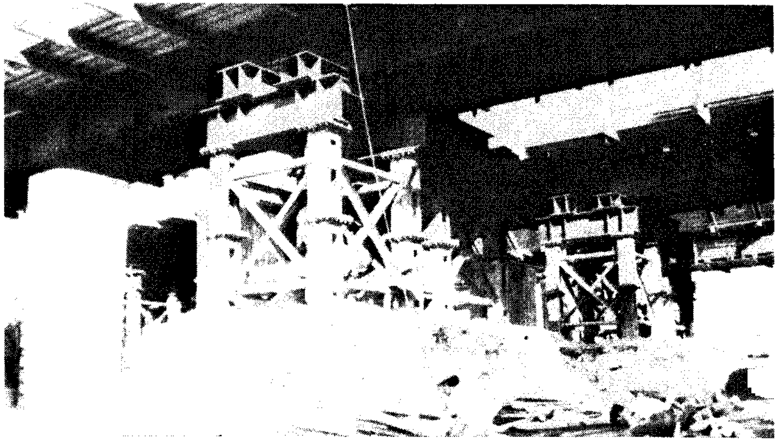
9. Age pattern of superstructure on DB railway bridges



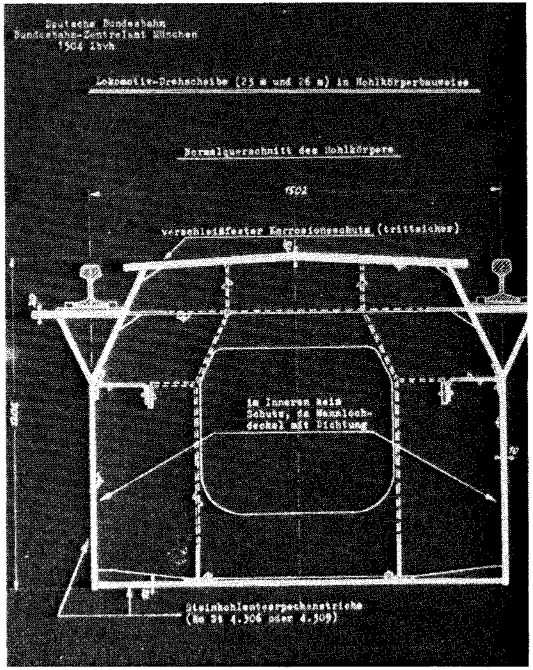
10. Frequency pattern of existing and renewed supported spans

11. Uninterrupted working makes for difficult building conditions

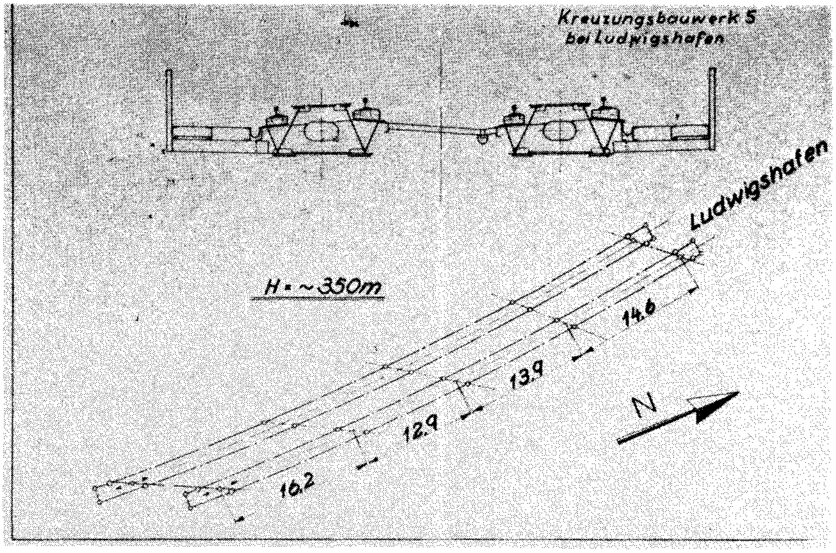




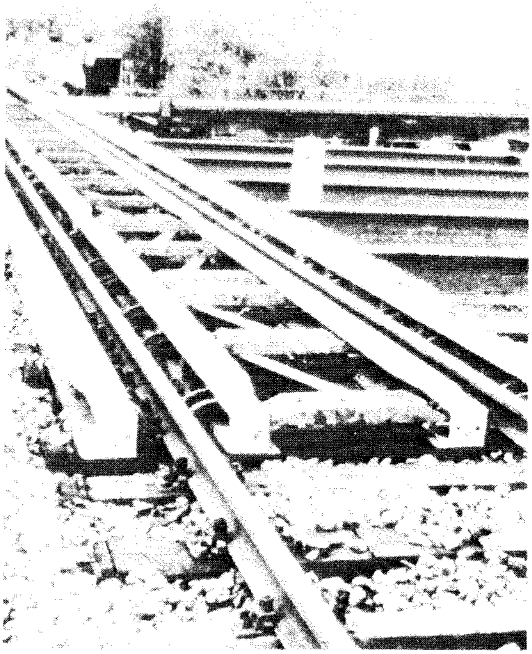
12. Local constructional conditions are a decisive factor for price



13. Hollow box for direct running

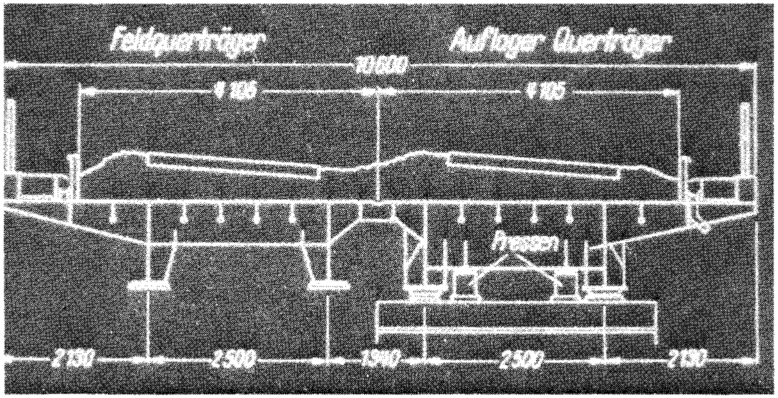


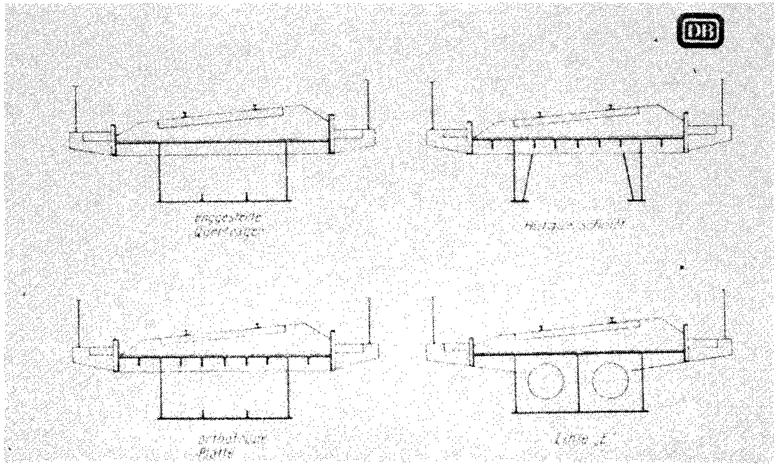
14. Low-level superstructure



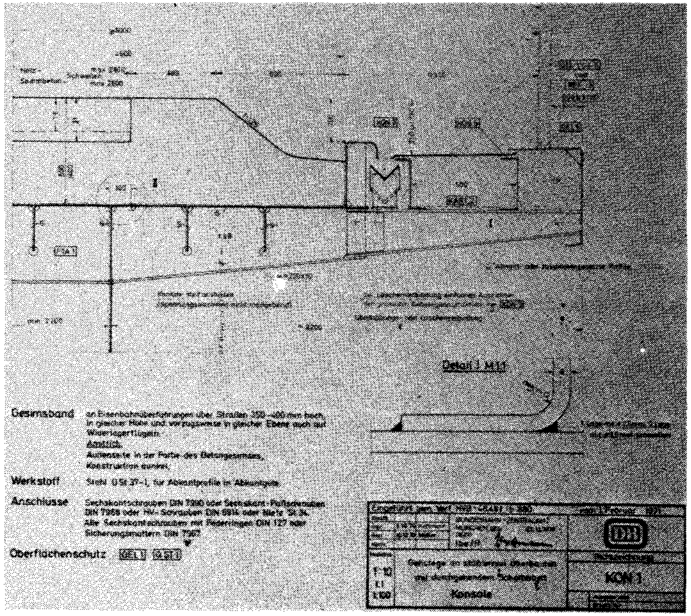
5. Ballast carried right through is a characteristic of the modern railway bridge; example of subsequently introduced metalling as ballast; noise bridge over centre strip remains

16. Ballast simplifies steel erection

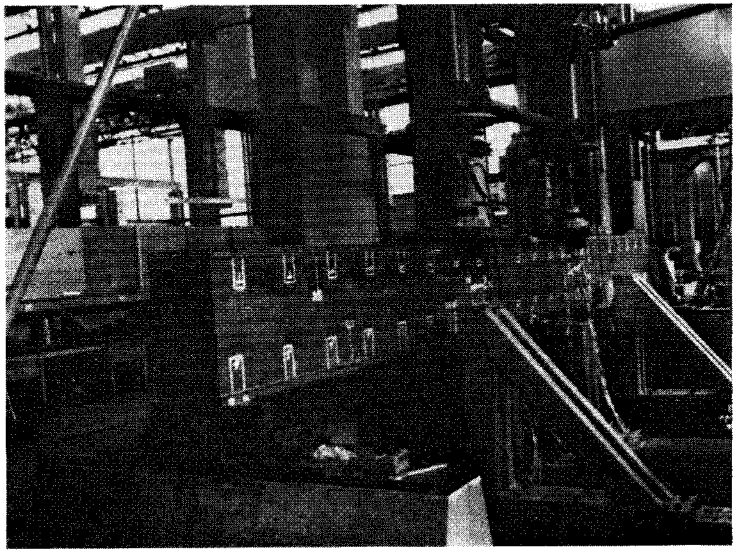




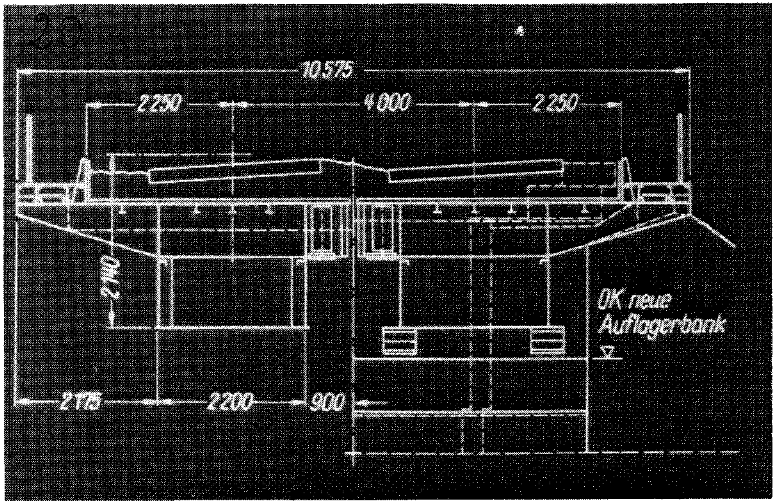
17. Track standardisation makes for better construction

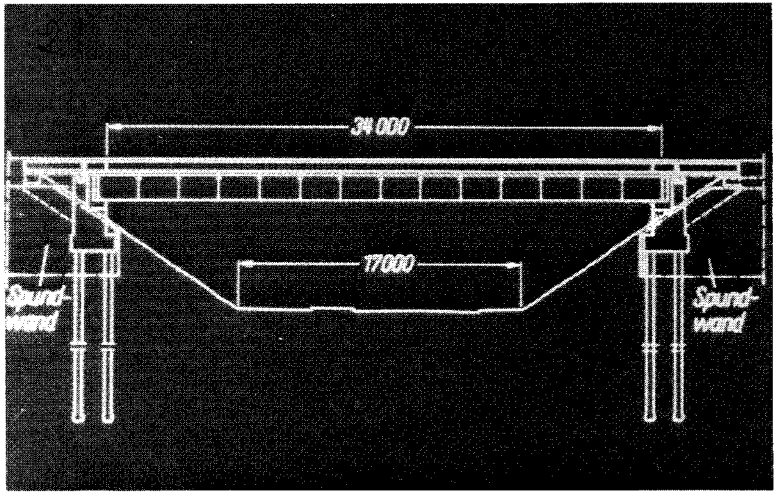


18. Good drawings make for sound construction guidelines

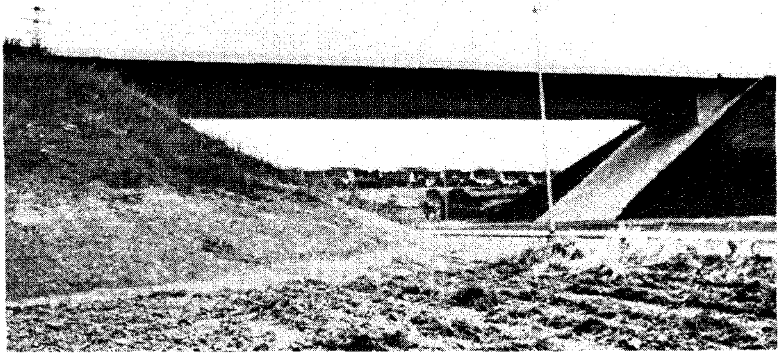


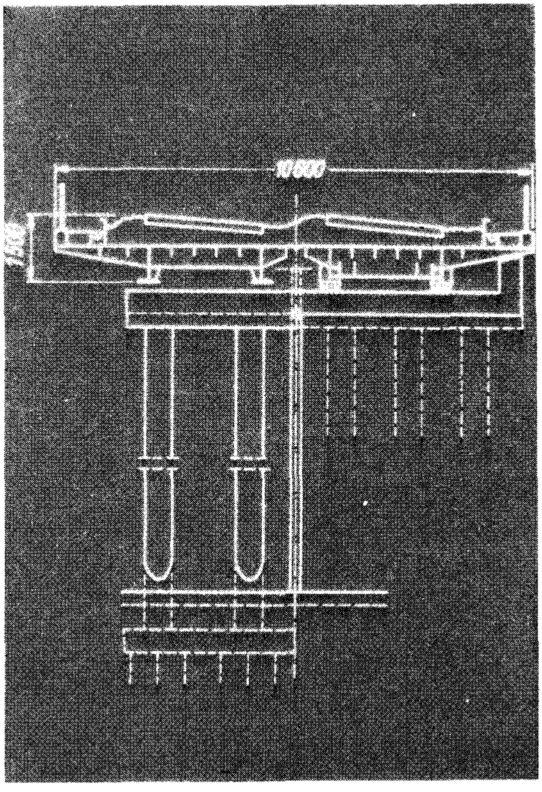
19. Large-scale materials testing facilitates proper dimensioning





20 - 25 Typical modern steel frames on the DB network





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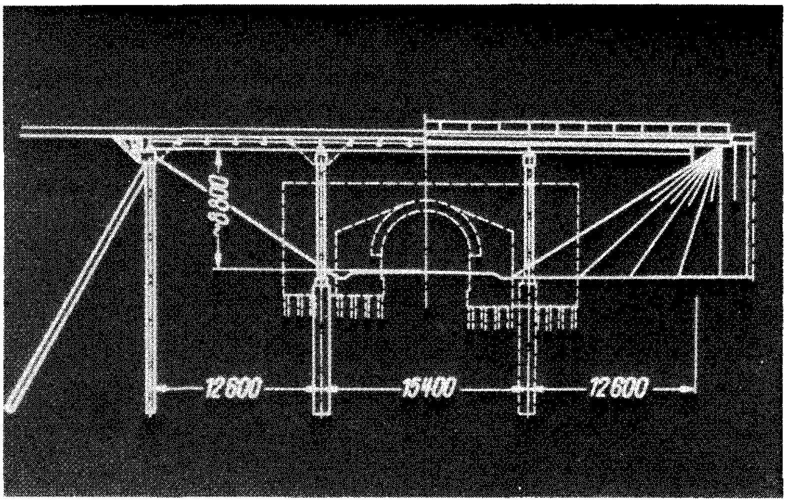

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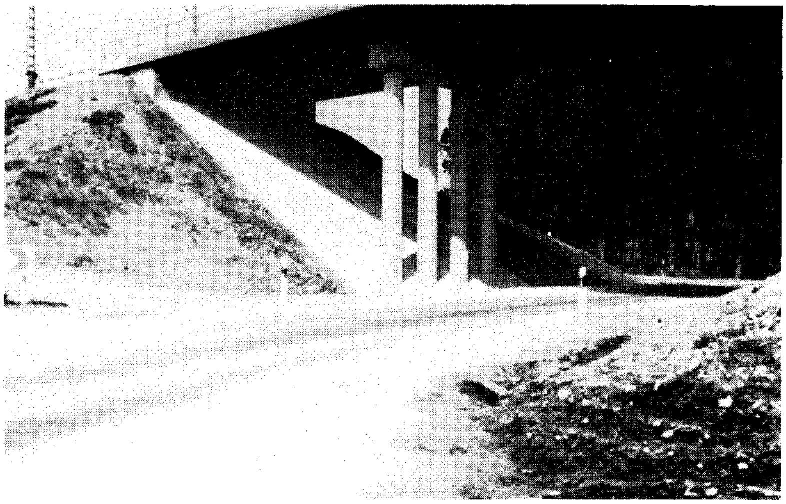

LIGHT STEEL BRIDGES TO FACILITATE TRAFFIC AND PEDESTRIAN MOVEMENT

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Summary

Today's steel bridges are characterised by modern developments in concept, design, and construction and superior materials technology. Cleanness and flexibility in planning, construction and operation are the criteria.

The increasing number and importance of footbridges over the last few decades is a striking documentation of these criteria. They have been determining factors in the control, easing, and channeling of traffic at crowded points and junctions. The added safety factor is a service towards the humanisation of our living environment.

With the above criteria in mind, and with due consideration for the user, steel footbridges have special characteristics and peculiarities in terms of choice of system, control, education and supply, that, in spite of usually small dimensions, offer a carefully engineered solution. Within the setting of town planning, they play an important architectural role. Here, steel is an especially appropriate material whether it be for use in combination, multifunctional, or entirely new roles.

After a general introduction, examples are given of footbridges in use in Europe to demonstrate design and execution criteria as well as the wide range of applications.

1. INTRODUCTION

Steel bridge building is characterised by advanced design and construction. For low weight, great advantages are offered: efficiency, flexibility, adaptability to changing conditions, rapid and convenient assembly following extensive prefabrication, short erection times, reuse of the whole structure or of its parts after trouble-free disassembly - or at least recovery of the material. All these advantages are particularly evident in the case of lightly constructed footbridges used in crowded points and junctions for the purpose of channeling and easing traffic as well as for the safety of the road user. Steel footbridges can, moreover, demonstrate clear advantages in terms of suitability, ease and economy when it comes to extra requirements such as weatherproofing or even air conditioning, frequent shifting and rebuilding, differing arrangement and design of approaches and access, lighting, and the provision of mechanised movement systems.

Over the last few years, footbridges have taken on increased significance in view of the ever-increasing speed of traffic. They fulfill the requirements of pedestrian traffic:

- separation from vehicular traffic, whether it be road, track, or water
- passage over natural obstacles or artifacts
- short routes to objectives
- rapid, comfortable and safe communication

As a component of urban development, a proper architectural approach to footbridges often plays a very important role.

When it is possible to consider all possible forms of framework, the beam, free or stayed, is to be preferred. As well as the open structure, usually in the form of a deck with the footway on top, there are also covered and enclosed tubular bridges. In some cases, the bridges are multipurpose or combined with other structures: bridges at motorway service areas which also serve as communication facilities, also partly or wholly movable bridges which permit the passage of high vehicles.

The question of vertical vibration due to continuous periodicity arises. The decisive factors here are the difference between the excitation frequency and the natural frequency and whether the amplitude would be found disturbing. Detuning and damping methods exist to produce acceptable levels.

2. EXAMPLES OF FOOTBRIDGES IN STEEL

By way of example, a number of design and execution criteria are given here to illustrate the variety of methods of problem solution and possibilities for application with regard to steel footbridges. (2)

2.1. OPEN GIRDER BRIDGES

The walkway over the Nettebach at Koblenz (Fig. 1) is the prototype of a very simply supported beam bridge. Its span width is 12.6 m. Two rolled steel I-beams form the main bearers supporting a wooden decking of 120 x 50 mm planks. All the steel components, main beams, ties and guardrails, are hot-dip galvanized and coated. The relatively small abutments in the banks of the stream permit level access.

Steps are often chosen for access to footbridges over urban expressways. Given a comfortable step ratio of 1:2, a midlle landing of 1 - 1.5 m and the most frequently selected height for walkway over street level of 5.0 m, the developed length is 11 - 11.5 m. By using twisted, scissored or spiral arrangement, the staircase can be made to fit the ground area available and to face in the preferred direction.

The main beams stretching 28.6 and 25.0 m over the Ruhr Expressway in Essen (Fig. 2) are in the form of a welded box 1.0 mhigh and 1.0 to 0.9 m wide. The box carries water piping. The useful width of the bridge is 3.5 m. A transversely stiffened 12 mm gauge steel plate projecting out on both sides of the box serves as the walkway. It is covered with gravelled asphalt. There is a smaller box girder under the stairway of 0.3 x 0.4 m which, together with the upward extended flange forms the drain.

When this bridge was built in 1970, it spanned two tram lines located separately in the middle, and two sets of three lanes of express carriageway as well as an adjoining minor road also with two tram tracks. Six years later, the tramway was set in a tunnel. At the same time, the stairs from the central section which were no longer necessary were removed, but since their posts served as the central support, they were replaced by an A frame of rolled steel joists to take the horizontal forces (Fig. 3).

The flexibility of footbridges here demonstrated can be exploited systematically for specific purposes. The opportunity is particularly there when the street widths to be spanned vary over narrow limits and where virtually identical spanned widths or openings are required. As a rule, these are about 15.0 m when using beams as load bearers. Unfortunately, taking the 'typical' approach involves standardisation and uniformity. The necessity, in any case, to suit the various elements and parts to local circumstances usually means that, in virtually every case, the typical footbridge is associated with originality. The bridge over the Miquelallee in Frankfurt am Main, already shifted several times, is representative of other typical bridge arrangements (Fig. 4).

Over motorways and expressways, or at junctions, it is often necessary to dispense with intermediate or central supports. Then large openings exist, such as the three-part footbridge over the autobahn at Neumünster (Fig. 5) with 21.8 + 46.0 + 21.8 m openings. The main beams of mainly single welded box construction had to be fairly low (1.0 - 1.2 m) to allow for a usable walkway of 3 m. The boxes were placed below the walkway for aesthetic reasons and to provide a housing for the water pipes. The upward curved gradient (R = 376 m) makes it possible to provide about 5 m clearance over the motorway, with only lightly banked ramp approaches.

The many variations of spanned width, useful width, ground plan and positioning of intermediate supports, all to some extent dictated by the surroundings, the space available and the traffic requirements, are well demonstrated by the forked arrangement of a favourite pathway in the spa area of Bad Harzburg, where it crosses a four-lane highway (Fig. 6). The spans are 16.4, 17.0, 25.0, and 27.0 m. Trapezoidal 1.15 and 2.1 m wide box girders are used; the main arm has a useful width of 4.0 m and the branch arm 2.5 m. The arrangement suits both traffic requirements and the setting, and the structure, due to the use of gradients and curves, can be used without steps for access by wheelchairs, prams and cycles as well as pedestrians.

Ramps, given a conventional arrangement and gradient of 1:8 to 1:12, require a run of 40 to 60 m to reach a normal walkway height, where natural landscape differences cannot be exploited. Ramps can also be scissored, curved or spiralled to suit the surrounding conditions and the main pedestrian direction.

A particularly large footbridge is arranged as a star in the centre of Leverkusen at third floor level, linking the Council House, the railway station and the cultural centre; it is over a roadway in a cutting for through traffic and an innercity road junction at normal street level. (Fig. 7) The main arm, which is about 105.0 m long, has a useful width of 8.0 m.

The 75 m branch arm, however, has a useful width of only 4.0m. Since only one eccentric support could be placed at the centre of the star, the span widths are relatively large. The through-running, trapezoidal hollow box girder system has a height of 1.5 and 1.8 m at widths of 2.0 and 5.0 m. The total weight of the steel frame is some 480 t. After prefabrication at the works, it was supplied in a small number of large sections and was erected by mobile crane during short night-time closures. The guardrails are filled with Acrylglas. In addition to the handrail lights, the bridge is illuminated by standard lamps on steel posts. The structure is served by ramps.

The Dammtor railway station bridge in Hamburg, which crosses three four-lane roads, passes through a building, and skirts a dangerous road junction, as it leads to the Alster pedestrian precinct, merits attention not only for its 300 m of footway, but also for the relief it provides in an extremely busy part of the inner city (Fig. 8). There are eight access points. Four of them have fixed staircases and ramps. Three have only staircases and at the end a fixed staircase with two independent flow escalators (Fig. 9). The useful width varies markedly. On the railway station end and in the park, it is 8.0 m to take account of the daily commuter traffic and the peak loads at exhibitions. The eastern branch is, on its narrowest side, only 3.1 m wide. The longest of the many different spans is 40 m.

Another means of access and departure is the lift. With suitable design they can make footbridges accessible to luggage, prams, and wheelchairs.

Where there are ramps (up to 12% slope) and at bridge level, moving walkways of rubber strip or treads increase the attractiveness and efficiency of footbridges (Fig. 18). Running at 0.5 - 0.75 m/s and with a width of 1 m, escalators and travelling walkways have a capacity of 4500 to 8000 persons/h, corresponding to a footbridge 2 m wide. Where traffic does not demand continuous operation, automatic on and off switching using photocells or contact pads can be installed.

2.2 COVERED GIRDER BRIDGES

Where it is necessary to provide weather protection for the user, a roof can be placed over the walkway, either on top of a high-sided structure or on stanchions or framework.

The main railway station in Kiel is connected by three footbridges of total length 130 m, which are roofed but open at the sides, with railway buildings, quays, main bus terminal, a multistorey carpark and the city centre (Fig. 10). The frame of both main bridges is formed by single-field Vierendeel beams of lengths 7.4 + 40.8 + 1.7m = 51.6 m, jutting out at the ends.
These 2.8 m high welded beams with hollow box cross-section separate the walkway in the middle, leaving 2.2 m each side of projecting 10 mm plate with asphalt covering; they have showcases in the openings. On the top structure is the trapezoidal sheet roof. The distance between the bottom edge and the walkway is only 40 cm, so that users have no serious floor height differences to contend with. The staircase towers stand on their own box sopports.

A similarly low structural height is also achieved by selecting a trough cross section for the framework as in the case of the 41 m footbridge over a six-lane road in Flensburg (Fig. 11). The 1.15 m height also forms the guardrail level. The separate trapezoidal sheet roof is placed on square section frames at intervals of 3.56 m. The walkway is the trough shaped plating with plastic coating. The useful width is 4.35 m. On the station side, there is a staircase with landing and an escalator.

During **restoration** of a turn-of-the-century art nouveau building in Hamburg City, communicating ways were installed at fourth floor level in the courtyard (Fig. 12). They are carried on two 0.5 m framework beams each on welded section brackets. They have a span of 15 m. By this means, an otherwise unused courtyard becomes a lively part of the commercial building with shops on the ground floor and four floors of offices above.

2.3 ENCLOSED GIRDER BRIDGES

Fully enclosed footbridges, or 'tubular' bridges, not only provide weather protection, but can also be provided with ventilation, heating, or even air conditioning, so that they become an integral part of an adjoining or communicating building. The 5.0 m wide footbridge between the multistorey carpark and the shopping centre at Bergedorf above the sluices is an example of this type of structure (Fig. 13). The bridge tube itself is separated from the buildings by fire-resistant glass doors. The bridge franework consists of two main box girders at roof level (1.3 x 0.55 m), which are continued into the building bottom edge. There, there are two rectangular longitudinal beams (0.6 x 0.6 m) which work as tie rods and which are connected via 9 suspension bars, with the box beams. At the top flange level, the trapezoidal sheeting roof is placed and insulated. At the bottom flange level, there there is more trapezoidal sheet with 7 cm concrete topping, insulation and PVC coating, all of which is the walkway. (Fig. 14) Above a laminated false roof in which the lighting is concealed, there is service piping. The walls are glazed over almost their entire height. All structural parts are of weather-proofed steel.

An unusual, though very effective, installation is an enclosed footway in an industrial plant in the neighbourhood of Cologne (Fig. 15). In this factory, the situation became very dangerous as a result of traffic and materials flow composed of criss-crossing stacker trucks, goods vehicles coming in and out, and heavy pedestrian traffic. In order to channel and speed up all forms of transport, it was decided to remove pedestrian flow to the second level. The total length of 215 m of bridge complex connect the various parts of the plant, the social facilities and the parking place via the loading bays and a federal highway. From the plant, the social building and the carpark, the overhead walkway system is reached by a total of 10 escalators arranged in pairs. Roughly in the centre of the overhead complex is a fixed emergency staircase and a hydraulically operated lift. The load-bearing section consists in all of up to 27 m wide welded channel. Stiffened 10 mm steel plate flooring covered with plastic forms the 2.5 m wide walkway. Since the whole network can be heated, the windows are of insulated glass and the other surfaces have heat insulating steelsheeting. The warm air ducting is above a laminated aluminium ceiling which has openings for air vents and lighting (Fig. 16).

The whole structure was assembled during normal operation with minimal disturbance. The sole exceptions were the installation of two sections of bridge and an escalator body installed at a non-working weekend, and the section over the highway which was put up during a two-hour suspension of traffic during one night. All the parts used were factory-assembled and preclad, with the exception of the impact areas.

The new fair territory in Düsseldorf is served by a 1000 m long overhead pedestrian system which links the main halls and the reception building (Fig. 17). The frame is of two IPB 500 main beams joined by IPB 200 cross members 2.5 m apart; it is connected by ribs to the 7.5 m wide tube. Every 15 m there are welded cross beams which serve as supports for the

4.2 m high tube braces. Above breast height, the outer skin consists of tinted Acrylglas windows; below, the outer cladding is foam filled aluminium panelling and the inner is steel sheet. The junctions with the halls and the tube junctions are of glass fibre reinforced polyester. The way is illuminated by strip lighting mounted on the ridge. The PVC floor covering is laid on boarding which is mounted on longitudinal wooden joists resting on the cross bearers. Two moving band walkways each of 225 m length speed the flow in the main 300 m tube in either direction (Fig. 18). The many access points are equipped with a total of 24 escalators. All have glazed balustrades and handrail-level lighting. The overhead pedestrian system is an integral functional component of the whole fair complex permitting parallel exhibitions in many halls and areas since the visitor streams can be separated. The entirely enclosed system runs at a height which is great enough not to impede the flow of fair service traffic.

Similar characteristics are exhibited by the communication tube linking two buildings across the Kasernenstrasse in Düsseldorf, which has a transparent plastic enclosure over the footway (Fig. 19). It is 27.0 m span and is at third floor level, bridging a busy four-lane road with pavements both sides. At the junctions with the two buildings, it is supported by two 20 mm thick steel bars inclined upwards. The welded main beam is 0.54 m high and 2.2 m across. The floor level plates form, with four longitudinal sections, a three-cell box. The spaces contain ventilation ducting, tubes for the message system, as well as heating, hot water, and electricity. The 2.0 m wide footway is insulated with corking 60 mm thick and rubber covered. The glass housing is washed by special car which is kept in a recess in the building.

A related type is to be found in the two superimposed tubes at the fair and exhibition ground in Basle (Fig. 20). Over the semicircular main bearers the three-quarter circular fluted using rectangualr sections as load-bearing elements grip the glazing. The tube diameter is 4.2 m. The fluted sections are integral with the air circulation equipment and distribute air through numerous holes. The surface of the walkway consists of boarding lying on the 15 mm plating of the main beams and sandwiching 5 cm rockwool. At the apex of the curve the clearance is 3.0 m and the useful walkway width is 4.0 m. Both main box girders rest on two-storey welded portal fames of rectangular section, stressed at the foot. The spanned widths are 1.0 + 20. 0 + 1.0 m.

In the case of polygonal, rectangular or square sections, the framework, the walkway below along with its walls and roof, can be used together for strengthening the wall and roof components. In this way, one can achieve the two 52.0 and 65.5 m footbridge and ramp systems like those in the main railway station in Belfast, whose load-bearing framework is of octagonal section (Fig. 21). The singly formed frame main beams span widths of 17.5, 22.0, and 20.0 m. They rest on the floor of the platforms on intermediate supports and on the station building. The rods and bars consist of rectangular or square hollow sections on the outside of which glazing is fixed by special method. The roof is formed by insulated trapezoidal sheeting fastened on from outside. The walkway is composed of 6 mm sheet with rubber nap covering (Fig. 22). The sheet is drawn up at the sides to a breast height of 0.75 m. Between the handrails, there is thus a useful width of 2.3 or 2.7 m and a clearance of 2.7 m (overall width 3.0 m or 3.8 m, overall height 3.0 m).

An interesting composite solution is to be found in Zoeterwoude, in the Netherlands, near the Hague, where a complex of footbridges crosses canals and roads on a beam framework. Over a length of 450 m, the square cross-section pedestrian tubes are hung on a pipe bridge (Fig. 23). The 4.8 m module framework of the pipe bridge are 2.0 m high. They are mounted on portal supports and have a maximum spanned width of 24.0 m. Inside, all electrical and other services are mounted on planking. Bracing and posts are of IPB sections like the portal posts. Rectangular or square rolled hollow sections form the diagonals and braces and the parts of the footway tubes used for bracing. The all-round horizontally running corrugated sheeting is insulated on the inside with glass wool tiles. Easily accessible cable is laid under the walkway. Rounded windows provide daylight via the sidewalls. The twin access staircases, likewise covered, are located as extensions at the corners of the footway complex.

2.4 OPEN GIRDER SUSPENSION BRIDGES

Where it is not possible to erect statically supported intermediate lengths, or where, because ofthe available clearance, access is limited, or the use of channel sections or elaborate framework is undesirable, the suspension bridge alternative offers itself. This is economical where the open spanned width exceeds 30 m. The cross-section of the stiffeners being constant over the entire length allows very limited height. The actual shape of such bridges depends on the suspension rope arrangement, the form and design of the pylons, and the arrangement of the bridge beams.

A suitable illustration is the 40.0 + 20.0 = 65.0 m length of the bridge across the Bundesallee, Berlin-Wilmersdorf (Fig. 24). The most notable characteristics of this bridge are the A pylons which go up to a height of 36.5 m, far above the rope guides, and the careful dimensioning and pitch. Between the two 0.65 m high welded box girders, the 3.5 m wide plate base of the walkway is placed. Electric heating is incoporated in its 15 mm thick covering of plastic. The structure is drained by virtue of a 2% fall in relation to the bridge axis, where there is a gutter. Like the stiffeners, the walkway has a 5.9 or 7.2% gradient in the direction of the ends of the bridge with its reinforced concrete abutments. On each end there is a ramp and a staircase for access. Strip lighting rüns along the handrail.

Even relatively closely placed spacers cause no problem, as the Lodemann bridge in Hanover shows (Fig. 25). The ropes anchored in the bridge axis, like the single-piece pylons, limit the useful width. It is, therefore essential to widen the bridge over the whole length of the superstructure, at least near the anchors and pylons. The disadvantage can be avoided by spreading the ropes round the edges or on the outside of the stiffeners and fastening below, or by having two rope planes outside and a twin-pylon arrangement. Side placing of a single pylon can also overcome the problem.

This solution was chosen for the Stephanie bridge in Bremen, which is bent in groundplan and in elevation (Fig. 26). Here, a torsionally rigid box girder in the lateral position is chosen for the rope tensioning of the 48.0 + 11.0 m span. On the side of the walkway it is 0.9 m high and on the outside it is 0.7 m. There is thus a trapezoidal cross-section with a system width of 0.5 m, bent 20 deg. on groundplan. This bridge is also bent in elevation, in order to provide landscape-oriented access over the abutments. The 2.5 m wide walkway is cantilevered out from the lower chord. It consists of a stiffened sheet with 3 mm plastic covering. Three retaining ropes are secured at the northerly abutment. One goes to the first and the other pair to the forward point of origin. The rectangular pylon has a total height of 12 m.

The foot suspension bridge aver the autobahn at Duisberg was formerly at the German Pavilion at the Brussels World Fair of 1958. Similar arrangements have been adopted (Fig. 27).

Statics requirements as well as design led to the bent shape of the welded pylon.

Forked and star-shaped suspension bridges are also possible for pedestrians. The footbridge over the Meridiana motorway triangle in Barcelona is an example (Fig. 28) of a forked arrangement. An obvious characteristic is the differing widths of the two stretches determined by the expected traffic. The main walkway has a 3.0 m useful width and the fork has 2.0 m. The system height of the box girders is 0.7 in both cases and the design is similar. At the fork, outside the bridge plane itself, is the tapered 36.4 m high pylon of heptagonal box section in which the parallel suspension wire is anchored in four stages one above the other. For the main opening, three ropes lie in a plane. The lower anchor point is in the axis of the bridge. The other two sets of four ropes reach the two 52.5 m radius main beams of the secondary stretch on the convex side which is about 50 m long; there they are secured. The shape formed is a star configuration of wires at the fork and a plane wall of rope in the direction of the axis of the 43.5 + 16.0 m long main stretch. All access points are ramps with a maximum gradient of 11%; a slightly curving one and two others which are spiralled at the ends (R = 7.5 and 9.0 m).

The 74.0 m bridge over the Max Strasse in Vienna is architecturally interesting in another way (Fig. 29). The clearly skewed main beam with longitudinally stiffened cover plate and two T flanges hangs at 4:1 on spiral ropes on an A pylon inclined at 15 deg. to the vertical. The rope anchoring at the top of the pylon over the centre of the bridge is 35.0 m above the street level. The walkway of 5.0 m width in the centre of the bridge consisting of asphalted steel plate widens towards the abutments to 6.5 m. Access is by ramp and staircase.

2.5 ENCLOSED SUSPENSION BRIDGES

A 72.8 m long main beam frame was selected as the structure for the suspended footbridge linking two railway stations at Zoetermeer in the Netherlands (Fig. 30). The rolled rectangular hollow sections at intervals of 3.6 m make up the 3.0 m high system. The parallel ropes are anchored in the tapered H pylons 20.0 m over the traffic level; the pylons have sunken stay hooks. The suspended centre section and the two short side spaces of the 120 m long system over the twin rail tracks are borne in the staircase towers of the railway stations. As well as stairs, there are also lifts.

The walkway is at the level of the lower chord and the roof is between the upper chords. They consist of 10 mm longitudinal and 6 mm transverse stiffened plate. Tar epxoy resin is used for roof insulation. The sidewalls are of ribbed glass on the inside of the suspended frame superstructure (Fig. 31). In the two short communicating bridges in the stations, plastic sheeting and bullseye windows are fitted. The through useful width is 2.7 m, which is the same as the clearance between the walkway and the aluminium ceiling panelling with built-in lighting.

3. CONCLUSION

The list of examples could be continued. The most important points and peculiarities with regard to design and execution have been demonstrated by those examples chosen here. They provide documentary evidence that the light steel bridge is the most fitting answer to today's requirements for traffic separation and safety.

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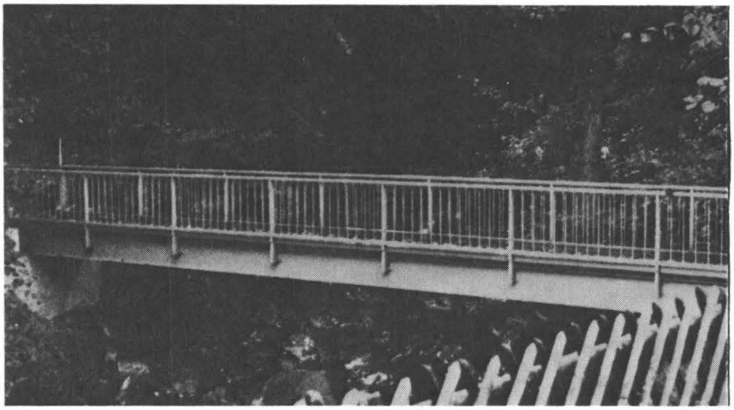

Fig. 1 - Nettebach bridge, Koblenz

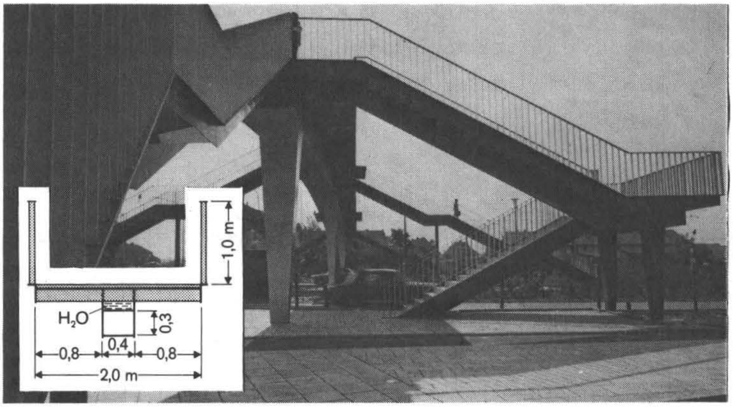

Fig. 2 - Footbridge in Essen (1970)

Fig. 3 - Footbridge in Essen (1976 after rebuild)

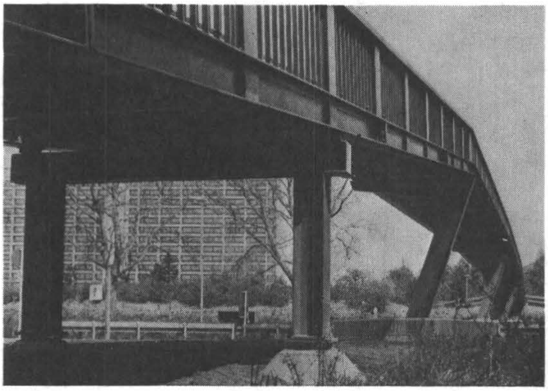

Fig. 4 - Typical footbridge, Frankfurt am Main

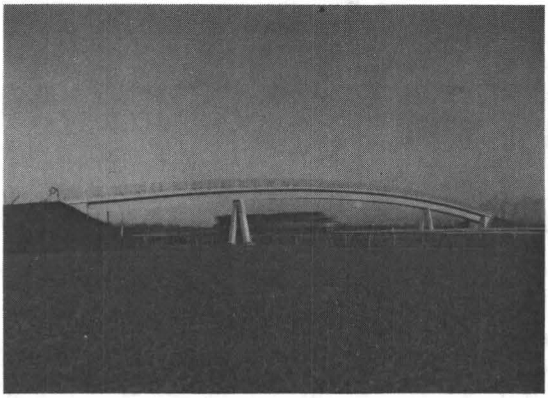

Fig. 5 - Footbridge over the Autobahn at Neumünster

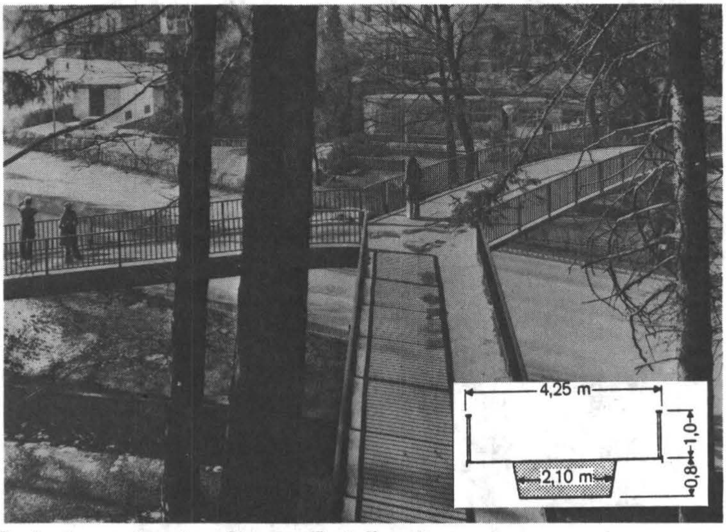

Fig. 6 - Forked overhead walkway, Bad Harzburg

Fig. 7 - Star-shaped footbridge, Leverkusen

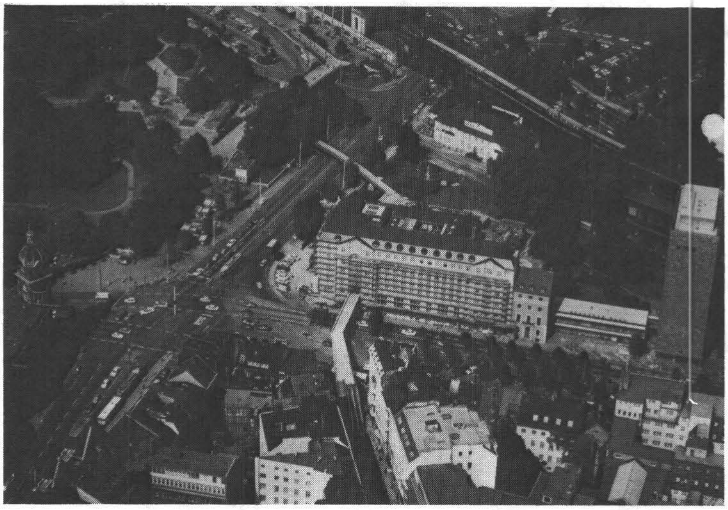

Fig. 8 - Footbridge complex at the Dammtor, Hamburg

Fig. 9 - Exit from footbridge complex at the Dammtor, Hamburg

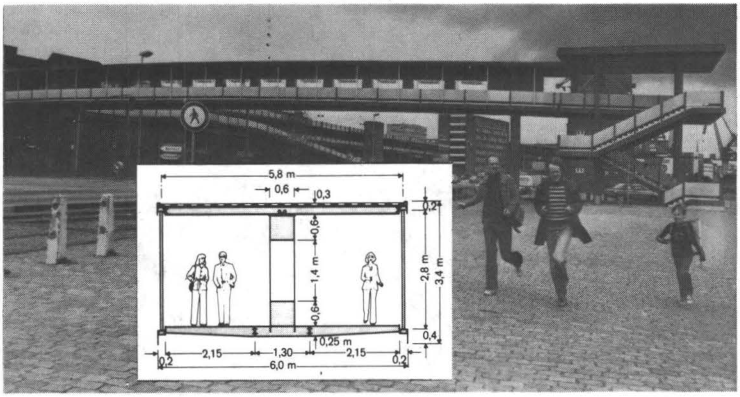

Fig. 10 - Covered footbridge with showcases, Kiel

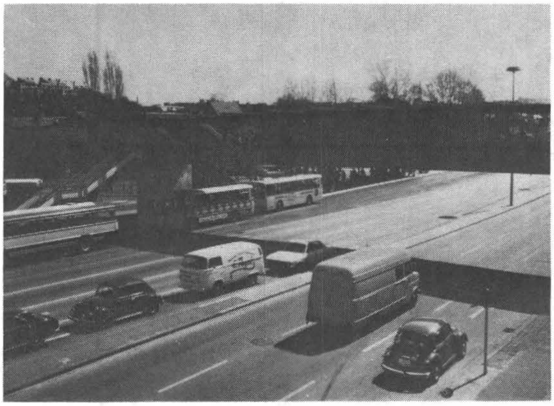

Fig. 11 - Exit from covered footbridge with escalater, Flensburg

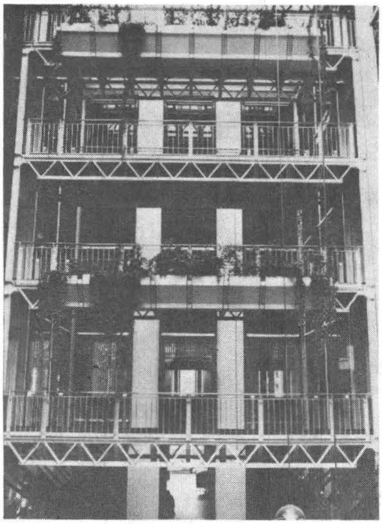

Fig. 12 - Courtyard in Hamburg with connecting walkways

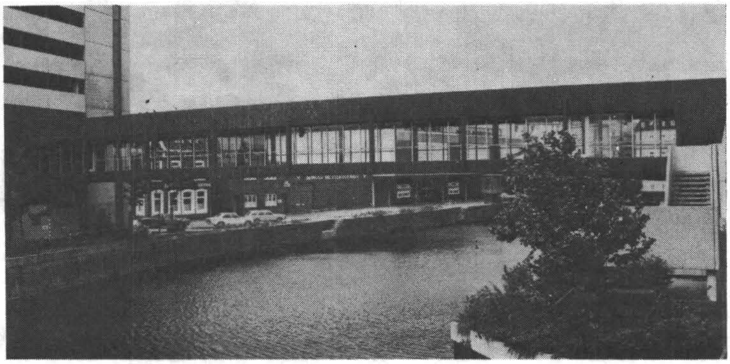

Fig. 13 - Enclosed footbridge, Bergedorf

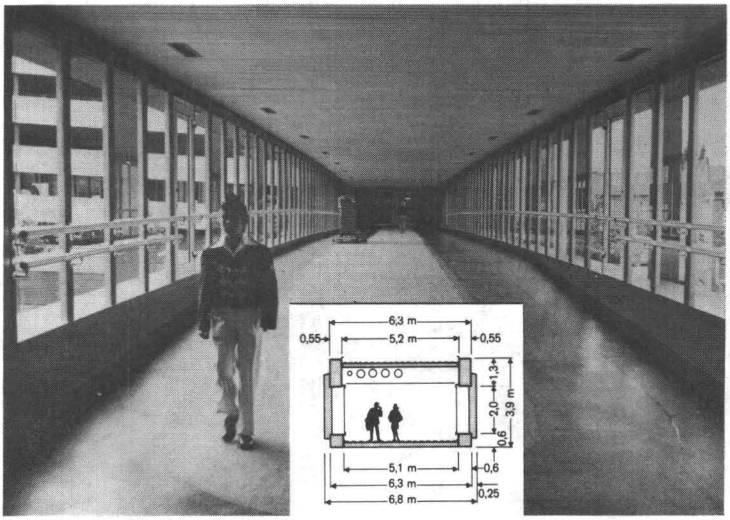

Fig. 14 - Enclosed footbridge, Bergedorf

Fig. 15 - Enclosed footbridge complex in a factory situation, Cologne

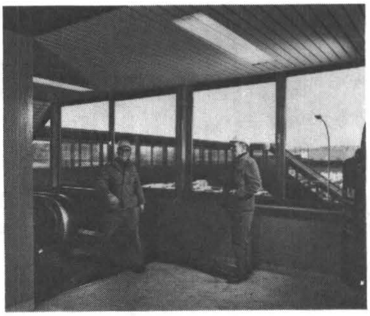

Fig. 16 - Enclosed footbridge complex in a factory situation, Cologne

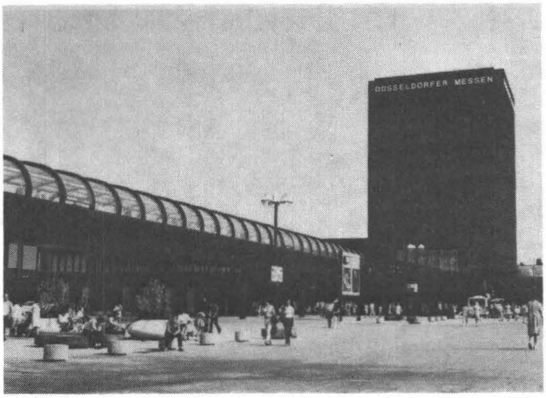

Fig. 17 - Enclosed footbridge complex at the new fair and exhibition site, Düsseldorf

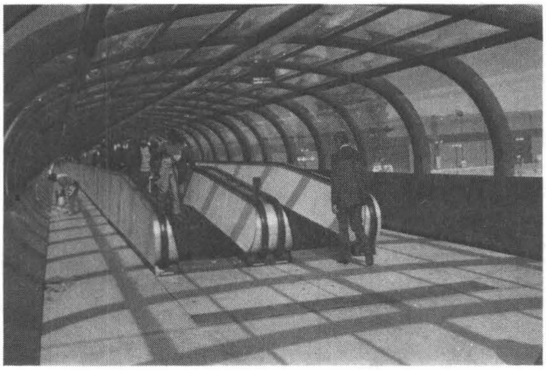

Fig. 18 - Enclosed footbridge complex at the new fair and exhibition site, Düsseldorf ; view in main tube with moving walkway

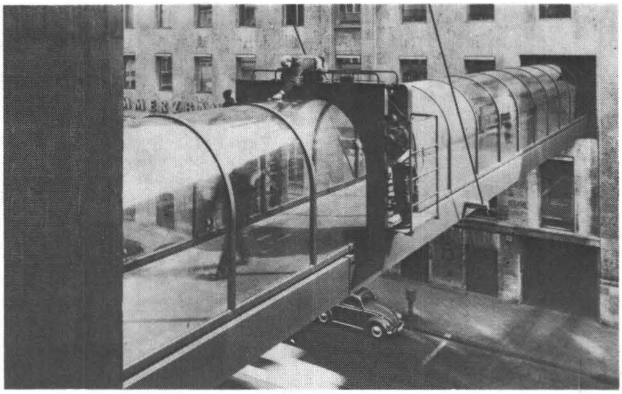

Fig. 19 - Enclosed communicating bridge in Düsseldorf with cleaning car

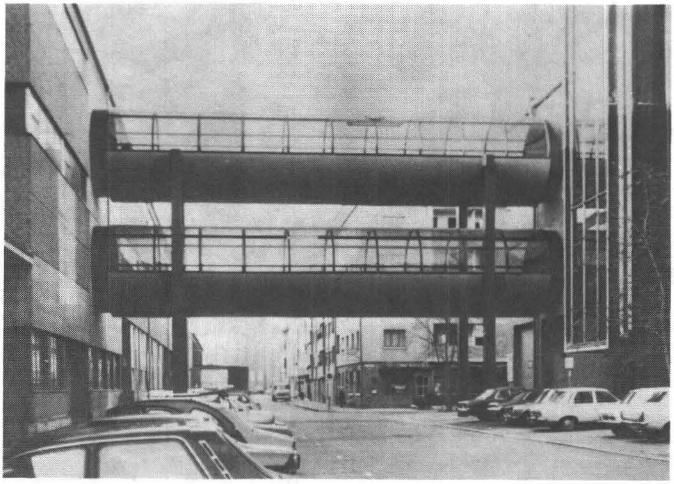

Fig. 20 - Enclosed footbridges at fair and exhibition site, Basle

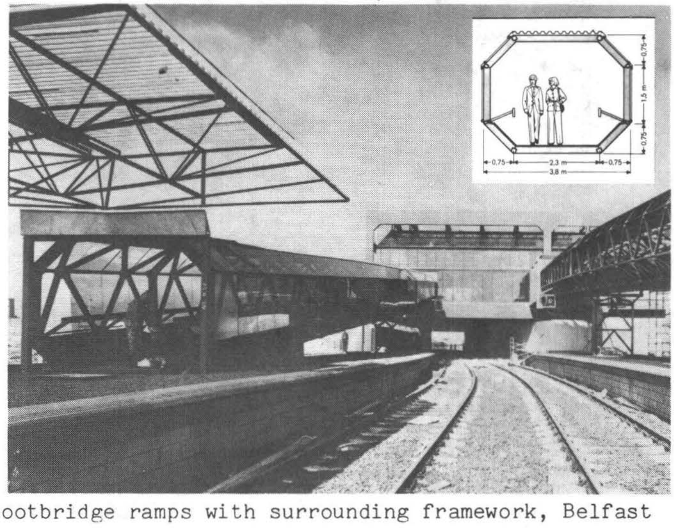

Fig. 21 - Footbridge ramps with surrounding framework, Belfast

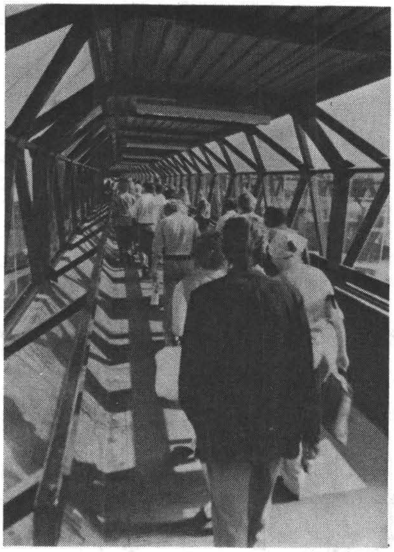

Fig. 22 - Footbridge ramps with surrounding framework, Belfast

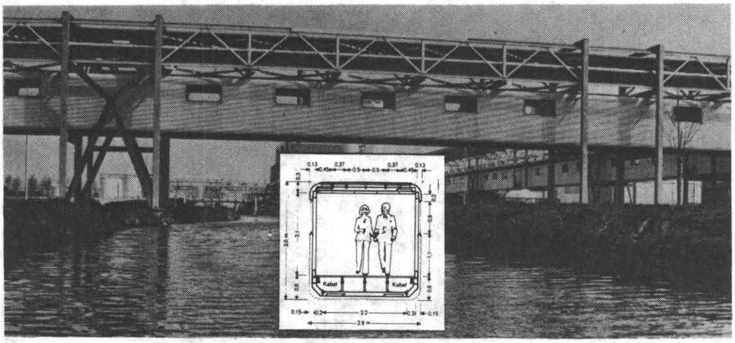

Fig. 23 - Enclosed footbridge beneath pipe bridge, Zoeterwoude

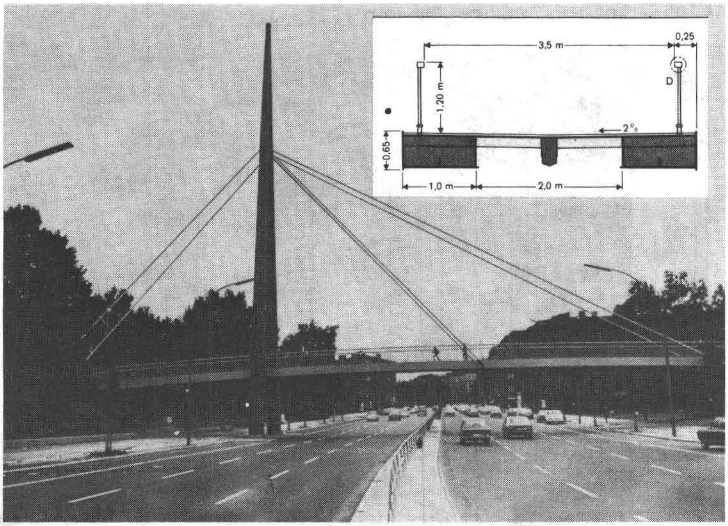

Fig. 24 - Suspended footbridge, Berlin

Fig. 25 - Suspended footbridge, Hannover

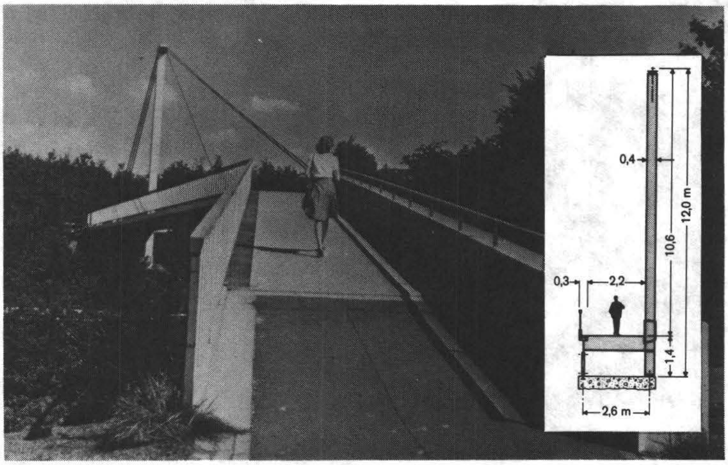

Fig. 26 - Suspended footbridge, Bremen

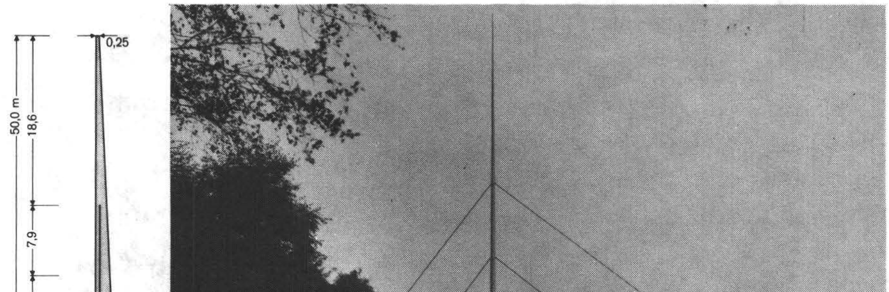

Fig. 27 - Suspended footbridge, Duisburg

Fig. 28 - Suspended footbridge, Barcelona

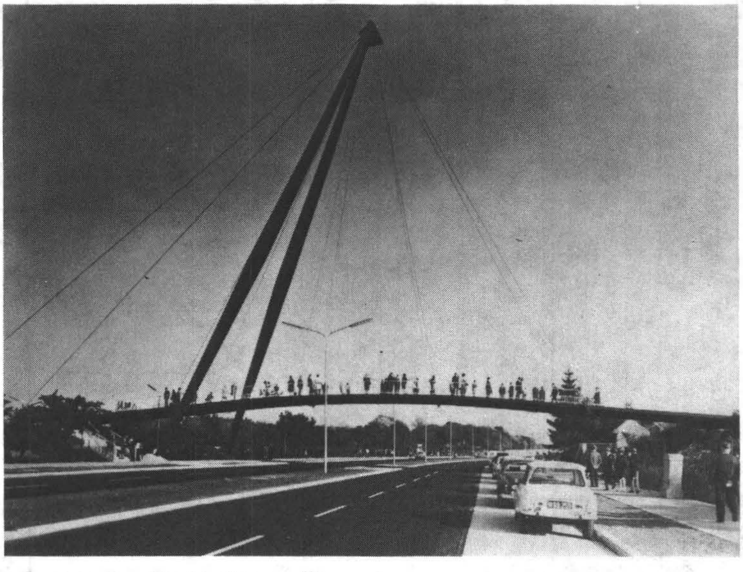

Fig. 29 - Suspended footbridge, Vienna

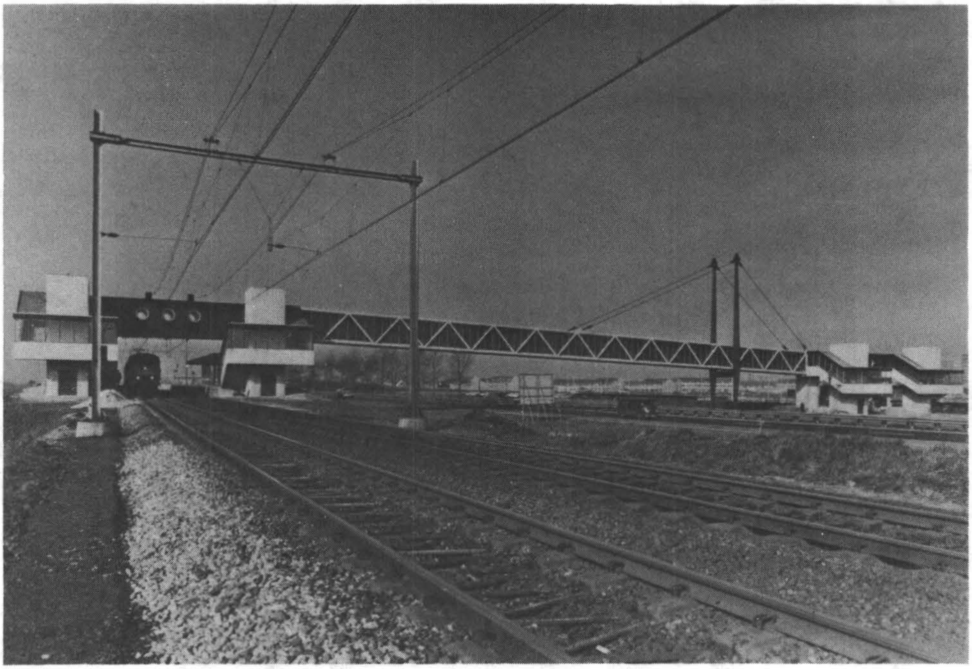

Fig. 30 - Enclosed suspended footbridge, Zoetermeer

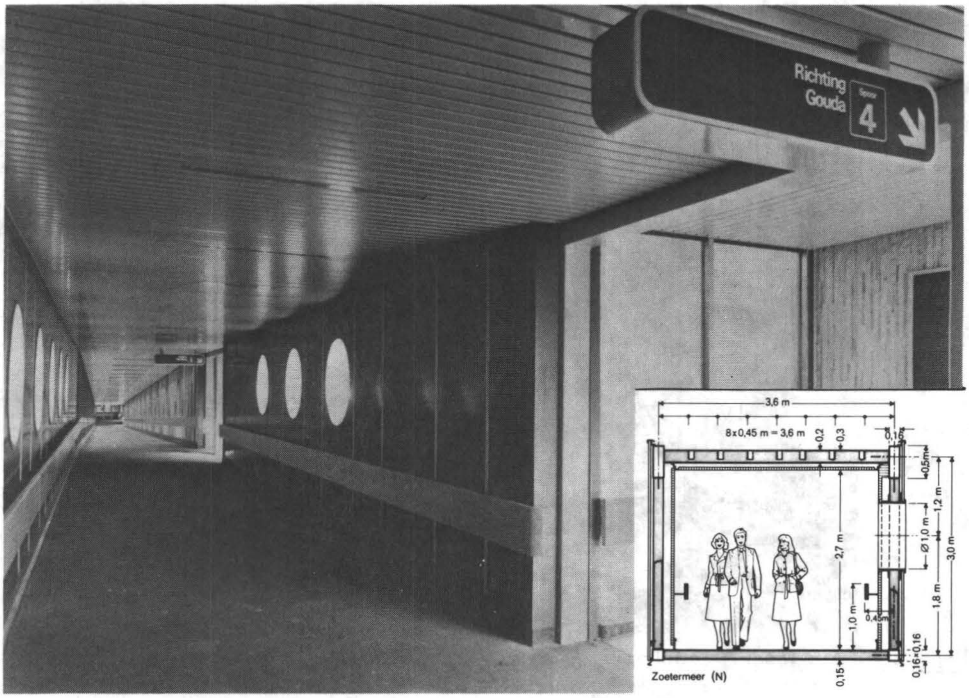

Fig. 31 - Enclosed suspended footbridge, Zoetermeer

THE MALTINGS CONCERT HALL, BUXTON OPERA HOUSE AND YORK MINSTER

A RECONSTRUCTION AND TWO RESTORATIONS

DEREK SUGDEN

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Summary

In October 1965 the Aldeburgh Festival wrote to Sir Ove Arup asking him whether we could survey a Malt House in Snape and say whether it could be converted into a Concert Hall for the Festival. From that first conversion followed many others by Arup Associates & Ove Arup & Partners; Malt Houses, Corn Exchanges, Dock Buildings, Churches, Opera Houses and a Cathedral. Some of these buildings have been restorations, whilst others have been converted to entirely new uses.

All have used steel as a very necessary part of their restoration and reconstruction and three buildings have been chosen to illustrate this theme.

The paper describes the creation of a Concert Hall out of a 19th century Malt House, The Maltings Concert Hall at Snape for the composer Benjamin Britten and the Aldeburgh Festival, the restoration of the 1903 Opera House at Buxton, Derbyshire and the restoration work at York Minster.

THE MALTINGS CONCERT HALL - SNAPE, SAXMUNDHAM, SUFFOLK, ENGLAND

A NEW CONCERT HALL FOR THE ALDEBURGH FESTIVAL

In her biography of Benjamin Britten, Imogen Holst describes the beginnings of the Aldeburgh Festival. It was Peter Pears' first suggestions during the English Opera Group's visit to the Holland Festival in 1947 to perform 'Albert Herring' that led to the first Festival in 1948. It opened in the Aldeburgh Parish Church with the first performance of Britten's newly written cantata 'St. Nicolas'. In the biography Imogen Holst describes Peter Pears' idea of 'A few concerts given by friends'. By 1965 the list of friends had grown impressively long but the atmosphere had miraculously survived.

Most of the larger orchestral and choral concerts were held in Aldeburgh Parish Church and the surrounding churches, especially Blythborough and Orford. The largest secular hall used for opera, chamber concerts and recitals was the Jubilee Hall with 320 seats. This hall has seen most of the first performances of Britten's Operas. As the Festival grew only a larger secular hall would provide for those who now wished to come and were needed to support the more ambitious programmes. A letter from Stephen Reiss, the Festival Secretary, to Sir Ove Arup in 1965 said that they had the opportunity of leasing one of the disused Malt Houses at Snape. Would Arups survey it and say whether it was possible to convert it into a Concert Hall?

The Maltings at Snape

The Maltings at Snape are perfect examples of what J.M. Richards called 'The Functional Tradition' and are well illustrated in the book of that name which he wrote with photographs by Eric de Mare. The Maltings were started by Newson Garrett in the mid-nineteenth century. Newson Garrett was a shipowner, grain transporter, Lloyd's agent and Mayor of Aldeburgh. He was the second son of the seventh generation of Richard Garretts who had originally made ploughshares in nearby Woodbridge and had founded the Garrett Engineering Works at Leiston some eight miles inland from Aldeburgh. He had also found time in his busy life to produce a large and talented family. One of his daughters, Elizabeth Garrett Anderson was the first woman doctor in England who, to overcome traditional English male chauvinism, was forced to pursue her medical studies in France. She was also the first woman Mayor of Aldeburgh. His eighth child was Dame Millicent Garrett Fawcett, the feminist, suffragette and pioneer in education. The Maltings are traditional mid-nineteenth century industrial buildings, - red brick from the local Snape brickworks, timber floors and deep timber roofs in the local shipwright tradition. The Malt House roofs were once finished with Welsh and later Italian slates and the turning bays and low buildings with red clay pantiles. When roof slates and tiles were replaced, asbestos slates or sheeting was used. These were rapidly covered with moss and lichen and blended well with the industrial scale of these buildings and the surrounding marsh.

The Survey

A detailed survey of the buildings chosen for conversion, including investigations of the ground conditions, drainage and electrical water supply was carried out in the late autumn of 1965. Plans, sections and elevations of the existing building were made including a layout of the whole maltings (Figure 1), a fully detailed sketchbook and a report on the conversion possibilities.

The Brief

The survey report was completed in November 1965 and in December 1965 Arup Associates were asked to prepare designs and supervise a contract for the concert hall to be ready for the 1967 Festival! The brief was for a concert hall to seat between 700 and 800. It was to be provided with lighting facilities for opera, an orchestra pit, and with a removable proscenium. It was to have a restaurant and changing rooms. It was to be wired for the BBC for recording during the Festival and for the Decca Record Company for stereophonic recording. Decca also require a flat floor within the auditorium and any rake had to be built up with removable plat-forms. Car parking had to be provided for 450 cars. Lorry access had to be provided to a loading bay which in turn had easy access to the stage. The stage was to be the full width of the auditorium and 40 ft. deep, to be 4 ft. above auditorium level and to have a 1 ft. rake.

The Design

Many modern auditoria have failed at many levels because designers, but more often their clients, have tried to create spaces for opera, concerts, drama and speech within a single envelope. Arups were fortunate in that Benjamin Britten himself insisted that the hall should be designed specifically as a Concert Hall and this was reconfirmed on many occasions during the development of the design. The design did however incorporate many of the technical installations necessary for opera production without compromising the concert hall acoustic. In the early stages of the design the idea of a removable proscenium was dropped from the brief when the client quickly recognised the potential of opera production on an open stage. It was also felt strongly by the designers that the whole conversion both inside and out should retain the character of the Maltings and that as much of the existing structure as possible be preserved.

The Plan

The plan for the conversion aimed at a single space enclosing auditorium and stage, the largest possible foyer to create the sense of occasion and to use wherever possible the existing brick walls. It had already been decided that the roof must be replaced and from this decision followed the removal of the long wall separating the two galleries in the Malt House. All the cross walls and hoppers were removed down to the lower level of approximately 3.25 O D.

After digging trial holes it was decided to make the auditorium floor at 3.5 O.D., some 2 ft. above ground-water level. This was slightly above the approximate floor level of gallery 3 and the turning bay. This also gave acceptable levels for the stage 4 ft. above the auditorium and which in turn fixed the level of the changing rooms and loading bay.

Plan and structure are interdependant and the large foyer that was really necessary running the full length of the malt house had not yet been achieved. The flat auditorium with a built up and removable raking floor was still retained. A further meeting with the Decca Record Company was a real breakthrough. Because of the size of the stage Decca only wanted a further 30 ft. of flat area and it was felt that this could be accepted as a permanently flat area in front of the stage and with the raked seating starting from this point. A suspended reinforced concrete slab was then proposed housing underneath plant rooms and lavatories. The foyer now ran the full length of the auditorium with steps and a half-landing at the west end giving access to the rear of the auditorium and with a staircase at the east end giving access to the restaurant. The two-storeyed annexe building was the natural place for changing rooms, giving access direct to the stage and for the restaurant at first floor level, giving wonderful views to the east across the marshes and good access from the foyer.

The Structure

The roof design was the key to the whole building . A solution was sought which would keep the basic shape of the old roof (Figure 2). In removing the long wall between the two galleries, it was essential to move the ridge of the roof over to the new centre line of the new auditorium. As much height and volume as possible was required to achieve the desired acoustic and a 45^{O} slope was chosen which was a compromise between the two existing slopes.

To retain as much character as possible it was also necessary to retain the smoke hoods. Studies for the heating and ventilation scheme were done at an early stage and confirmed the existing size for natural exhaust. This led to a flat top to receive the ventilators of some 12 ft. minimum width. After many sketches a simple roof truss was finally adopted at 12 ft. 2 in. centres of approximately 60 ft. span (Figure 3). It was of standard triangular construction except for the centre section with the minimum 12 ft. flat top where crossed ties were used. The auditorium width varied by as much as 18 in. so the solution was ideal in that all the truss halves could be identical and any variation taken up in the cross-braced centre section. The trusses were designed with all the compression members in timber and all the tension members in steel. The rafter backs are of 2/10 in. x 2 in. Douglas Fir, the crown struts of 1/12 in. x 3 in. Douglas Fir and the internal struts of 6 in. x 3 in. Douglas Fir. All the ties are of 1 in. diameter high tensile steel with bottle screws. All connections are made with standard timber connectors and purpose-made mild steel gussett plates and 2 in. diameter pins and lock nuts (Figure 4). The purlins are of 6 in. x 2 in. German Whitewood and the roof is formed with two layers of ¾ in. finished tongued and grooved boarding. The first layer is laid normal to the purlins and the second layer at 45^{O}. The roof truss has a fixed end on the north wall, with a mild steel shoe and 2 in. diameter pin and is fixed to the reinforced concrete ring beam with four ¾ in. diameter rag bolts. The south wall bearing has a free end with the shoe carried on a "Glacier Metal" bearing to ensure that the main roof ties are always in tension.

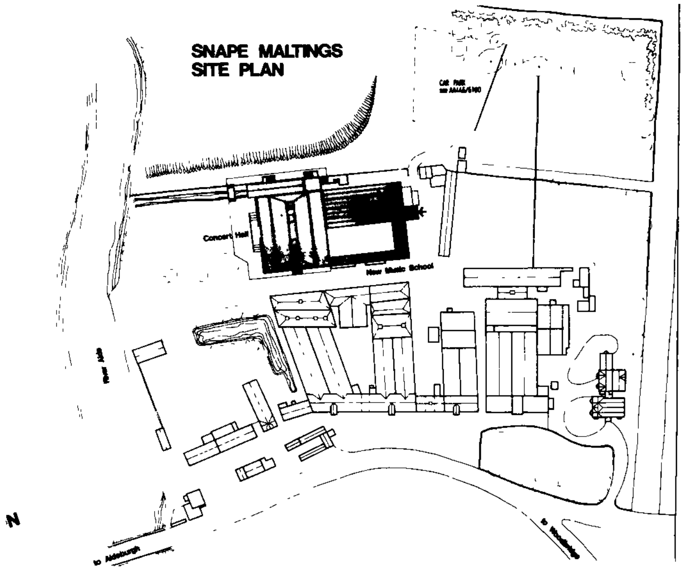
The hip rafters are of 2/10 in. x 2 in. Douglas Fir. The rafters and purlins were assumed to be propped during erection and advantage was taken of the shell action of the two layers of boarding to limit the deflections of the purlins and rafters. The analysis of the roof truss was done on the Eliott 803B computer using the plain frameworks programme. Before the plan and main outlines of the reconstruction were finally resolved it was decided to raise the existing walls by 2 ft. This resolved many problems, primarily it gave the necessary volume to ensure the two-second reverberation time chosen in the acoustic design. It gave good clearance above the staircase to the restaurant and rear auditorium entrance. It improved the gutter detail between the junction of the main hall and the restaurant and improved the junction of the new turning bay roof and the main hall and gave adequate room for the main ventilation duct. In addition to raising the walls and because cross walls had been removed, the main auditorium walls were stiffened by the addition of 2 ft. 3 in. x 13½ in. piers and arches on the foyer side and by 13½ in. x 9 in. piers on the turning bay side which carried a reinforced concrete beam. Above the arches and the beam, the walls were thickened to 2 ft. 3 in. and were finished with a reinforced concrete ring beam which provided a seating for the roof trusses and tied in the tops of the raised walls with the gable walls. Benjamin Britten had asked for an orchestra pit where the orchestra rail did not extend more than 10 ft. in front of the stage, and which placed the wind and brass under the stage, similar in some ways to the technique first used at Bayreuth in 1876. These demands for opera facilities and trap doors together with the orchestra pit already planned for led to a decision to open up the whole area below stage down to a depth of 4 ft. 6 in. below the auditorium to give good access to both sides and choice for the depth of the orchestra pit underneath the stage. The area under the stage was designed in reinforced concrete with an internal waterproof rendering. A sump was provided. The rake of the stage had been the subject of much discussion and it was finally decided to provide a steel frame operated by suitably coupled jacks (Figure 5). The jacks finally chosen were 10 ton 'Simplex Unilift' worm gear screw jacks operated by a single 2 h.p. motor. They were fixed inside 6 in. diameter columns and operated through a pin connection. The main frame of the stage used 15 in. x 6 in. U.B. 32 lbs beams of 30 ft. clear span with a 10 ft. cantilever, with the individual cantilever beams supported on the individual jacks housed within each 6 in. diameter column. The cantilever beams were connected at the front edge by a 6 in. x 3 in. x 12 lbs channel and the jacks were connected with removable coupling bars for operation of the stage raking mechanism (Figure 6). The stage surface was constructed of 9 in. x 3 in. softwood joists spanning between the cantilever beams and finishes with 1¼ in. hardwood strip.

A simple sliding bearing using two layers of polytetrafluorethylene was provided at the rear support of the stage to ensure that the jacks operated vertically. The base floor to the auditorium is in concrete with a suspended reinforced concrete slab over the lavatories and plant rooms. The foyer floor was excavated down to the auditorium level and a new concrete floor provided with reinforced concrete staircase and landings to the rear of the auditorium and the restaurant. The foyer roof was a simple lean-to roof using 9 in. x 3 in. Columbian pine joists and one layer of ¾ in. tongued and grooved boarding.

The eventual size of the opera lighting control box with access outside the auditorium as well as inside, led to the only addition outside the original walls of the old Malt House, and this design was based on the granary hoists on the main frontage, supported from similar rolled steel joist brackets and clad in white weather-boarding (Figure 7).

The concert hall was destroyed by fire on the first night of the 1969 Festival, only two years after being opened by Queen Elizabeth II. It was rebuilt in 42 weeks and the only alteration of any significance was to provide a mechanical system to raise and lower the orchestra pit floor and to enable its use as a forestage (Figure 8). This structure and mechanism was linked to the original design for changing the rake of the stage.

The Queen opened the Maltings Concert Hall for the second time in June 1970 (Figures 9 and 10).



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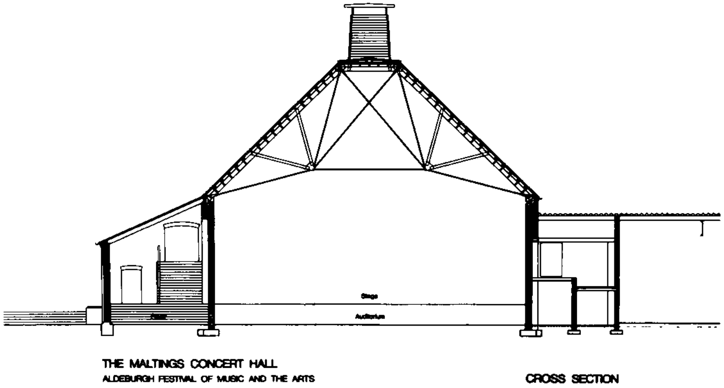

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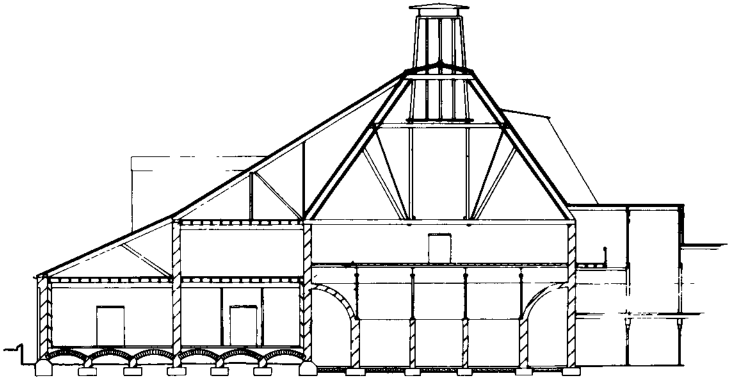
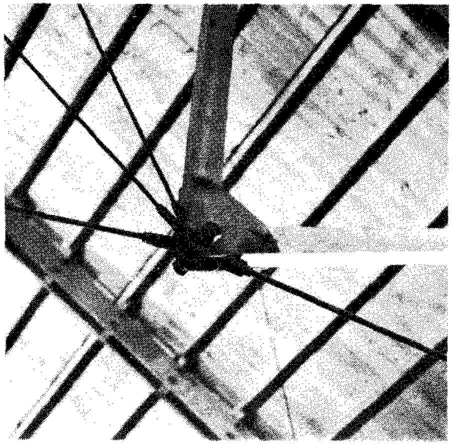


Fig. 1 Site plan

Fig. 2 Survey showing cross section of original roof

Fig. 3 New cross section



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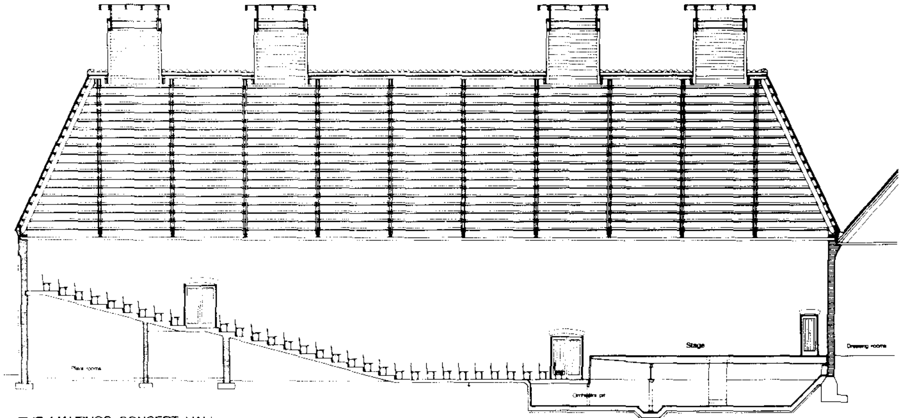

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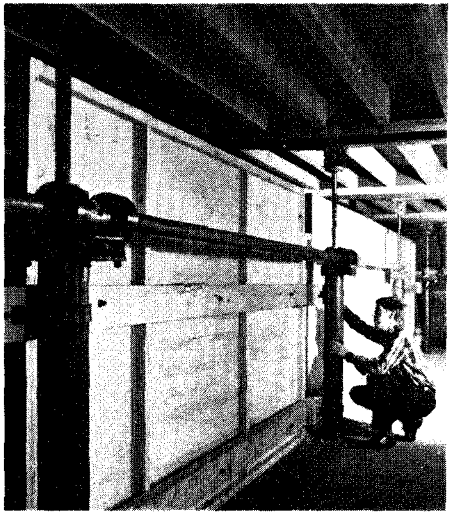

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Fig. 4 - Main node of roof truss

Fig. 5 - Longitudinal section showing orchestra pit and stage steelwork

Fig. 6 - Stage raking mechanism

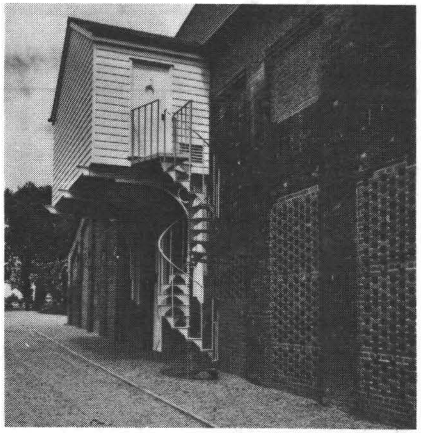


Fig 7 The opera lighting control box

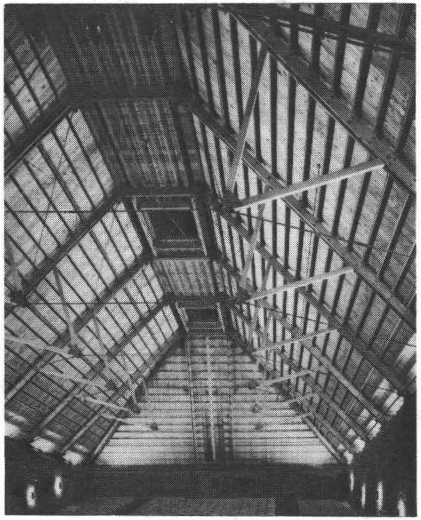


Fig. 9 The Roof

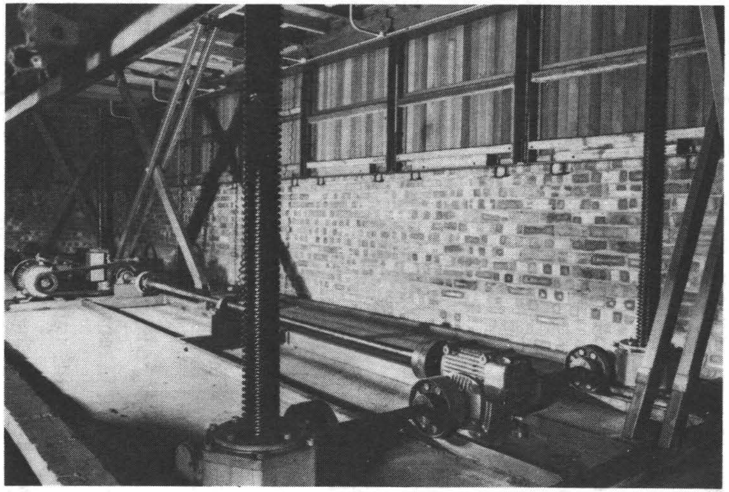


Fig. 8 Mechanism to raise and lower orchestra pit floor

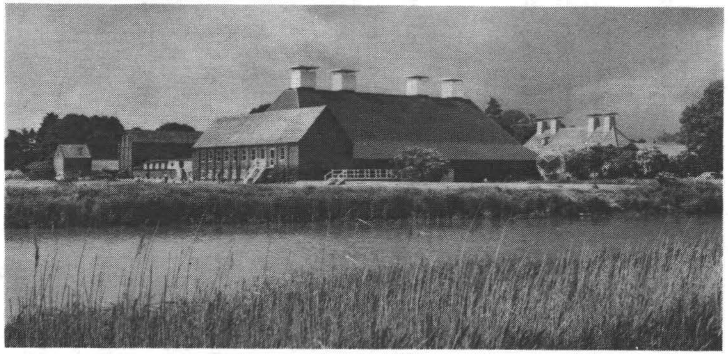


Fig. 10 The Concert Hall from the Marshes

THE OPERA HOUSE, BUXTON, DERBYSHIRE, ENGLAND

A RESTORATION AND THE BIRTH OF A FESTIVAL

Buxton is a very special place. It was a Roman Spa used in Elizabethan times where Mary Queen of Scots took the waters whilst a prisoner at Chatsworth. It had its heyday in the eighteenth century when the Duke of Devonshire built the Crescent and reached its zenith at the turn of the nineteenth century when Matcham built the Opera House in 1903.

It is the highest borough in England standing one thousand feet above sea level with a collection of buildings all constructed before the First World War and tied together by a street pattern which always brings one to the forecourt of the Opera House and that 'green lung' and river which sweeps in, without any apparent interruption, from the surrounding Derbyshire hills.

The Opera House (Figure 1) is the last building of a remarkable group linked by a conservatory designed by Edward Milner and Sir Joseph Paxton and overlooks the 'green lung' which terminates in the Pavilion Gardens. The other buildings in this group are a Playhouse, the shell of which dates from 1892, the Pavilion itself designed by Edward Milner in 1971, and a steel framed octagonal Concert Hall designed by Robert Rippon Duke in 1876.

When Matcham's Opera House opened in June 1903 there was accommodation for twelve hundred people: eighty in the stalls, five hundred in the pit, one hundred and forty in the dress circle, two hundred in the upper circle and two hundred and fifty in the gallery, plus some thirty standing in the upper circle. The price of a seat in the gallery was 6d.

Matcham's design has remained virtually intact, apart from the introduction of a projection box for the cinema. The seating however has been replaced over the years. Gone too is the class structure of Matcham's seating design. Originally there had been individual seats only in the four rows of the orchestra stalls and the dress circle, the rest of the house being in traditional benches. Slowly this Caste system had been eroded and the benches replaced with individual seats, except in the gallery. In the upper circle, a raised timber floor had been introduced above the concrete risers giving a greater width between seat rows but requiring a handrail above the rester. As well as being badly designed and detailed, this handrail seriously impaired the sight lines from the upper circle.

In addition to a few but damaging deviations from Matcham's design, the Opera House had been badly neglected for decades. Fortunately, the house had been well constructed in masonry, concrete and structural steelwork, and apart from some isolated cracking of the gallery floor slabs due to the increased load from the projection room, the structure of the building itself was in a good condition.

In the Autumn of 1977 Arup Associates were asked to prepare a report on its restoration and opening in time for the 1979 Summer Festival.

The brief can be summarised as 'The provision of an orchestra pit as large as the geometry and acoustic of the auditorium would allow, and the restoration of the Opera House as near as possible to Matcham's original design'. (Figures 2 and 3)

The main constructional work was confined to the orchestra pit. After the first detailed surveys of this area, it was decided to design a steel frame which could be inserted without interfering with the existing stage structure. A system of steel cantilevered beams was designed such that the beams could be placed beneath the existing timber beams.

The main cantilever beams are 18 in. x 7½ in. U.B. 66 lbs with an edge beam 10 in. x 10 in. U.C. 60 lbs supported on the proscenium walls. The cantilevers are supported on a new 9 in. masonry wall which formed the back wall of the orchestra pit. The fixed ends of the cantilevers are supported in the rear wall of the theatre and counterweighted with an insite reinforced concrete beam. After construction of the new 9 in. masonry wall the existing stage structure was propped each side of the main timber beams. The existing timber columns were then removed and the new cantilevers slid into position directly under the old timber beams, with their fixed ends housed in the rear wall and counterweighted. With the stage thus supported the old proscenium wall below the stage level was removed, the edge beam fixed and the new pit excavated and constructed (Figures 4 and 5). The final analysis of the stage steelwork was carried out on the ARUP DEC 10 machine using a gridframe analysis (PFT) part of the FRANCIS suite of programmes.

The rest of the constructional work was concerned with extensive repairs to the auditorium front-of-house areas and dressing rooms.

The whole of the electrical installation was renewed and in the auditorium new positions for modern stage lighting were introduced and appropriate decorative light fittings were reinstated throughout the building. On stage there is a choice of lighting controls, either the reconditioned Grand Master of the 1930's or the opportunity to connect a portable modern memory system.

A new heating system was designed using the old radiators. The Cost Plan did not allow for any major mechanical ventilation in the auditorium so the original natural ventilation system was reinstated by restoring the gas fired sunburner in the centre of the dome. This was dismantled, cleaned, modified for North Sea gas and put back into service under the guidance of Brian Benn of Theatre Projects Consultants Limited, and in the inspiration of Terence Rees author of 'Theatre Lighting in the Age of Gas'. It is now controlled by a modern electronic system from the restored projection box. A new mechanical ventilation system, with the necessary sound attenuation, was provided in the orchestra pit.

An appreciable amount of research was done in arriving at a scheme for the decorations, and restorations of the furnishings. There were many descriptions in the Technical Press of 1903 which describe the house as being in cream, gold and blue, and with more detailed descriptions in the Local Press of striped seating coverings and blue silk curtains to the boxes.

A real breakthrough, however, was the discovery in one of the boxes of a pale grey-blue carpet, with a darker blue classical motif which fitted descriptions given by local people who still remember the house when it was first opened. This carpet proved to have been made by a firm in Brighouse who undertook to weave a new carpet to the identical colour and pattern on an old loom of 1907.

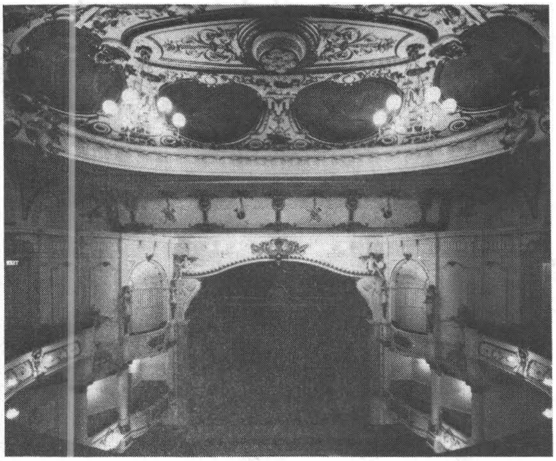
All the seating, apart from the fixed gallery benches, was removed and either replaced with restored seats of the period or with the removed seats restored and re-covered. The seats were covered with a velvet fabric, chosen to match the dark blue of the carpet. Existing brasswork was restored where possible but a new brass orchestra rail was designed together with new brass rester rails at the ends of the aisles and gangways. The existing tabs were vacuum cleaned in position and fit quite well with the new colour scheme. In the foyer, the ceiling pictures were cleaned and old wallpaper removed to expose the original white marble of the walls and staircase. Pale blue wallpaper was used in the panels which had originally been covered in pale blue silk.

Matcham was no purist where architectural style was concerned and juxtaposed classical and art noveau forms with enormous confidence and panache. All the stained glass panels and windows were restored and their combination with classical forms can be seen in the upper circle and dress bar. Although in a somewhat sorry state, the original 'Mackintosh' - like sofas in the upper circle saloon have been retained.

Acoustic measurements taken in October 1977 indicated a powerful direct sound with a very good distribution throughout the house. For such a small intimate compact auditorium, the reverberation time of 1.1 seconds is quite high. The restoration of the auditorium attempted to keep this to a maximum by limiting the carpet to the aisles and using a weave with an absorbency coefficient of only 0.2. The big challenge was to produce a pit which would provide a natural balance between the stage and the pit sound and, at the same time, provide a comfortable acoustic for the orchestra, especially those under the stage. As yet, no measurements have been taken but conductor, orchestral players, singers and audience seem impressed with the acoustic performance of the house. In wandering around the Opera House during the second performance of Lucia the sound was powerful, even and clear, but perhaps the violins could have done with a little more shine.

Fig. 1-The opera house restored

Fig. 2-The auditorium restored



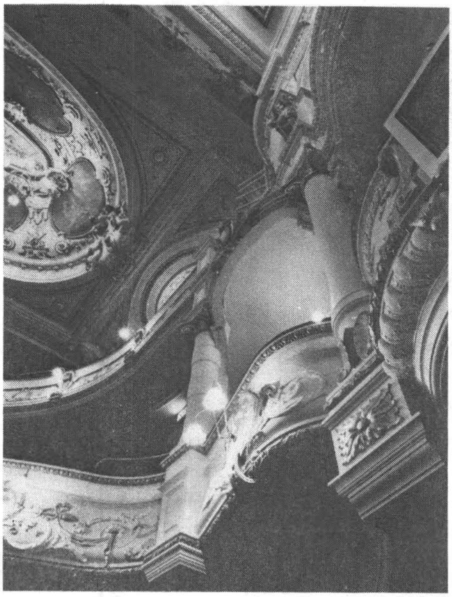
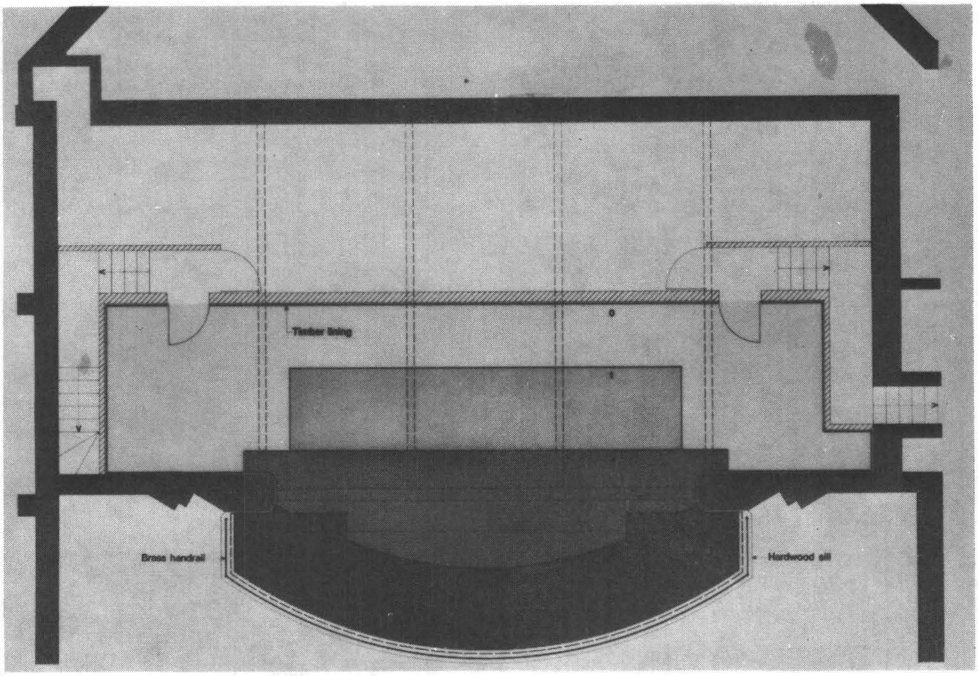
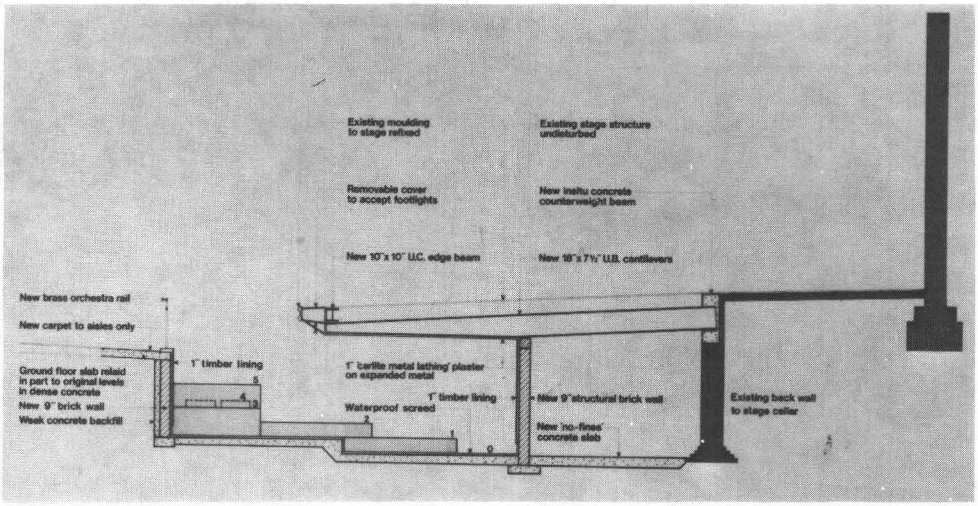


Fig. 3-The boxes restored - 'Edwardian Baroque'



4 b OPERA HOUSE–BUXTON. PLAN OF NEW ORCHESTRA PIT



5 b OPERA HOUSE–BUXTON. SECTION THROUGH NEW ORCHESTRA PIT

YORK MINSTER

York Minster is one of the largest mediaeval buildings in Northern Europe. Although part of it dates from the 11th century, the building in the form that it exists today was completed in 1472. Its most noticeable features are the central tower 200 ft. high, weighing 18,000 tons and the two western towers of similar height each weighing 10,000 tons. The combined length of the nave and choir is 524 ft. and its height is over 100 ft. Figures 1 and 2 show the plan and elevation of the Minster with the various parts of the Minster referred to in this paper.

In 1966 an inspection by the Minster's newly appointed 'Surveyor of the Fabric', Bernard Feilden revealed cracking and severe distortion of the masonry around thè central tower. Further investigations and excavations revealed poor quality masonry, badly distorted and cracked as a result of large differential settlements.

The east wall was found to be over 2 ft. out of plumb and cracks in the 19th century repairs indicated that outward movement was continuing.

Structural Investigation

At this stage Ove Arup & Partners were appointed to make further investigations and these were carried out on three fronts:

- The glass tell-tales which had been repeatedly broken were replaced by small stainless steel discs so that relative movements either side of the crack could be determined by measuring the distance between the conical holes in the disc using a 'Demec' mechanical strain gauge.

- A detailed survey of the Minster to establish precisely the differential settlements. The results shown in Figure 2 indicate that the piers of the central tower had settled up to 9 in. and the western towers up to 3 in. with respect to the nave.

- A detailed site investigation to evaluate the strata on which the Minster was founded. Eleven boreholes showed that there was 12 to 15 ft. of highly variable fill, the product of centuries of habitation and development on the site. Below this was 11 ft. of clay, very sandy at the base, overlaying 37 ft. of stiff boulder clay and below this, about 60 ft. below ground level, dense fine sand representing the weathered surface of underlying sandstone bedrock. Two bench marks, founded in the sandstone, were installed to provide a stable datum for subsequent levelling measurements.

The advice of historians and archaeologists was also sought. The site was covered by part of the headquarters building of the Roman Legion stationed in York (Figure 1). In 1080 ancient records describe the building of a Norman Church built to replace a timber one destroyed by fire in 1069. Another fire in 1137 led to the rebuilding with longer transepts (Figure 1). During the 13th to 15th centuries the Minster was gradually transformed into its present form. About 1400, attempts to restyle the four main piers carrying the central tower in Perpendicular style led to its collapse. Rebuilding was completed in 1470.

Analysis and Design

A comprehensive description of all the structural investigations analyses and designs are included in a paper (No. 74155) given to the Institution of Civil Engineers by David Dowrick and Poul Beckmann of Ove Arup & Partners in December 1971 and a further paper written by Dr. Lord of Ove Arup & Partners for the 'Military Engineer' No. 466. Nov/Dec 1976.

To summarise these very briefly:

– An attempt was made to reconstruct the sequence of settlements. By making an assessment of the loads and imposed soil pressures for the different building phases, and by using consolidation data from laboratory tests on soil samples, estimates were made of the settlement of various parts of the structure since 1080 (Figure 3). The differential settlements predicted in this way correspond remarkably well with those observed and provided further evidence of the overstressing and inadequacy of the foundations.

– To determine the cause of cracking in the lantern at the top of the tower two analyatical techniques were employed; graphical thrust line analysis and a mathematical model in which the tower was represented by a rigid frame of thin members enclosing shear panels where appropriate to simulate the effects of masonry panels. The two methods were found to complement each other. Attempts to predict deformation due to gravity loading were unsuccessful. However, if the observed differential settlements of the north-western and south-western piers relative to the two eastern piers were applied to the three-dimensional framework, the zones of high tension corresponded exactly with the position of major cracks.

The Remedial Work

The Foundations to the Central Tower

The object of the design was to reduce the stress imposed on the underlying clay. Underpinning schemes relying on point bearing piles were considered but rejected because of the dangers of creating a 'hard spot' and further differential settlements, apart from the problems of constructing the piles beneath the piers. The chosen method (Figures 4 and 5) was to encase the old Norman footings in concrete 7 ft. thick and to drill horizontal holes through the resulting composite footing into which prestressing bars could be inserted to stress the whole together. To mobilise the shear strength of the soil beneath the foundations which would normally only occur as a result of settlement a compression pad 2 ft. thick was cast beneath the new foundations. Hydraulic flat jacks were inserted in the gap between the new raft and compression pad. After stressing the main foundation the flat jacks were inflated to transfer part of the pier load to the new foundation by precompressing the underlying clay and the gap between the compression pad and raft was grouted up. The prestressing rods in four layers, with two layers in each orthogonal direction were of stainless steel 1¼ inches in diameter, and each was stressed to 35 tons. The maximum length of stainless steel rod available was 18 ft. and the rods were joined by specially designed stainless steel couplers. The ends were anchored with a nut and anchorage plate.

The Lantern Girdle

Before the strengthening of the foundations to the central tower, a girdle of horizontal tensile reinforcement was installed below the Lantern windows of the central tower. The purpose of this reinforcement was to avoid any further deterioration of the vertical cracks in the Lantern due to unavoidable differential settlement during the foundation work. The bars used were identical to the stainless steel rods used in the central tower foundations except that in the Lantern girdle they were threaded along their entire length to increase their bond strength when grouted. At that time the best available precipitation hardened steel was manufactured by Firth-Vickers and their designation FV520B was used which was over-aged in a temperature 550°C for two hours. A guaranteed minimum 0.1% proof stress of 800 MN/m^2 was accepted for the 32mm (1¼ in.) diameter bars used.

The Lantern Roof Rung Beam and Structure

In addition to the Lantern girdle, a simple reinforced concrete ring beam was provided at the top of the Lantern. Placing the 90 cubic yards of concrete for this was achieved by pumping it to a height of 190 ft. in a single stage. The original oak beams dating from 1472 were 3 ft. deep and 18 in. wide spanning 42 ft. They were found on inspection to be infested with death watch beetle and were cut out and totally removed. They were replaced by simply supported N trusses in structural steel (Figure 6). Because of the craneage limitations these trusses were lifted 'piece - small' by a hoist and assembled in position using bolted construction. The old lead was salvaged, melted down and re-rolled and used in the construction of the new lead roof.

The East Wall

The southern buttress of the east wall had been found to be over 2 ft. out of plumb in a height of 80 ft. The condition of the east wall was aggravated by the fragility of the great east window. This window, constructed in 1405-1408, is one of the biggest and most beautiful expanses of stained glass in the world measuring 75 ft. by 31 ft. wide. In addition to being out of plumb it bowed outwards 5 inches in plan at mid-height. To secure this great window, 1 in. diameter stainless steel wire cables were stressed across the window and fixed to the major mullions of the tracery at gallery level and three positions above (Figures 7 and 8). A small exploratory excavation adjacent to the main buttress had shown that the buttress had been added after the construction of the wall and that there was no bonding below ground level. Neither wall nor buttress broadened out below ground level to any form of footing. A graphical analysis indicated a line of thrust dangerously close to the outer face of the wall. To prevent failure of the east wall it was necessary to provide a substantial toe to the existing footings. Before underpinning temporary shores of structural steel (Figures 9 and 10) founded on simple spread footings were erected to prevent any outward movement. These structural steel shores incorporated at their base a pair of 'Freyssi' flat jacks connected to a constant pressure cell so that temperature movements as well as any induced vertical settlements could be accommodated without overloading. The underpinning was the traditional one of driving 4 ft. wall headings to replace the existing foundations with new ones of twice the size. The new footing width of 18 ft. gave a new average bearing pressure of 2.5 tons per square foot. The centre of thrust from the superstructure was arranged to be well inside the inner half of the footing so that the tendency of the wall to rotate outwards was reversed.

Most of the remedial work is out of sight or below the ground level. To the visitor the most striking aspect of the restoration is the cleaning of the stonework and the redecoration. Something of the engineers work however can be seen. The excavations beneath the central tower for the underpinning works presented the opportunity to create a permanent new crypt or undercroft museum in which can be seen remnants of the Roman Legion Headquarters and the walls of the original Norman Church. The space has also been used to display some of the Minster's treasures and to provide a permanent exhibition of its history and the story of its restoration.

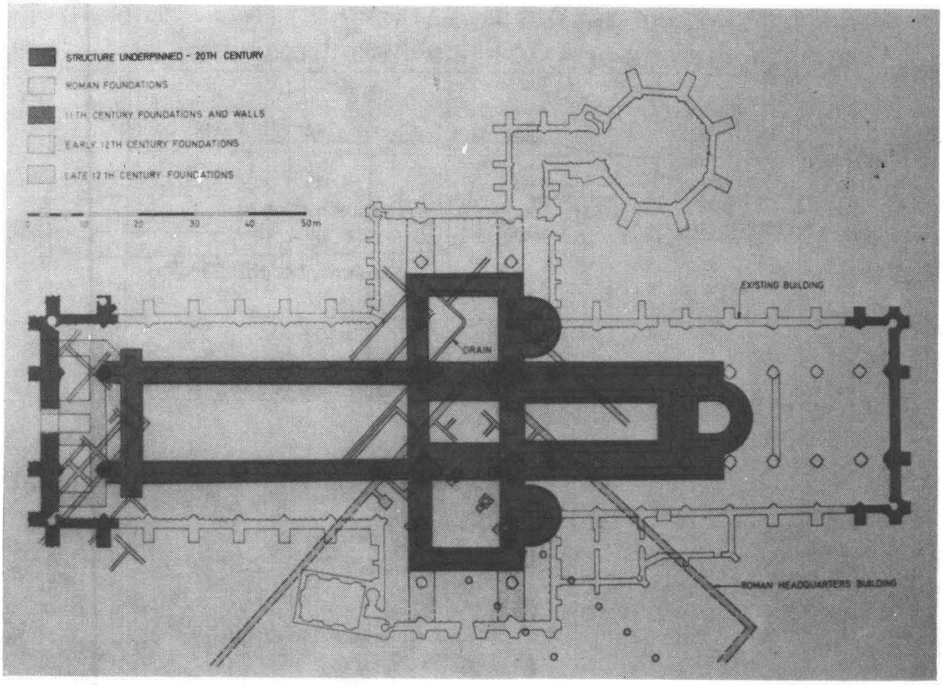


Fig. 1 Plan showing dates of various foundations

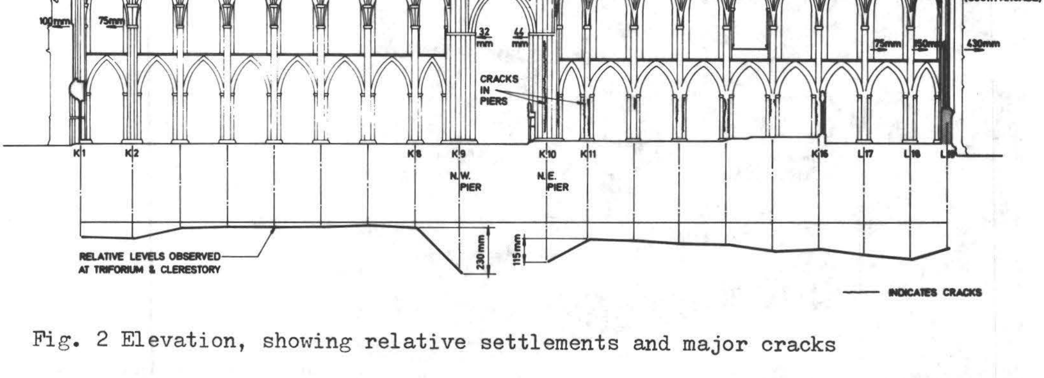


Fig. 2 Elevation, showing relative settlements and major cracks

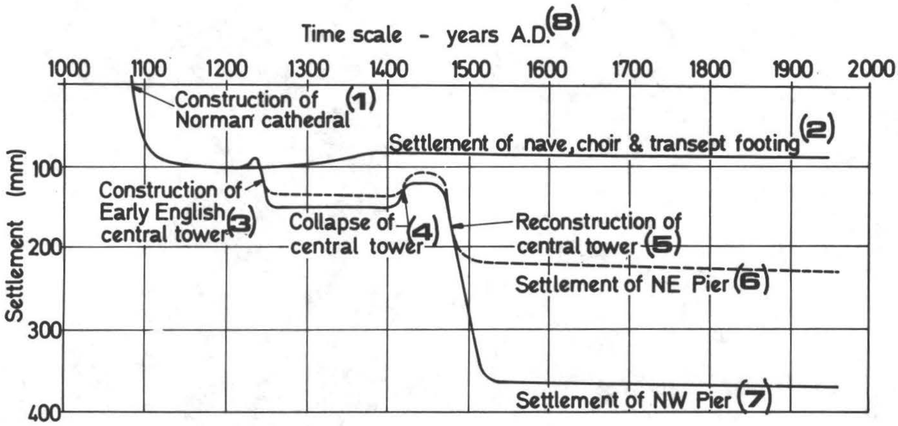


Fig. 3 Settlement estimates

Fig. 4 Temporary structural steelwork supports above the prestressing to the old Norman footings

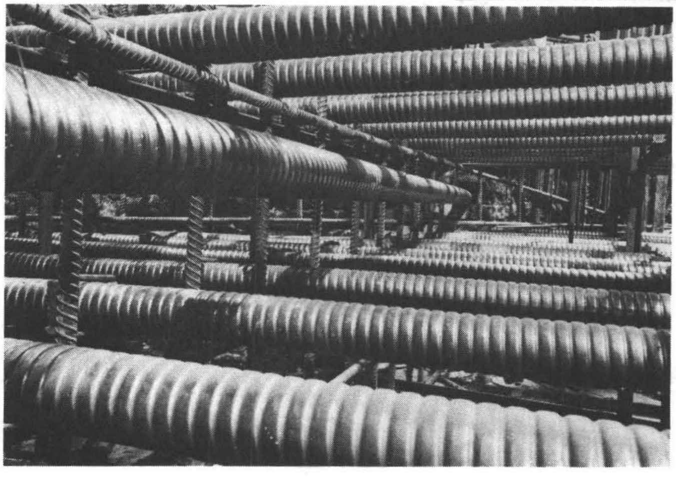


Fig. 5 The layers of $1\frac{1}{4}$ in. prestressing bars

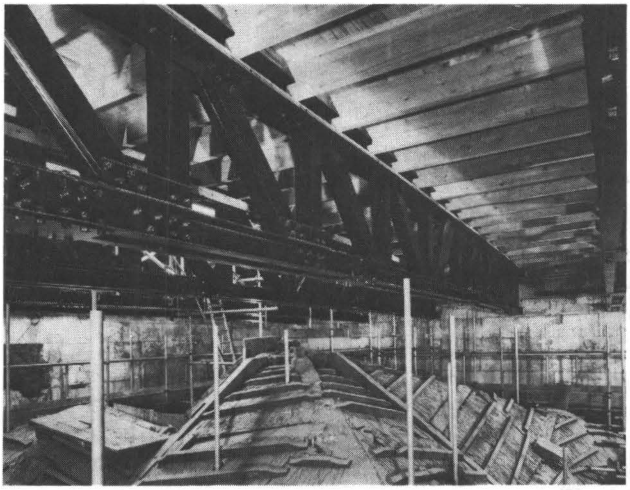


Fig. 6 The structural steel trusses which support the new Lantern roof

Fig. 7 The stainless steel cables securing the Great East Window

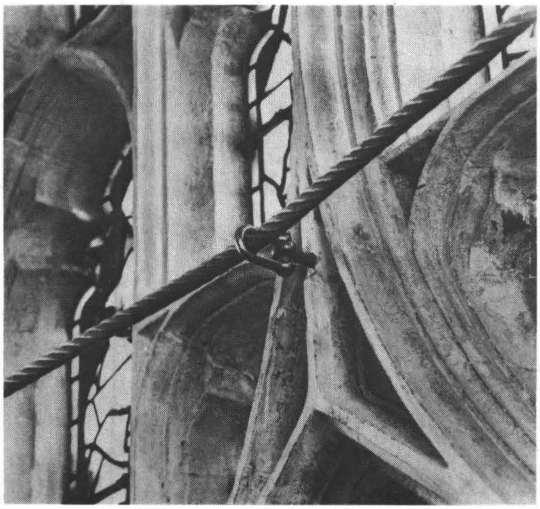


Fig. 8 The stainless steel cables securing the Great East Window

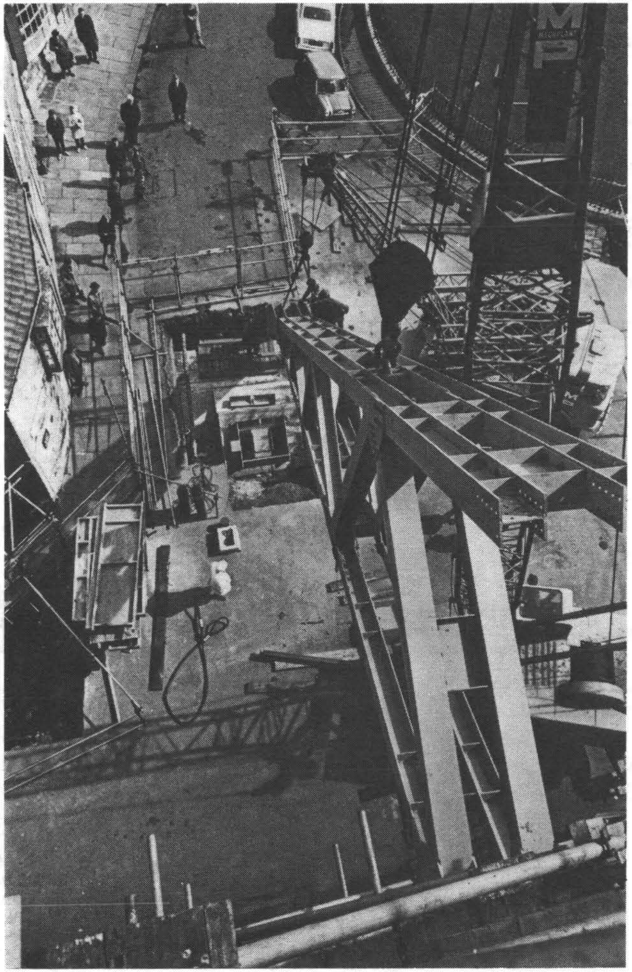


Fig. 9 Erecting the east wall temporary shores

Fig.10 The east wall temporary shores in position

STEEL: A BONUS IN THE RESTORATION, CONVERSION, AND ADAPTATION OF REAL-ESTATE HERITAGE

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ummary

or several years now, our urban habitat has been undergoing a change; an ttempt is being made to give it a human face. Man has embarked upon the econquest of the heart of his towns. To rediscover the old communities s a serious and delicate task.

For a long time, it was sufficient to restore historical monuments, or o find new uses for them.

This work, often of a prestige nature, is still very much a reality. ver the last few years, however, the restoration and modernisation of old wellings and large stores has assumed a measure of importance.

A third element has entered into the effort to maintain our real-estate eritage: the conversion of old industrial buildings.

The present paper is concerned with examples of all three kinds of ctivity:

- restoration of historical monuments:
  - Rouen cathedral spire
  - Comtesse block in Lille
- warehouse conversion
  - Laîne warehouse, Bordeaux, as a leisure centre
  - rue de l'Ourcq warehouse, Paris, as dwellings
- modernisation of stores
  - rooflights above the magasin du Louvre, Paris

The role of steel in all these operations is large; it could even be said that without it, the work would have been scarcely possible.

1. FIRST EXAMPLE

Conversion of building, rue de l'Ourcq, Paris 19e.

Contractor: Habitat Social Français
Architects: J. Levy DPLG and C. Maisonhaute
Surveyors: ARUP France Entreprise Générale; SAE Heulin
Steel erection: A. Laubeuf

The building, situated at 134-145 rue de l'Ourcq and 24-36 rue Labois-Rouillon, was an industrial building originally intended as a depository and as a place for baling paper and rags; later it became a furniture warehouse.

The two-storey section was built about 1894 and the single-storey part running along 135-137 rue de l'Ourcq was added ten years later towards 1904.

The project involved adapting the structure to its new use as dwellings while retaining the character of the industrial architecture of the end of the 19th century.

The arrangement chosen

The height of the building did not lend itself to integral use of the floor for division into dwellings. It was therefore decided to arrange the floors around a central 'hole'. The architects exploited this constraint by creating an original interior space, quite assertive but also varied, which formed a kind of central column giving on to all the dwellings, adding light and opening them onto a peaceful, planted space sheltered from the traffic noise. The arrangement gives each flat an individual character and the feeling of an interior private street.

Small shops and studios were placed on the ground floor along the rue de l'Ourcq and in the courtyard. The scheme was chosen because of the access thus provided and in order to enliven the street.

The interior assemblage of floors, beams and columns was quite acceptable. No serious deterioration was found and the internal parts had not suffered abnormal or otherwise unnacceptable corrosion attack.

Despite its heterogeneous origin, the metal framework lent itself very simply to the transformation, especially since the various elements had been designed for industrial loads.

The foundations

The building was constructed on superficial foundations. The nature of the site:

- filling (3.70 m)
- sandy rubble (3.70 m to 5.0 m), marl (5.0 m to 15.5 m)
- greensand
- marlaceous limestone of Saint-Ouen
- Beauchamp sands

Predicted loadings:

The buildings being intended as dwellings, the new general loadings were those of the old standard NF P 06-001 (June 1950), i.e.:

- 175 daN/m^2	living areas, floor, mezzanine, terraces with private access
- 250 daN/m^2	stairs, corridors and gangways, covered or not
- 75 daN/m^2	interior partitioning

The structure

General

The facades of the building run for about 78 m on the rue de l'Ourcq side and 70 m along the rue Labois-Rouillon.

The distance between the party walls furthest spaced is about 95 m. The general grid is 4 m in two perpendicular directions.

At its largest part, the width of the building varies from 35.7 to 38.2 m.

Columns

The interior columns supporting the floors are cast iron.

- at first-floor level, their diameter is 150 mm and their effective height 3.20 m
- at ground level in the two-storey section, the majority of the columns are 160 mm diameter; some of them are hollow, especially those which run around the courtyard; in the more recent single-storey section of the building, the columns are 150 mm diameter and about 4.2 m high.

The variation in the capitals matches that of the diameters. The capitals without all the flanges miss the thrust surface of the beams. The object of the flanges was to centre the beams resting on the columns and hold them laterally in place.

According to whether or not the columns were capable of supporting the new loads, the following measures were taken:

- light loads: columns left free
- heavy loads: the columns were sunk into a square of reinforced concrete; retained at mid height by the mezzanine beams or by the facade sections

Beams

The beams, too narrow, were sometimes off-centre. In the majority of cases they were twinned and separated from each other by the distance of a flange. In some cases, a main beam consisted of two separate beams of different heights. Sometimes they were together, sometimes separate. The modes of assembly were equally diverse.

All the arrangements were checked and rectified and reseated on the columns.

Floors

The original floors were joists with brick and clinker doming and a coating of reinforced cement and mortar.

In certain areas, the floors had been subsequently concreted over the whole height of the joists.

In the conversion project, some floors were demolished and others were brought up to standard.

Roof

The roof consists of lean-tos arranged parallel to the streets. The glazed flanks face north and the tiled flanks south. The span is twice that of the girder frame of the floor below. The roof columns are in the main sections of IPN type.

The arrangement of little courtyards inside necessitated the removal of some of the lean-tos.

General

The interior and exterior facade walls, whether or not they gave onto the open sides, were strengthened: Vaugirard brick (22 cm thick) or 20 cm external bonding (400 kg/m^2 of surface).

The mezzanines were of wood and metal. The deadweight was very much reduced: about 50 daN/m^2. The weight of these intermediate floors is carried by stanchions mounted on the cast iron columns of the first or ground floors.

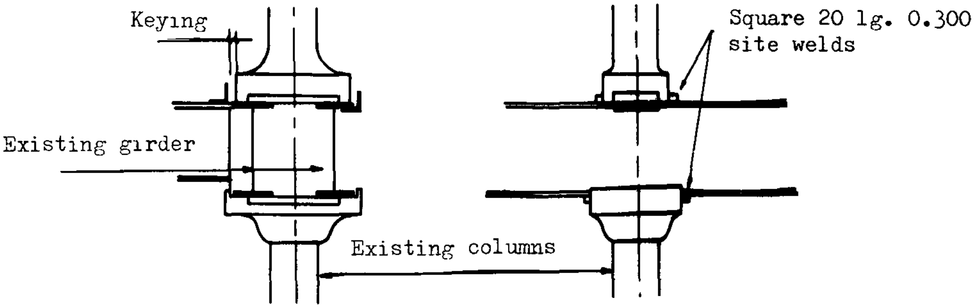
The general orientation of the building and especially of the roofing lent itself to the installation of solar panels for the hot water system.

Fire protection

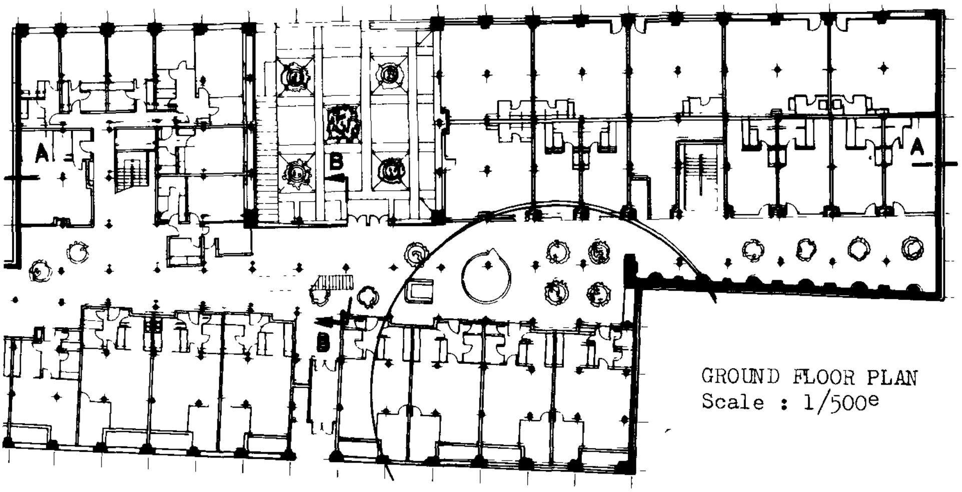
The required fire resistance time for load-bearing components and floors was ½ h.

The column stability was provided:

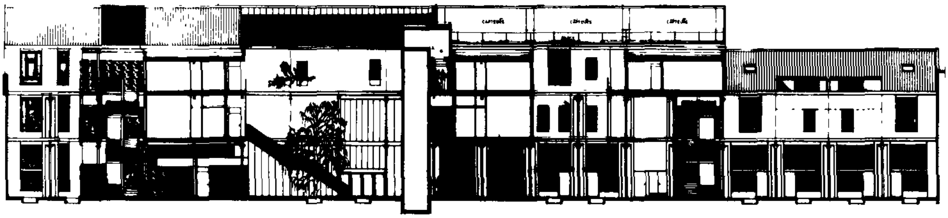
- **for the appartments: by a 7 cm thick reinforced concrete jacket where they were sunk into the party wall; or by means of an intumescent paint coating**
- **for the shops and studios: a layer of rockwool (shell or cushion) with a plaster skin.**



Method of clamping free columns
scale : 1/20^{e}/ = 0,05 m/pm.



GROUND FLOOR PLAN
Scale : 1/500^{e}



SECTION A-A scale: 1/500^{e} = 0,002 m/pm.

2. SECOND EXAMPLE

Annex for municipal library, Comtesse block, Lille (nord)

Principal: City of Lille

Contractor: G. Jourdain, architect DPLG

Surveyor: BET Razemon

Steel erector: Baudon-Ronchin

Within the framework of the plan for the renovation of the Comtesse block, the municipality of Lille decided to include an annex for the municipal library in two buildings situated at 25 and 27, place Louise de Bettignies, right in the middle of the historic quarter of the city. In order to carry out the project, a framework in reinforced concrete, oddly topped by a metal former, accommodates a Flemish facade which first saw the light of day in the 18th century on the rue de Paris side.

In the neighbouring building, which also has a scheduled facade, a metal gantry has replaced the retaining wall.

Roof over no. 25 place Louise de Bettignies

Structure

The entire structure is in hot rolled sections:

. main rafter	IPE 200
. hip rafters	IPE 200
. trimmers	IPE 200
. purlins	IPE 200

Erection

The frame was factory prefabricated, delivered to the site, assembled on the ground and mounted by crane on reinforced concrete blocks. It is considered to be base-articulated.

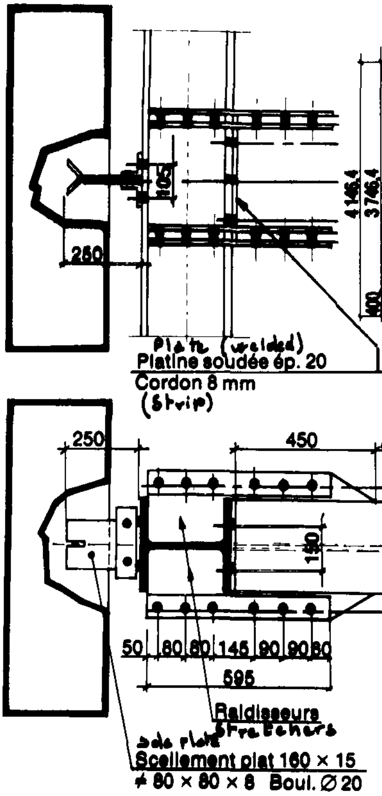
Gantries inside no. 27 place de Louise de Bettignies

Structure

Multiple gantries over two floors using hot rolled HEB sections

Stability

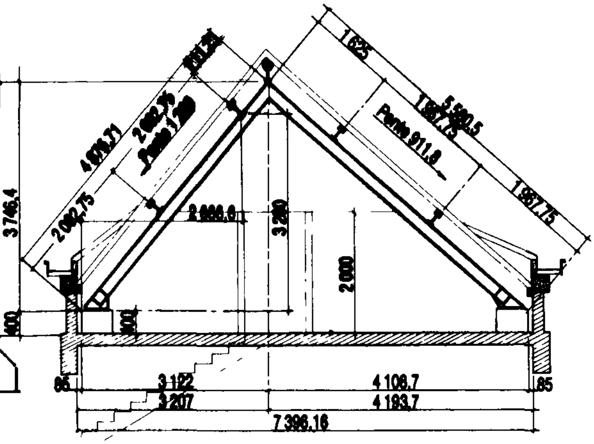
- partly by lateral anchorage on the facade walls
- gantries articulated at the base.



DÉTAIL

scale : 1/20e

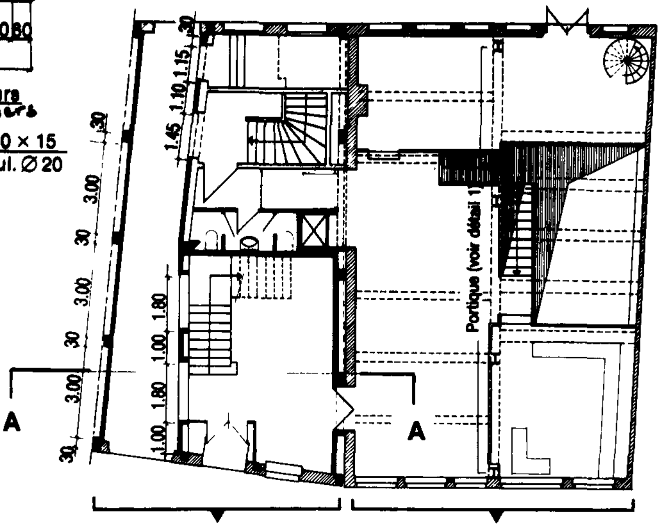
Building at no. 27



SECTION A-A

Éch. : 1/100e

building no. 25



PLAN Éch. : 1/200e = 0,005 m/p.m.

N° 25

Place Louise de Bettignies

N° 27

3. THIRD EXAMPLE

Renovation of the spire of Rouen cathedral (Seine-Maritime)

Principal: Ministry of Culture
Architects: M. Froidevaux, Inspector General of Historical Monuments
Consultant Engineer: L. K. Wilenko
Steel erector: CFEM

On 15 September 1822, the 'City of a hundred spires' was disturbed from its sleep at 5 a.m. by the discovery that the spire of the cathedral was on fire. It was not the first time. From the 12th to the 19th century, fire followed fire. Restoration work was carried out after each disaster. The last fire took the situation back to 1514 when R. Becquet had rebuilt the spire in wood.

In 1822, the fire, by the time it had been brought under control towards evening, had ravaged the roofs of the choir and transept as well as the spire. The architect Alavoine attempted to restore to the cathedral its dominant character, that of the 13th century, by reconstructing a perforated spire in the Gothic spirit but using cast iron (height 75 m, total weight 950 t).

One hundred and fifty years later, in 1974, the first cast iron components were showing signs of age. Restoration work began to be planned.

The first step was completed by 1976 when the cast iron tabouret was rebuilt in patinating steel.

Then a part of the spire was reinforced in steel. Already, 250 t steel have been used in the first phase of the work and it is expected that a further similar quantity will be reuired for the rest of the spire, the bell tower, and the rebuilding of the interior staircase.

The working plan which is now being executed makes doubling-up on the original elements impossible. The decision was, therefore, taken to eliminate the cast iron spire supports and replace them using self- patinating steel.

Structure

Gantries

Eight groups of gantries at three levels. Each group consists of two gantries placed on either side of the radiating cast iron elements destined for removal.

The complex of gantries rests on 03 (existing first level) on a platform frame composed of beams crossing at the centre.

The piers are tubes built up as rectangular sections of 150 x 300 x 15.

Beams

Like the gantries, the beams are arranged in pairs on either side of the inclined cast iron columns destined for removal.

. level 03 (lower level of tabouret)

The beams rest on a peripheral beam of reinforced concrete which is , in turn, on the masonry of the tower. Those beams are welded up in ‖ section and have great intertia.

- height 1500 mm
- width 500 mm
- treads 40 mm thickness
- web plates 15 mm thickness

The various groups of smaller girders are linked by secondary beams (trimmers) which form a secondary framework to carry the 30 cm of reinforced concrete floor.

. levels 01 and 02 (intermediate level of tabouret)

Cross members in HEB or PRS 300

. level 00 (level at which spire and tabouret join)

Cross members in HEB or PRS 500.

The interior piers of the gantries are linked by a system of beams crossed at the centre. This complex serves to seat the new spire staircase newel. The oblique and straight hip members of the spire are supported at platform level by the cross members. They are seated on welded up sections. Beneath each hip they are housed in the gantry cross members thus transferring the vertical and horizontal forces onto the tabouret.

Floors

These are 20 cm thick reinforced concrete joined to the new steel structure by pins welded onto the beams.

Fabrication

All the framework of the tabouret was welded

Assembly

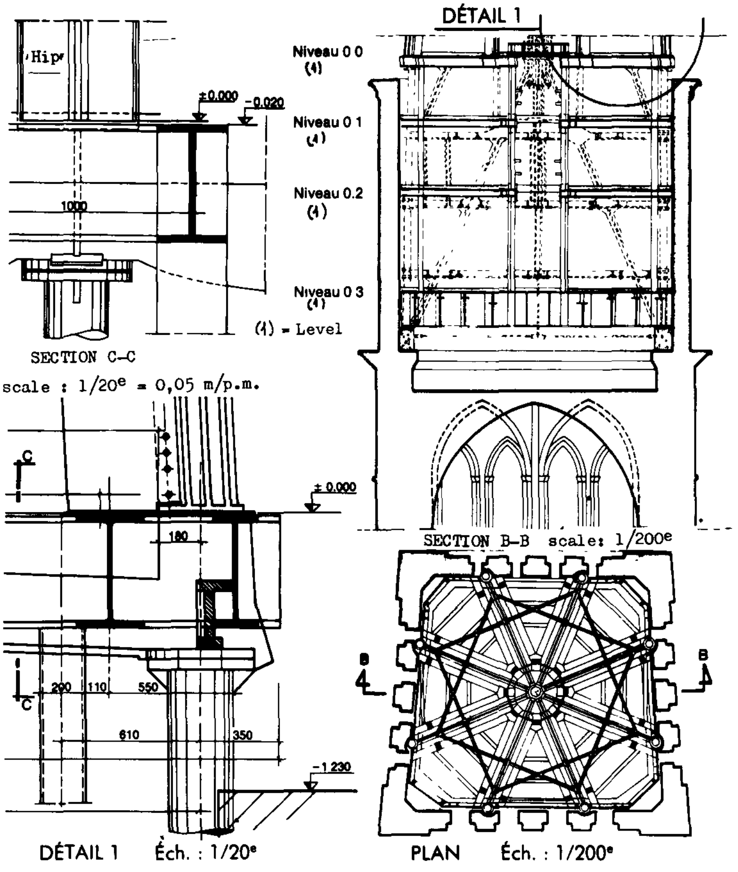
The tabouret

. level 03

- installation, after complete setting of the concrete, of the 25 mm steel plate ring, covering the peripheral cage in reinforced concrete.
- positioning and assembly of the large welded-section beams.
- mounting of secondary beams and trimmers.
- welding of steel beams round the ring.

The gantries

- installing gantries (column and beam complex) level by level.
- mounting of secondary beam system (trimmers) on gantry cross-pieces.
- . level 00
- positioning of old roofing and mounting of the central assembly supporting the spire staircase newel.
- positioning of transverse beams on which the new staircase columns rest
- installation of transversely radiating members on each side of the existing cast iron beams
- installation and assembly on the cross members of the beams supporting the new hips; this operation carried out face by face, taking all precautions to prevent sinking of the spire.
- assembly of the new spire structure on the support system
- removal of old cast iron framework.



4. FOURTH EXAMPLE

Conversion of the Laîne warehouse, Bordeaux (Gironde)

Principal: City of Bordeaux (Action Culturelle)

Director of operations: M. Joanne, Architect DPLG, Chief Architect and Director General of technical services to the City of Bordeaux

Direction of works: MM. P. Mazery, D. Valode, J. Pistre, Architects DPLG

Scenic engineering: B. Guillemot

Site direction: SATORG, Bordeaux

Scenic detail: Ets Fechoz

The transformation of the Laîne warehouse in Bordeaux into a leisure centre is a good example of a new use for an old building. At a period when the demolition of the structure was being contemplated, the City of Bordeaux was also carrying out a study for a large-scale provision of leisure facilities. It was, therefore, decided to convert the building into a meeting place.

The Ministry for Cultural Affairs entrusted the study to a team of architects compsed of Mazery and Valode. Their 'ideas project' was accepted by the city.

The first phase of the work, which is just completed, comprises the following facilities:

1. a central multi-purpose area intended for musical and theatrical performances.
2. An exhibition area situated on the west side along the rue Foy, of which one part, on two levels, is mainly reserved for children's art.
3. A space on the south side, along the rue Farrère, for a small permanent theatre. Two small auditoria are planned.

The second phase of the work will probably be subdivided into two parts:

- setting up of artists' workshops (2nd floor, rue Foy side)
- facilities for the National audiovisual institute (1st floor), cafeteria, reception areas and general administration, creche, etc...

The interior fixtures and fittings in steel adapt themselves well to all the new functional needs, while at the same time blending in with the size and style of the existing stone and wood.

General dimensions

A trapezoidal shape bounded by: Xavier Arnazon to the north (the former 'pavé des Chartrons'), rue Foy to the west, rue Farrère to the south and Place Lainé to the east.

Two facades 100 m, one of 92 m, and one of 47 m on the entrance side. The building covers an area of 6760 m^2.

Internal layout

In a square grid of 6.5 m, three principle parts can be distinguished:

- a main entrance hall 350 m^2 and 9 m high;
- a central part consisting of two large parallel 'naves' separated by a line of pillars up the centre; each nave is 13 m wide (two grid units), 45.5 m long and about 12.5 m high;
- a peripheral ground floor plus two upper floors around the central naves.

A two-level gallery separates the two zones, completely surrounding the central part.

Structure

Dressed stone for the column and wall foundations, hewn rubble, brick arches.

Floors

Apart from the vaulted areas (hall, intermediate first floor gallery and stairs, all the floors are wooden and consist of boards on wooden joists supported on metal joists 2 m apart.

New interior arrangement

Considering the original structure as fixed, and with the aim of making the whole both flexible and capable of development, the following internal fittings were selected:

- partitions: dismountable and interchangeable panels
- lighting frames on a modular grid of 6.5 x 6.5 m
- frames for other equipment also on a modular basis

Ceiling equipment

In each nave, the following metallic items are installed:

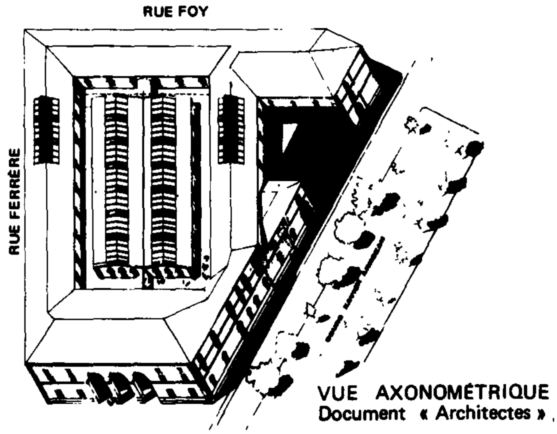
- a fixed longitudinal catwalk, about 1.7 m wide, suspended from the arches
- the catwalks of the two naves are connected by little bridges 1.3 m wide
- at the extremity of each nave, there is a transverse fixed catwalk at a level of about 2.5 m lower than the longitudinal ones
- four transverse mobile catwalks, about 1.6 m wide, making a travelling deck system, at the same level as the other transverse catwalks.

Steps/tiered floors

Mobile landings mounted on rollers. Each landing is a drawer forming a metal box in which the seats are folded.

Modular stages

Modular elements either squares or equilateral triangles with sides 1 m. Metal trusses mounted on screw levellers; wooden flooring.



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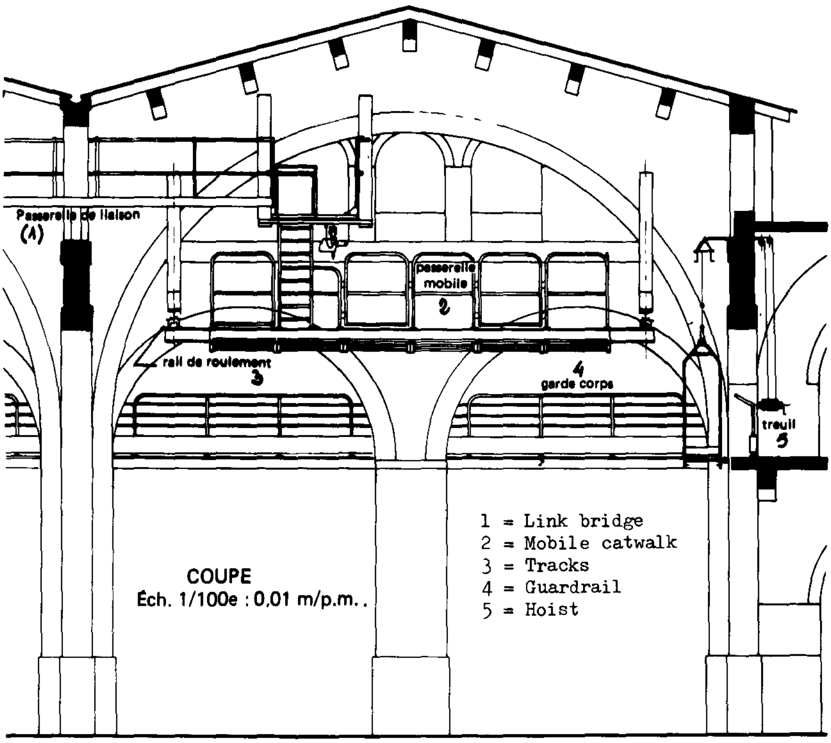


COUPE
Éch. 1/100e : 0,01 m/p.m..

1 = Link bridge
2 = Mobile catwalk
3 = Tracks
4 = Guardrail
5 = Hoist

5. FIFTH EXAMPLE

Glass roof over the magazins du Louvre, Paris 1er
Principal: FIPARIM et UFFI
Architects: W. Lentzy DPLG - Inspection office: SOCOTEC
General contractor: Bouygues

Within the general scheme of renovation of the grands magazins du Louvre building, situated in the heart of Paris and scheduled as a historic monument, an arrangement of four glazed canopies in 'diamond point' was set up to cover the four courtyards.

Three of the glass roofs are identical and are on a square base of 8 m sides; the fourth is larger, with 11.72 m sides, and this is the one referred to here.

The large glass roof is made up of three distinct parts:

- a primary external structure
- a subsidiary framework suspended from the first and which carries the glass roof
- the glazed structure itself, fashioned using the ILFER putty-less glazing system

Framework

Main, exterior

Hollow stainless steel sections 18 x 8 (18% Cr, 8% Ni).

Subsidiary

Steel tubes fastened to the joints of the primary frame.

Glazing supports

ILFER sections bolted onto the subsidiary frame.

Stability

The exterior framework was designed on a triangulation system in which the loads are applied at the joints in order to make the members work in compression and thus better to exploit the characteristics of the metal. The system being hyperstatic, the calculations were carried out by computer.

The stainless steel hollow sections were thus provided with optimum dimensions.

The ILFER process

The ILFER process is a glazing technique for facade roofs which can be classified as a putty-less technique. It enables complete roofs to be constructed using individual component parts.

Steel frame

The frame consists of cold-drawn steel sections with omega cross-section for supporting the glazing and facilitating drainage of rainwater.

The sections were cut and treated to order then either hot-dip galvanised or plastic-coated to offer a wide range of colours.

Glazing

The process accepts any kind of glazing: reinforced glass, toughened glass, anti-glare, double glazing, laminated glass.

The glazing is held in place by junction plates in prepainted galvanised or stainless steel, or aluminium.

Peripheral joints

Ridge plates and clips for the upper and lower parts. Joining of glazed strips to the roof by galvanised steel or aluminium plates.

Spans

The permitted span for each section depends basically on the angle of inclination of the glazed area. Above 3.5 m between supports, a suitable steel reinforcement is welded to the upright before galvanising. In this way, spans of up to 6 m can be achieved without intermediate support. The ILFER section was shaped before galvanising in those areas where the glazing was mounted overlapping.

Assembly

The main structure was assembled on the ground, braced, then hoisted, taking care to impart one eighth turn so that the bars entered the diagonals of the opening.

The subsidiary frame was then mounted, the feet bolted on and then the ILFER sections bolted onto the feet. After adjustment, the glazing was begun. No welding was necessary on site.

Fire protection

This was necessary due to the openings in the neighbouring buildings.

ILFER sections

- a second junction plate of stainless steel added between the glazing and the first joint; that also in stainless
- tightness was ensured by a double asbestos strip
- the sections were coated with intumescent paint.

Glazing

DRAVEL glass was used due to its fire-resistant properties (class 1½ h on metal chassis). The glass used was of 7 mm nominal thickness, reinforced by 12.5 mm square mesh.

Secondary framework

Coating of intumescent paint.

Automatic exstinguishers

Sprinklers.

Fume outlets

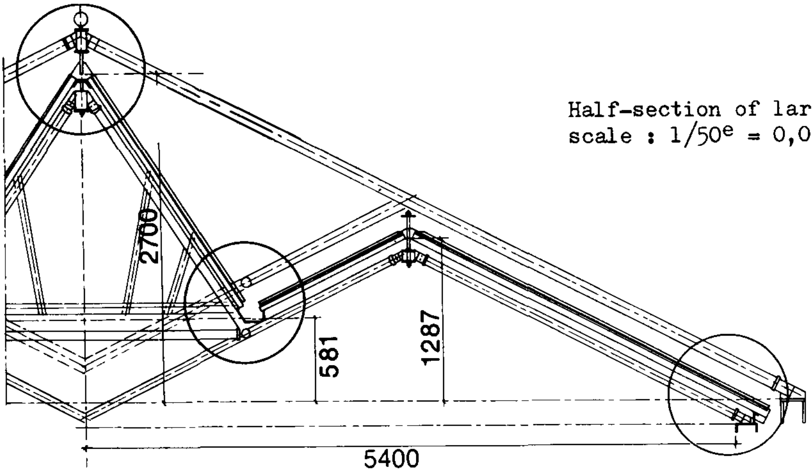
Putty-less glazing, screw operated and operating simultaneously in rose-petal fashion.

This automatic outlet is engaged by fume and gas detectors placed below the roofing.

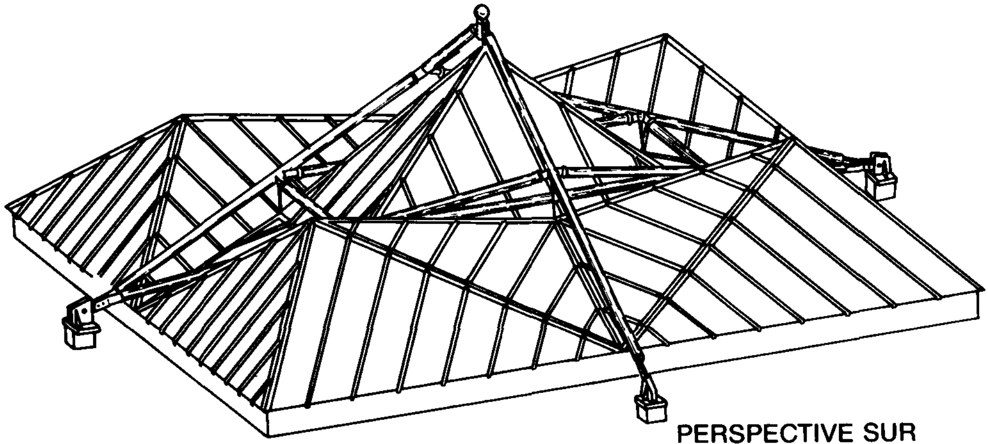
During normal conditions, they can be opened and closed electrically.

General

All parts of the roof are accessible and can be cleaned with ease.



Half-section of large roof
scale : $1/50^{e}$ = 0,02 m/pm.



PERSPECTIVE SUR
LA GRANDE VERRIÈRE

STEEL FOR RESTORATION, REBUILDING AND CONVERSION OF REAL ESTATE

E. GIANGRECO

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Summary

After several statements of a general character on the theme, 5 examples of restoration work are presented: 3 in Italy, 1 in Belgium and 1 in Holland.

The Italian cases deal with:

- the protective metallic structure for the work of consolidating the Leaning Tower of Pisa, which is the object of international discussion,
- the work of reinforcing with steel a large market in Florence, dating from the second half of the last century and constructed in cast-iron,
- the work of restoring a historic building in Modena, intended for various uses.

The Belgian example deals with a patented flooring system for rapid replacement of old joists; and the Dutch example relates to the renovation of the facade of a building used for a variety of purposes, employing new construction techniques.

The term 'structural restoration' lends itself to a variety of interpretations among which are:

- the preservation of a building as a temporary structure pending definitive restoration
- the repair of a damaged building and thus the re-establishement of its static integrity.
- the reinforcement of a building, which could imply also an enhancement of function, as in the case of conversion to fulfil a new purpose (functional reconversion) or to cope with alterations in surrounding conditions (e.g. seismic movement)
- the partial or virtually complete reconstruction of a building demolished for various reasons (irreparable structural degredation, rebuilding inside a preserved facade, etc.)

In all these cases, steel holds a privileged position due to its strength, ductility and suitability for industrialised building: reduced weight of the various structural elements in steel, their lack of encumbrances, speed of installation and functional flexibility give steel a leading role in the most significant and difficult restoration operations.

The examples which we will illustrate refer to three examples in Italy of the use of steel in the preservation of a monument, in the reinforcement of a damaged building and in the rebuilding and functional conversion of a historic edifice; a Belgian example of use of galvanized sheet flooring to renew the internal frame of a building and a Dutch example of steel in the external renovation of old facades in the civic and industrial buildings.

The first example concerns the Tower of Pisa. The Italian Minister of Public Works launched an international competition in 1972 for its reinforcement specifying that the Tower preserve its present aesthetic aspect, that its lean be maintained with maximum diminution of a 60th of a degree, and that the work be without prejudice to the buildings of the Piazza and in particular to the Cathedral.

The solution proposed by the firm Fondedile of Naples using plans by Giangreco, Kerisel, Lizzi and Moranti provided for reinforcement using piling (Fig. 1) and temporary steel work for preservation.

The preservation structure was intended to cope with rotary motion in the 1st stage and rotation due to subsidence in a 2nd stage (Fig. 2).

Referring to the 1st stage, designed to resist unwanted rotation the characteristics were:

- no application of external force
- speed of response and proportional reaction to any disturbance
- application on the walls and ground of modest stress, uniformly distributed
- no sensitivity to temperature variations
- possibility of reaction in all directions
- functional simplicity and reliability
- direct control

All these requirements were satisfied using the concept of a child's walking frame, i.e a reticular bell (Fig. 3), in the form of a conical trunk on a circular plane, made up of 30 robust linked ribs forming a pattern of horizontals and parallels.

Contact with the Tower is secured by grooved butresses supported by adjustable jacks in contact with the brickwork through metal caissons. Support of the bell on the ground is through resilient grooved butresses, on a round reinforced concrete base.

The second example concerns the Central Market of San Lorenzo in Florence which has a cast-iron structure planned in 1869 and finished in 1874 (Fig. 6).

It is significant that such work was placed with a structural steel firm, GUPPY (Naples), rather than with building contractors. Such construction is related to the large covered areas designed for markets such as the Billingsgate Market in London and the Paris Madeleine Market, as well as to the great exhibitions such as that of '89 in Paris: buildings which, as Gedion affirms in his work 'Time, Space and Architecture', "have no debt to the past and provide the solutions to the fundamental problems of architecture of this century".

The San Lorenzo Market covers an area of some 5000m^2 with a central aisle of 30m and 2 side aisles of 24m each (Fig. 7). These were, for the time, of exceptional length, as was the height of 23m of the cast-iron columns placed every 5.90m to support the central part of the roof and which were formed of pillars of varying section, octagonal, circular and square (Fig. 8). The roof was supported by external walls 14.50m high.

The state of degredation which was first dealt with by props and then by the reinforcement initiated in 1975, was manifested in considerable distortion of the principal load-bearing structures. This was countered by the introduction of secondary resisting elements. The lack of longitudinal wind-bracing was compensated by tubes, while transverse stability was assured in part by supporting brackets of cast iron in the roof trusses and in part by the introduction of falsework under the roofing tiles from gable to gable. In addition, some tie-beams were present in the roof cavity, separate from the cast iron shackles with the columns.

To all this is added the great age of the building, lack of maintenance and, consequently, considerable corrosion.

The improvement has been made with due respect to the monumental ambience, external appearance, internal architectural form, and, as far as possible, uninterrupted use of the surrounding area.

The idea followed was to devise a structure which would take over from the old part of the building the tasks which it could no longer fulfil and would at the same time take advantage of the static characteristics which have allowed it to survive for a century.

The new structures are made up of frames of the 'Faltwerke' type (Fig. 10) which cover the central aisle of 30 x 56.5m with a thickness of 360mm, and the two side aisles 24 x 66.5m with a thickness of 230mm; to these are added the old structures (Fig. 11) which are now supported only from span to span. The new structures, which are visible from inside and out, apart from supporting all the external characteristics and those of the old roofing, both stabilize the horizontal action and serve to transfer to the peripheral walls of a fraction of the loads which were first applied to the thin 'columns'; these last, therefore, and work distinctly better without in any way altering the relationships of form.

The work was commissioned by Florence Council and carried out by the contractors Guarducci of Florence, to the architectural plans of Orlandi

Cardini of Florence and structural plans of Romaro of Padua.

The third example concerns a 17th century building in the historical centre of Modena, owned by a bank and intended for use as a branch (Fig. 12). The condition of the brickwork and the wooden horizontals did not absolutely preclude their continued use, provided that rebuilding and conversion to the new functional requirements did not slavishly follow the old. On the other hand, urban restriction and protection of scheduled property did not rule out complete demolition, preserving only the facade and overall volume of the building. This meant substituting all the internal structures with a series of vertical frames of 2 or 3 elements, placed at varying intervals, which constituted the chief load-bearing elements, and providing an effective horizontal windbrace on the facade during the period of rebuilding (Fig. 13).

Consequently, underpinning was begun and with partial demolition the existing plinths were reinforced with steel columns: these were introduced into the building and (Fig. 14) became structural elements.

The columns up to the height of the roof were linked to the main beams so as to complement the load-bearing frames. Subsequently, the structural order was completed with secondary beams and horizontal wind-bracing.

At the same time provision was made for anchoring the existing facade to the skeleton of the new structure as it took shape. The metal structure having been inserted into the old building, the joints were welded and demolition work started, leaving the perimeter facades standing, but anchored to the steel frame (Fig. 15).

The aggregate weight of the steel structure was about 130 tons and that of the mesh about 21 tons. The restoration was planned and directed by Vintani of Milan.

The CBLIA example concerns the application of a patented system called Floorkit (Fig. 16), which lends itself well to the support of old floors, combining the resistance of steel with the rigidity of concrete and with a good fire resistance confirmed by laboratory tests.

The system consists of galvanised sheet allowing rapid installation, freedom from scaffolding, minimal accessories, and ease of handling (Fig. 17).

In the application of this system in two buildings in Brussels (Fig. 18) two phases occurred; the construction of a wall (Fig. 19) necessary for the new functional distribution (the beams of the old floor were considered), and the positioning of electricity supply cables and finishing.

The last example concerns some renovations of old facades of Dutch buildings. The example taken is that of an industrial building intended as a store for naval instruments and machinery.

The old facade consisted of a frame in light steel with glass panels and the renovation work was intended to preserve the existing steel frame, improve insulation and reduce energy costs, while optimizing the working conditions in general.

The new facade (Fig. 21) consists of sandwich panels in steel sheet (Isowand type) with a nucleus of polyeurithane, which meets the conditions of not increasing the total weight with respect to the old facade, of insulation of the building in conformity with the regulations (and thus making use of a government grant) and of assuring long-term conservation of the facade without onerous maintenance. In addition the panels adopted proved adaptable and easily renewable in case of damage.

All the work, which was effected without disturbing the work inside the building, comprised 2000m^2 of frontage raised in 2½ months, in spite of adverse weather conditions, with a total of 800,000 HfL (1976) and an energy saving of 25,000 HfL per year.

Two other interesting examples, also in Holland, of facade renovation, are those of the Interpol building in Roermund and that of some buildings in Amsterdam-Nieuwendam.

The first facades comprised concrete panels faced with marble slabs which are easily removable, with danger to public safety, loss of their protective function and alteration of the aesthetic aspect.

The operation consisted in the replacement of the marble floor tiles with a mesh with plastic covering on which is deposited two U outlines enclosed in the stone of the building and steel panels, fixed to these last, in galvanised sheet iron faced with a skin of PVC (Fig. 22).

In the second case the facades were faced at the time of building with slabs of concrete which had deteriorated in time and no longer guaranteed

thermal insulation or waterproofing.

Renovation took the form of panels of refaced steel sheet of the Skinplate type with insertion on the side exposed to the north of a layer of insulating material between the old concrete and the new facing. The new panels fixed to the old slabs by Ω brackets and coated with thin PVC sheet.

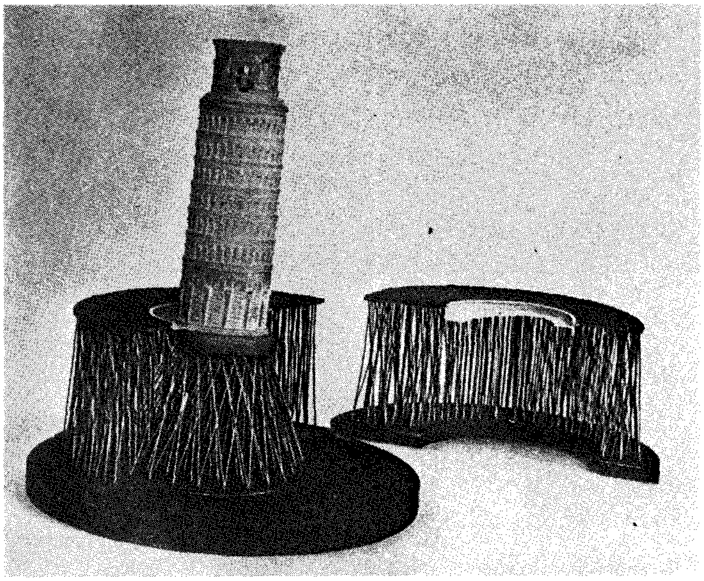
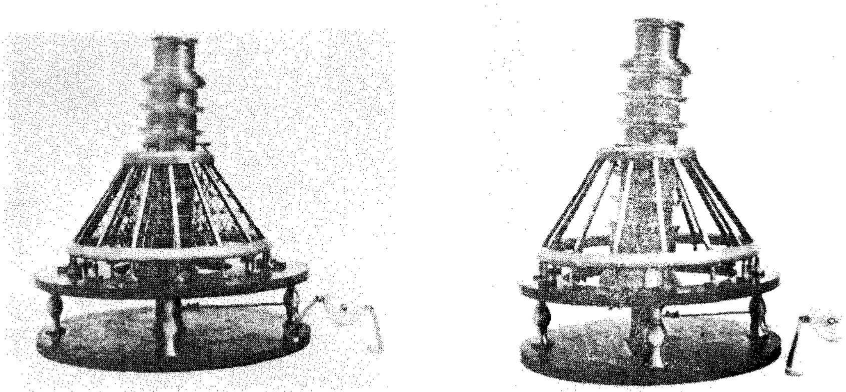


Fig. 1 : Tower of Pisa : reinforcement



a) Primo stadio operativo.
— Struttura [illegible] per contrastare i soli movimenti di rotazione

b) Secondo stadio operativo.
[illegible]

Fig. 2a - 2b : Tower of Pisa: 1st phase and 2nd phase of the preservation work

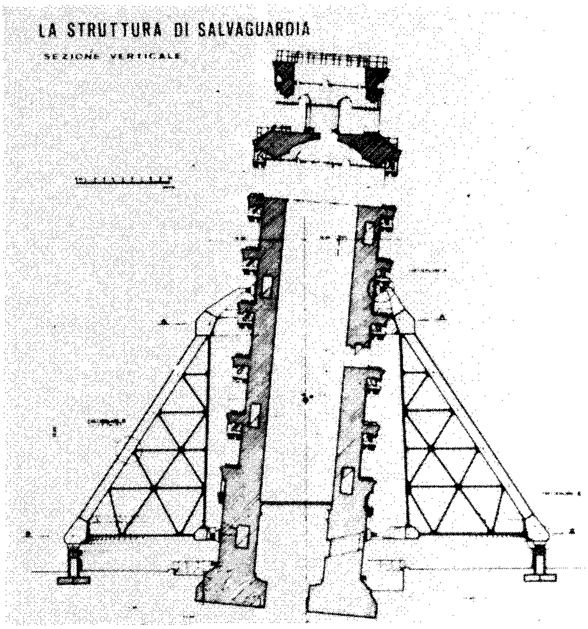


Fig. 3 : Tower of Pisa : bell cage

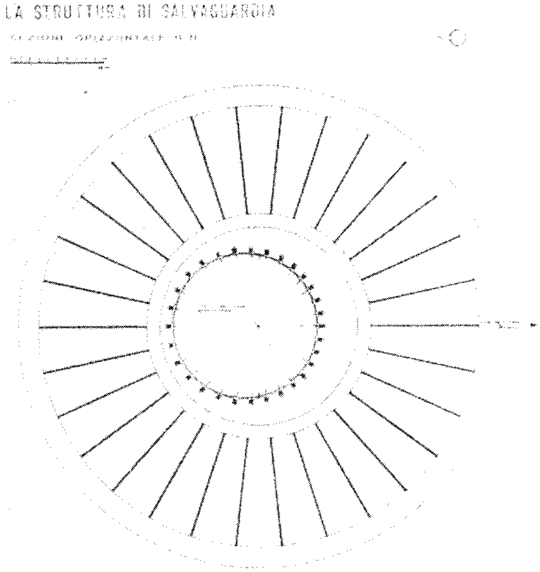


Fig. 4 : Tower of Pisa : circular ground plan

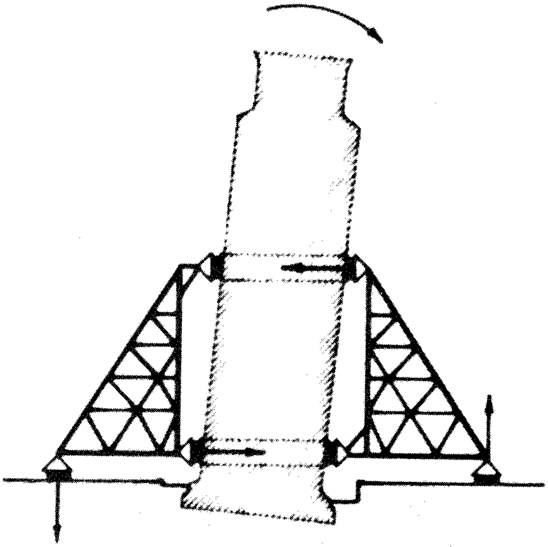


Fig. 5 : Tower of Pisa : mechanism for supporting pressure

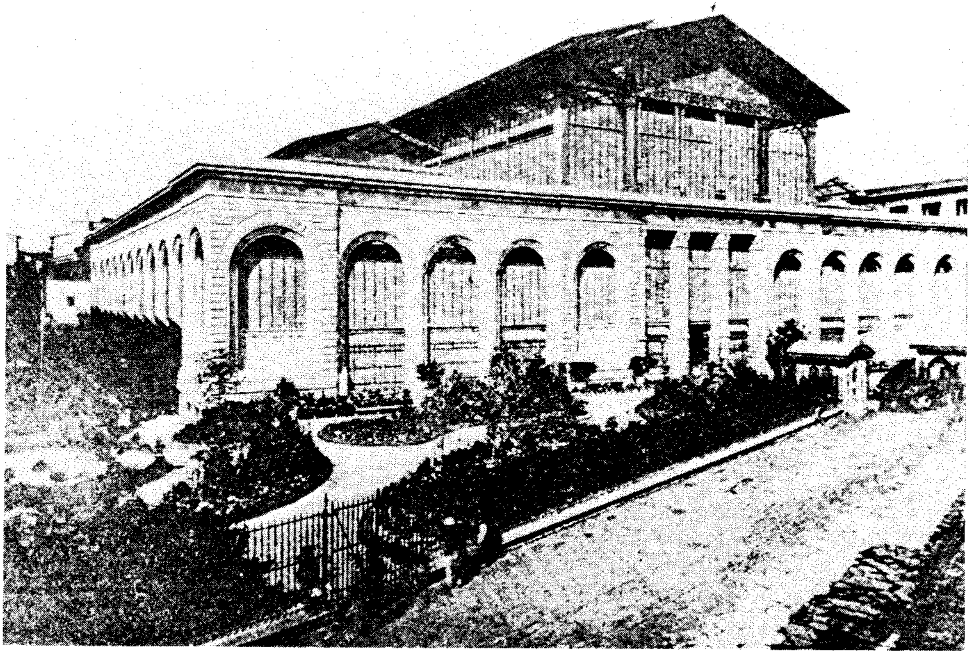


Fig. 6 : San Lorenzo Market in Florence : view of the market at the time of building.

Fig. 7 : San Lorenzo Market, Florence : central and side aisles

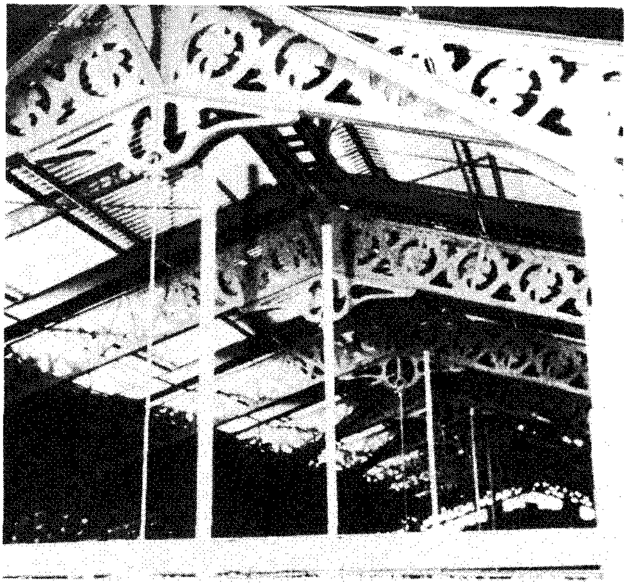


Fig. 8 : San Lorenzo Market, Florence : the columns supporting the roof.

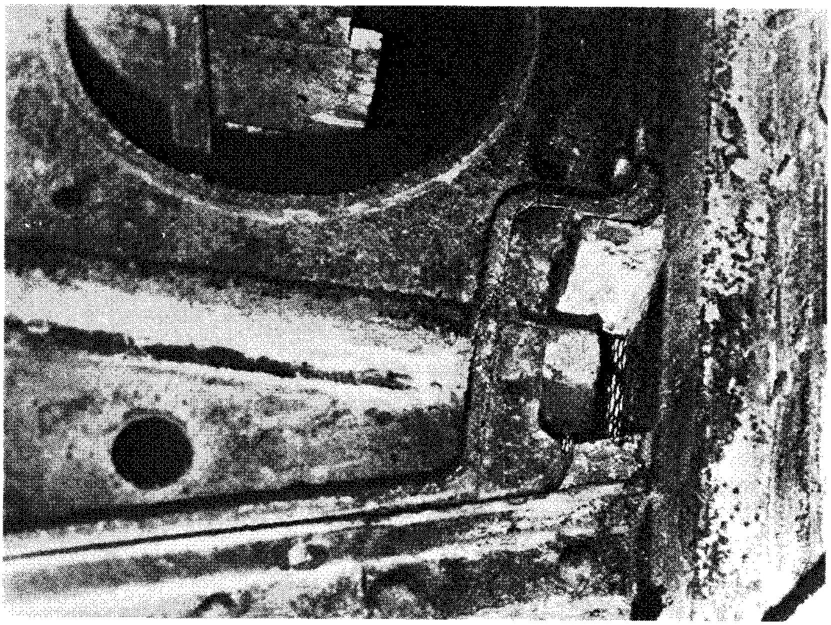


Fig. 9 : San Lorenzo Market, Florence : cast iron members

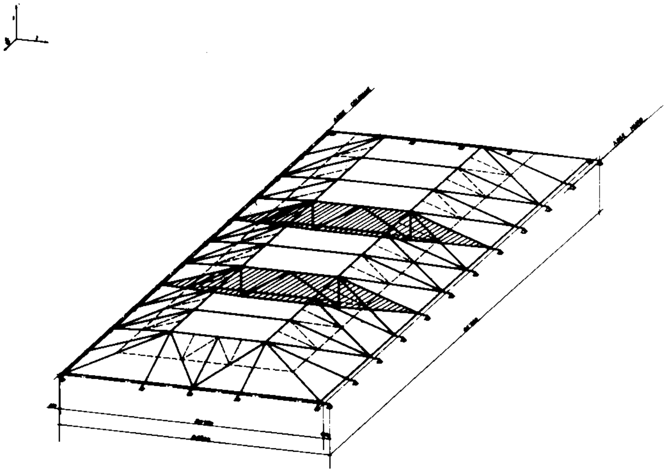


Fig. 10 : San Lorenzo Market, Florence : isometric drawing of the new structure

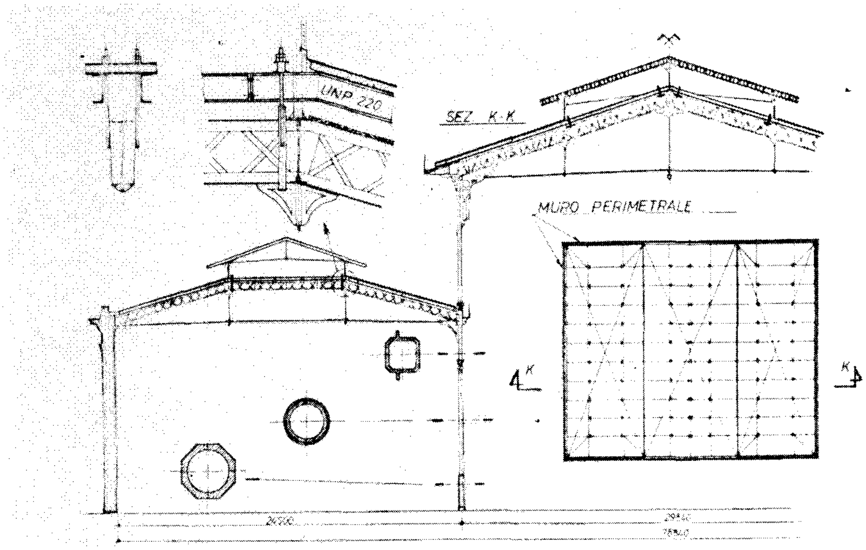


Fig. 11 : San Lorenzo Market, Florence : detailed structural scheme

Fig. 12 : Building at Modena: view of the edifice during rebuilding.

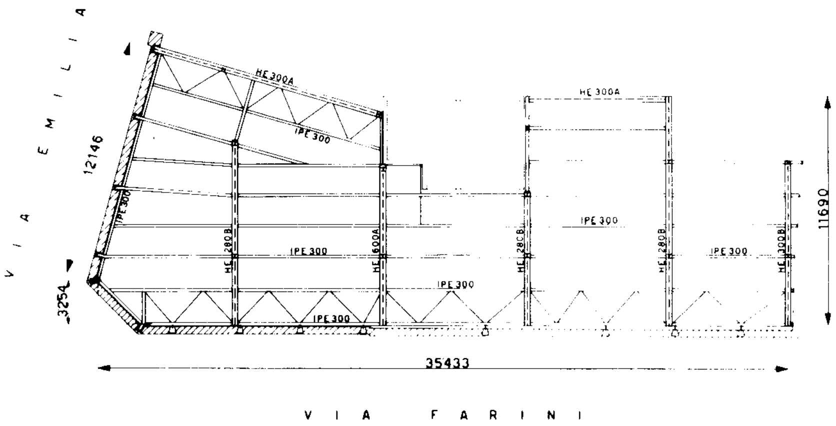


Fig. 13 : Building at Modena : ground plan of the new structure

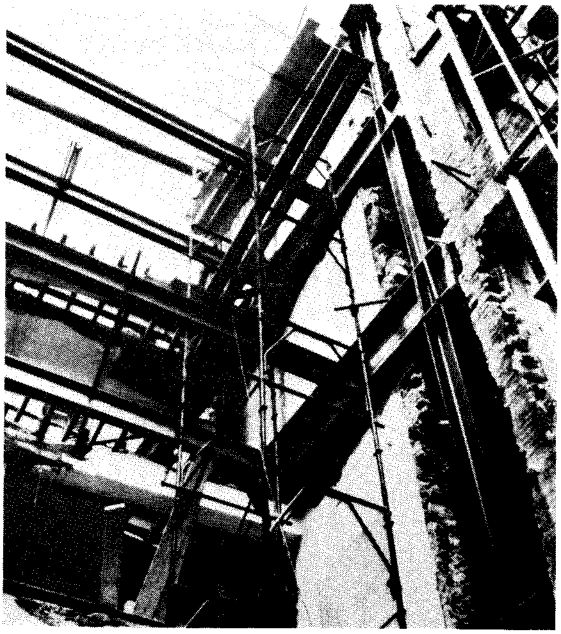


Fig. 14 : Building at Modena: a phase of the operation

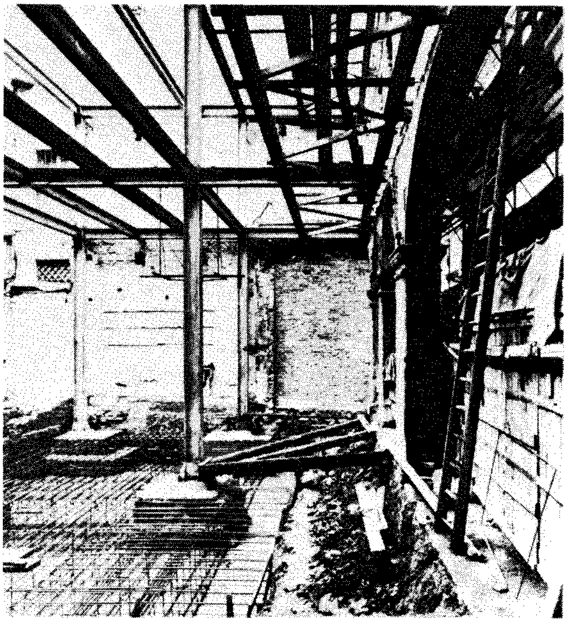


Fig. 15 : Building at Modena : view of the interior of the new structure.

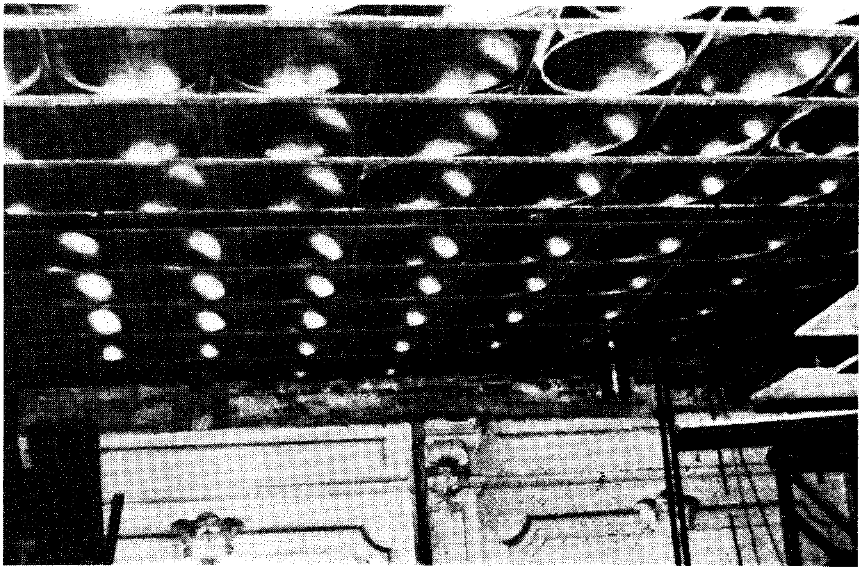


Fig. 16 : Belgium: Floorkit system

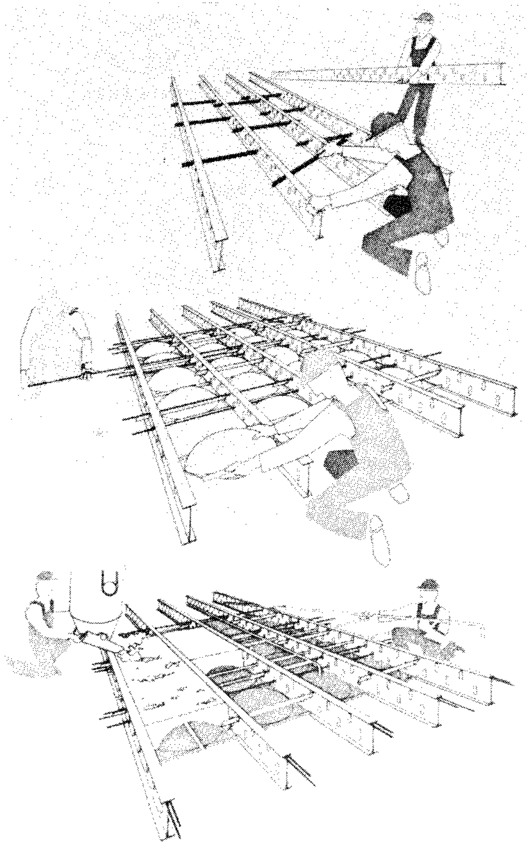


Fig. 17 : Belgium : laying and assembling

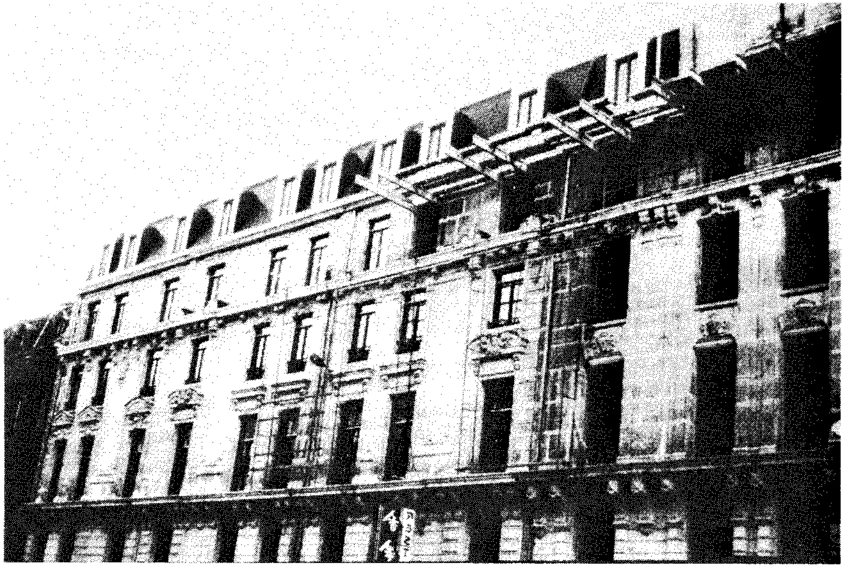


Fig. 18 : Belgium: view of a building during operations

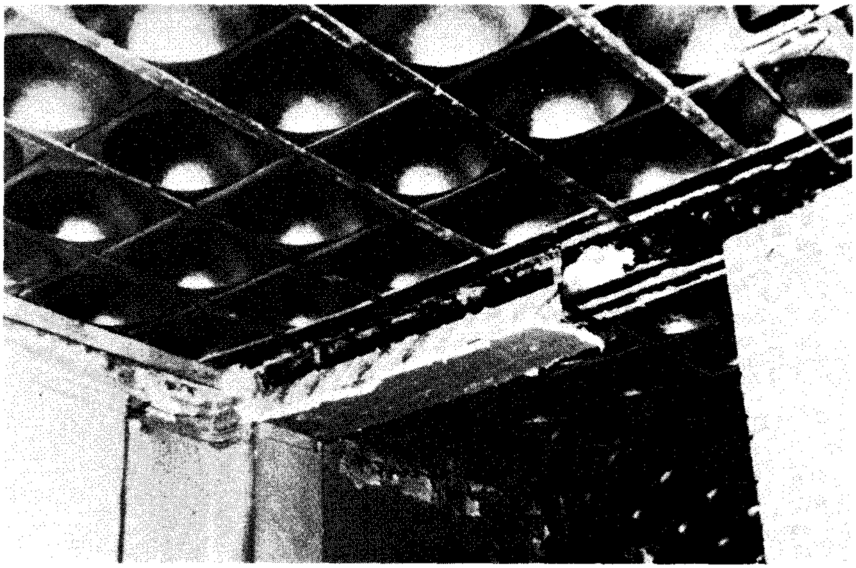


Fig. 19 : Belgium : floor and related wall

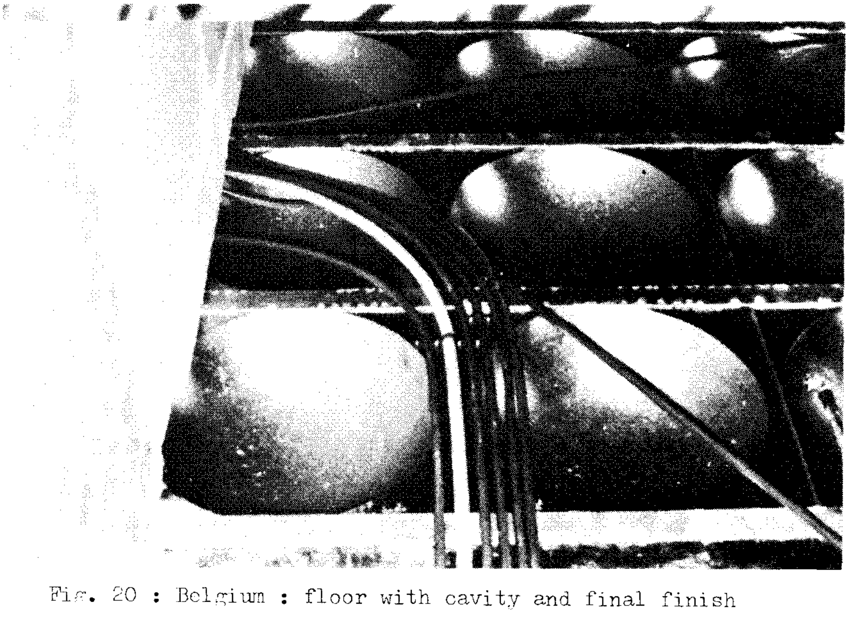


Fig. 20 : Belgium : floor with cavity and final finish

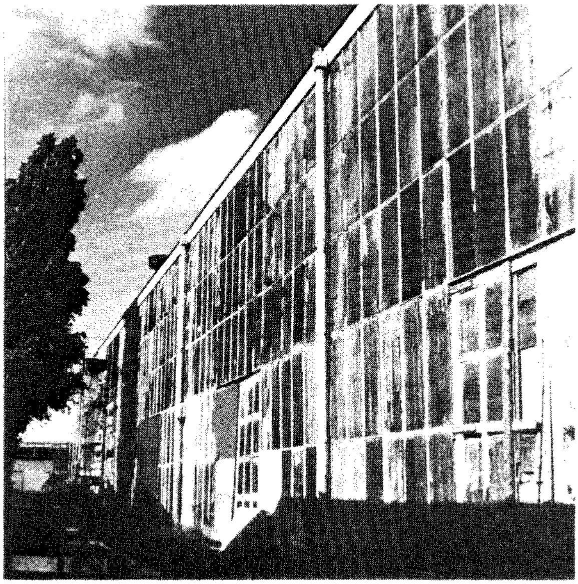


Fig. 21 : Holland : industrial building in Schiedam

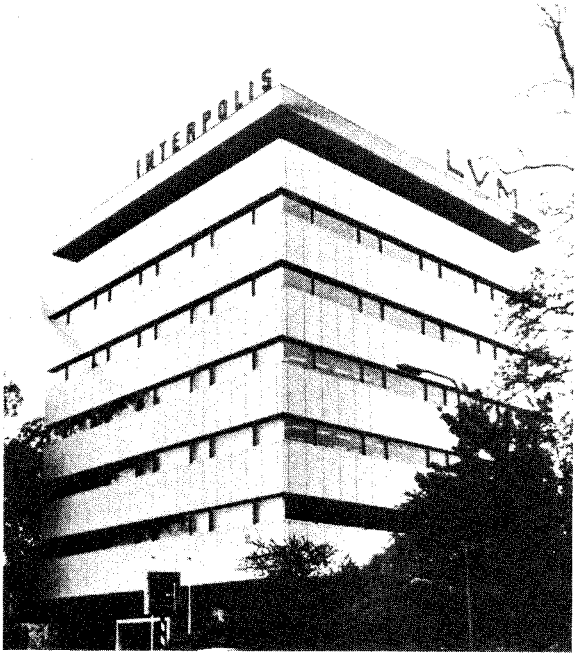


Fig. 22 : Holland : Interpol building in Rotterdam

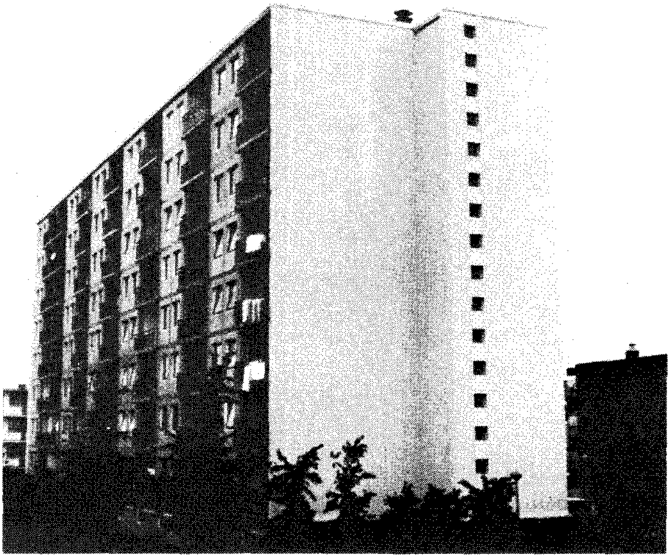


Fig. 23 : Holland : Amsterdam-Nieuwendam building

EUROPEAN PARLIAMENT HEMICYCLE IN LUXEMBOURG

J.B. SCHLEICH

Engineer for the Paul Wurth Company Ltd, Luxembourg

Summary

This paper deals with the new role of main contractor which is to be filled from now on by the constructional engineer (ref. Mr. P. METZ's speech) and also with topic 1 on the conference agenda : steel meets present-day requirements.

1. INTRODUCTION

It is always deeply gratifying for the people in charge of project to discover on its completion that is was an outstanding achievement from the point of view of design, organization and construction time.

And the construction of the new European Parliament hemicycle in Luxembourg was just such an achievement.

The new European Parliament building was constructed in a record 16 months. Its members, directly elected for the first time in 1979 in the member countries of the Common Market, sit as they did prior to the direct elections alternately in Strasbourg and Luxembourg. To contend with the new situation, the Department of Public Buildings in the Grand Duchy commissioned the Paul Wurth Company Ltd to undertake the project based on the very original design of architect P.M. BOHLER (Fig. 3) on an all-trades basis.

The developer of this building was the MecanARBED-Paul Wurth Ltd joint venture company. The main contracter engaged the Luxconsult Company Ltd as consultant engineers.

So it was that first official sessions of the European Parliament took place in the new hemicycle in Luxembourg as early as June 1980, while the Consultative Assembly of the ACP-EEC countries met from 22 to 26 September 1980.

As well as the hemicycle itself with its 774 seats and nine interpreting booths (Fig. 4), the building with a total volume of 84 000 m^3 has all the necessary substructure to ensure the smooth running of the plenary sessions. Furthermore, for practical purposes the complex was integrated into the existing group of European Centre buildings and is in keeping with the natural surroundings.

2. PROJECT DESIGN

The wings of the building are designed in gradated terraces which conform to the natural lie of the land. The central section on the other hand, which holds the plenary chamber, is designed in gradated corbellings so that the required depth for the hemicycle is reached at the level of the bottom corbelling (fig. 3).

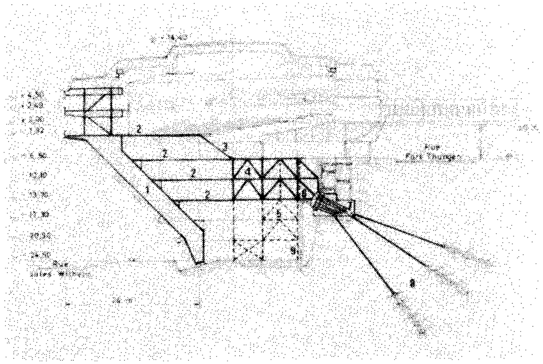


Fig. 1 : Cross-section of the building with KEYLOAD-BEARING SYSTEM

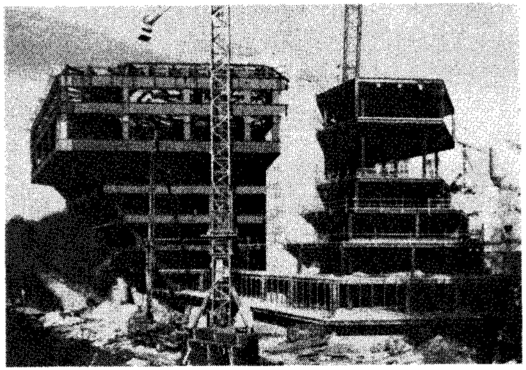


Fig. 2 : Steel framework after erection mid-May 1979

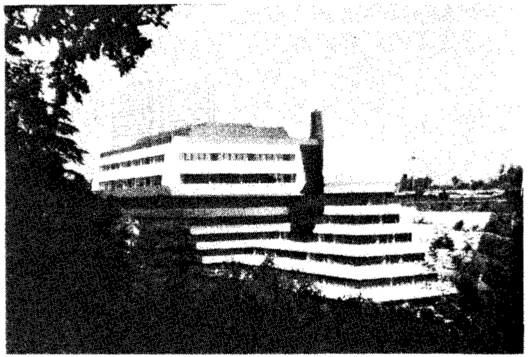


Fig. 3 : View of the half-finished building, 1980

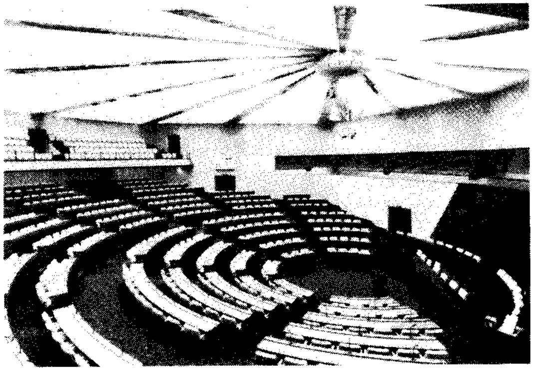


Fig. 4 : Plenary chamber, 1980

Because the projects needed to be completed so rapidly, but more especially because of the very unusual architectural and structural design of the building, the load bearing structure had to be build around a steel framework. The main contracter Paul Wurth Ltd, a subsidiary of the ARBED group, designed and built a KEY-LOADBEARING SYSTEM which is original and unique of its kind to ensure the stability of the central section of the building which gives the appearance of an inverted shaft of a pyramid (see Fig. 1).

The key-load-bearing system comprises :

- two sloping box-columns set at right-angles to the outside edges of the pyramid (see Fig. 1: 1)
- triangular girders incorporated into four floor levels (see Fig. 1: 2)
- vertical wind-braces behind the building (see Fig. 1: 4, 5, 9)
- the wind-braces are anchored to the rock by means of prestressed and anchoring cables (see Fig. 1 : 6, 7, 8)

The stress analysis, which was carried out by computer using the SAPL15 binite element program from the University of Liège which was fed into the computer at ARBED Centrale, proved the necessity of choosing this type of key load-bearing system.

As a result, deformation at the 24 m overhang due to the permanent load could be only 20 to 30 mm. This has been confirmed by measurements carried out on the building since the erection of the steel framework until recently. The analysis gave a system of 5 030 equations; the structure was divided into 1 422 girder-parts sectioned off by 873 joins.

3. CONSTRUCTION TIME AND METHODS

The time taken to construct the building on a turnkey basis was extremely short. Preliminary studies did not begin until November 1978, the steel framework was erected between mid-February and mid-May 1979 (see Fig. 2) and the building was commissioned at the beginning of 1980.

Such a fast pace for the successive stages of work could only be kept up under the following conditions :

Work was carried out round the clock in certain areas such as concreting the stairwells and lift shafts in January 1979, or the erection of the steel framework (3 200 tonnes).

The framework was divided into nine distinct phases so that the plans drawn up by four consultancy bureaus could be completed more rapidly and construction could be carried out simultaneously in eight workshops.

Joint venture companies were formed for the most important areas of work such as the carcass work, air conditioning and heating, major electrical circuits, etc.

A PERT method was used in planning the project. This was strictly adhered to. The project was monitered daily, to ensure it had met the target.

All work carried out by the 80 sub-contractors was co-ordinated by the main contractor who is the sole person responsible to the awarding authority.

4. SPECIAL TECHNOLOGY

Monitoring of load-bearing structure

In view of the building's size and its anchorage to the rock, periodic inspections need to be carried out on the most important elements i.e. :

- measurement of the prestressing force on the anchoring cables to detect any drop in stress
- measurement of the stress between the main girders attached directly to the two anchoring blocks
- measurement of horizontal and vertical deformation in the two sloping box-columns.

Acoustics

Special attention was paid to the acoustics of the building, in particular in the plenary chamber, the acoustic insulation between the hemicycle and the outside (since Luxembourg airport is so close), the acoustic insulation required for the television and radio studios, etc.

Fire protection

A very comprehensive set of fire safety measures has been drawn up, including among other things :

- subdivision of the building
- three reinforced concrete staircases which will resist fire for up to two hours and will be used as emergency exits
- alarm buttons, fire alarms and ionic and thermic fire detectors
- steel framework and floors which will resist fire for up to two hours.

Air conditioning

The three upper levels consisting of the hemicycle and those areas directly surrounding it are air-conditioned. In the plenary chamber the air is blown across grilles set in the steps, and is drawn out by a set of anemostats situated above the false ceiling of the hemicycle. The grilles are fed by a plenum system below the steps which allows the air to be distributed evenly in the hemicycle (37 000 m^3 per hour).

This system of ventilation ensures complete comfort from all points of view.

5. CONCLUSION

It must be pointed out that for this type of construction steel was the only structural material which could meet all the exceptional demands imposed by the architectural design and the time limit.

SUMMARY OF DISCUSSIONS ARISING FROM THE SESSION

J.A. RORET, Chairman

Following on Mr. BRANDI's paper, Professor MESKENS drew attention to Otto FREI's wonderful designs and expressed the desire to see the Crystal Palace in London better appreciated.

In connection with Mr. VAN WETTER's paper, Mr. G.B. GODFREY wished to know whether the welding of connecting studs onto beams through floor plates created difficulties (in fact, no problem arose here), and whether there was a significant market for asymmetrical sections in composite construction. As for beams designed for concrete slabs, there was certainly a market for such asymmetrical beams.

Mr. R. NANITZI wanted to know the final results of a comparison between the cost of a steel structure and that of a traditional concrete structure for a low-cost housing building. If there was a difference, was it due to the cost of materials or the cost of labour in prefabrication or assembly?

To make a valid comparison, all cost factors had to be taken into account. As steel construction considerably shortened completion time, the interim interest saved had to be put on the credit side. Moreover, a metal structure generally imposed much higher standards than did traditional structures in matters such as heat and acoustic insulation, allied with low upkeep and maintenance costs.

The low cost of labour on the worksite was certainly what decided the advantage of steel construction for the present, but even more so for the future as savings would have to be made on labour costs anyway.

Mr. HEVER's paper prompted a floot of comments.

Mr. R.R. PRESTON expressed surprise that the lower side of the bottom girder under tension was not protected. That was a fact, yet the whole structure had displayed high strength in tests.

Mssrs M.J. TONDELEIR and RORET brought up the same problem of the protection of the structure assembled on the worksite, for example between upright and cross member of the portal structure. The solution found had been to concrete in the empty space after assembly.

Mr. PECHON wondered whether this method had any decided advantage as against that of using a hollow profile filled with concrete. He was told that there was a definite advantage in the fact that the protective concrete was on the outside of the steel, and this construction used beams, which were easier to assemble than hollow profiles.

Mr. WYSS was worried about the economic aspect and wanted a price comparison between this method and conventional construction with protection. It seemed likely that the fact that the protective material contributed to the strength should mean a saving.

Several speakers, including Messrs WAPLER, FRUITET and RORET, complained that the paper appeared to adopt some of the arguments advanced by supporters of competing materials. It was pointed out that a steel structure need not necessarily be protected, that present regulations were far from up to date and that preconceived ideas could not simply do away with clear facts.

Much remained to be done in this field to improve administrative regulations and bring about a change in insurance companies' behaviour.

It was not true to say that metal construction made industrial buildings more hazardous (see the survey carried out in Sweden and Mr. BARTHELEMY's study in the Revue du Feu).

On the subject of Mr. SIEBKE's paper, Mr. RORET expressed surprise at the comments made concerning the alleged resonance of metal bridges carrying railway tracks; this argument was in fact also being put forward in France, and studies should be undertaken on the subject within the European Convention.

Mr. OBMA VOSSNAK required information on the advantages or drawbacks of two types of railway tracks, those laid on ballast, or directly on longitudinal girders as in Holland.

Mr. TISSIER Would have liked Mr. BOUE' to mention the utilization of hollow profiles in the construction of elevated structures; their appearance and good bending resistance appealed to users.

Mr. SCHLEICH showed some slides of the new Parliament building in Luxembourg, a remarkable design in which steel had been used to excellent purpose.

Mr. DU CHATEAU would have liked to have heard more about the use of tubes. He quoted references in France, the USA, Poland and Yugoslavia and considered that this technique allowed the problems of large spans to be resolved aesthetically.

Because of lack of time, discussion (in particular on the very interesting reports from Mssrs. SUGDEN, LUCAS and GIANGRECO) had to be curtailed.

MEETING THE CHALLENGE FOR STEEL IN CONSTRUCTION

Chairman: W. EASTWOOD, Eastwood and Partners,
Consulting Engineers, Sheffield

III. Steel meets construction needs in the developing countries

- Introduction by the chairman of session III and IV
- Export of prefabricated constructions for greenhouses and buildings to Third World countries
- Construction of industrialised housing
- Prefabricated bridgework for developing countries

IV. Innovations: Opportunities for developments in steel construction

- Building with components: an opportunity for steel
- The use of self-supporting building compoments
- Solar energy and use of steel for a new architecture
- New developments in the use of structural hollow sections
- Heated façades with hollow sections - A topical use for steel in building
- Steel: the power and the tornment of modern architecture

FOREWORD TO SESSIONS III AND IV

W. EASTWOOD, Chairman
Eastwood and Partners, Consulting Engineers, Sheffield, UK

The papers presented in this session were devoted to two themes, both of which are concerned with innovations which will increase the market for steel in structures.

Steel meets construction needs in the developing countries

Three papers were presented on this theme, each concerned with some form of prefabrication.

Mr VAN OWEN's paper describes a system designed primarily for constructing the frames of hot houses for horticultural use, but which can be readily adopted to the construction of dwellings by substituting an alternative infill for the glass. Cold formed beam sections joined together by pressed steel connections obviously offer a high strength to weight ratio, and will be easy to transport and erect. But as most developing countries have a warm climate, the market for hot-houses may be limited. The system may have a greater possibility of success in the housing field, and the market may not be restricted to developing countries. It could be utilized in remote areas even in the highly developed countries.

Mr VAN HAEKENDOVER's paper discusses industrialized housing from the viewpoint of the architect. He points out, quite rightly that industrialized housing must be socially and aesthetically acceptable as well as technically adequate and economic. Design has to be as much philosophy as technique.

Unfortunately, Mr BREACH had been delayed in the Far East and his paper was presented for him by a colleague Mr B. TROWBRIDGE. The system of prefabricated bridge building which he describes uses a range of standard components. The inidividual members are chosen from tables to suit the span and loading of the particular bridge under construction. This system has long since passed the experimental stage and is now in use in a number of countries.

Obviously, prefabricated steel highway bridges face less severe competition from local craftsmen using indigenous materials. But many of the developing countries, including some major oil producers, are short of timber and of craftsmen. Suitably designed housing using cold formed steel frames and insulated steel cladding may well find a mass market.

Innovations : Opportunities for developments in steel construction

Of the six papers in this section four were basically engineering papers and two were written more from the viewpoint of the architect. However, both the papers with an architectural base had a technological message. Mr BACIGALUPI warned of dwindling energy resources in the world (and of various metals too). The enormous waste of solar energy was highlighted, and ways of utilizing it to heat buildings were discussed including sheathing a building in glass with an air space between the glass and the walls thus producing a "hot house effect". The heat absorbed by the wall behind the glass can then be reclaimed by circulating air between the glass and the wall, and back into the building. He also gave information concerning the development of large scale wind mills including the use of steel for the trellises. Mr BACIGALUPI calculates that if solar panels providing 60 % of the heating requirementf of a dwelling are installed there is an extra steel requirement of 85 kg.

Mr DADDI have an interesting review of some of the major buildings of the world which are steel frames.

In introducing his paper Mr FRUITET gave interesting information concerning building systems in France. Only two out of about 20 are based on steel although two others use tubes filled with concrete for the columns. He suggested that any system which is developed should be capable of erection by the general contractor and the component manufacturer should be prepared to let customers buy "off the shelf".

Mr HANGLEBROEK showed interesting examples of quite large span frameless construction utilising the steel sheeting as a stressed-skin. The extra strength in bending which is needed in the roof deck, including that required in the erection stage, has been obtained by using two layers of decking fixed to each other back-to-back.

Two papers, by Mr HAUK and Mr JENSEN were concerned with developments in tubular construction. The latter described a building using rectangular hollow sections as columns through which hot water is circulated in cold weather to provide heating. Filling the tubes with water to achieve fire protection is of course no longer novel, and incorporating the water-filled columns in the heating system is perhaps a logical development. Unfortunately, there was inadequate time to discuss technical problems which arise, such as the dimensional changes in the columns, and the effectiveness of the vertical column compared with say a horizontal radiator below window level.

The session as a whole produced evidence of new roles for steelwork in structures and of its versatility in its traditional field. None of the new roles is likely to have a spectacular effect on overall steel consumption by itself, but the cumulative effect of these and other developments gives some grounds for optimism.

Export of prefabricated constructions for greenhouses and buildings to third world countries

G.Ph. van Oven

Director PRINS N.V. - Dokkum - Holland

Summary

Prins nv is bringing prefabricated constructions on the market for greenhouses and buildings.
The constructions consist partly of coldroll formed steel beams, combined to one unit by means of pressed steel connections and partly of additional elements for walls and roofs.

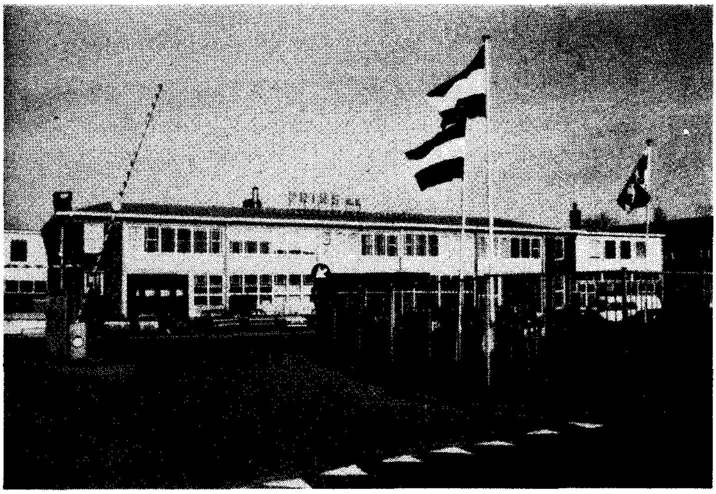
Each beam in the steelconstruction performs its own specific function, therefore the conditions for each section are different. They are designed in such a way that these functions can be performed at an optimum, coupled with a minimum use of material and a maximum demand of strength and rigidity.

Essential with this type of steelconstruction is a standardized production in the factory and a minimum of assembly time at the building site.

Greenhouses are suitable for countries where the aim is to increase foodproduction in a controlled climate, while prefab buildings can be built where there is a housing shortage or lack of any accomodation.
Supply and use of steel for the loadbearing construction provides a good opportunity for a fast and effective realization of planned programmes and projects. The additional elements, such as glass, wall panels, roofing, etc can be delivered as a complete packet, or as an alternative can be locally obtained and/or produced.

1. INTRODUCTION

Two basic needs of all human beings are food and shelter. Prins nv tries to contribute in both fields. For the production of food Prins nv manufactures greenhouses, in which the climate can be controlled in such a way that a wide range of products can be grown throughout the year. For the second basic need, a roof over the human head, Prins manufactures simple prefabricated buildings, suitable for tropical and sub-tropical climates, but if required also for colder climates. Both products, greenhouses and buildings, can contribute to a more substantial existence of human beings in many countries.



During the conference the theme: "constructing for mankind" will be approached in a philosophical way. Let me first make a remark about the human being. When one talks about food and accomodation for this human being, why should not the human being himself be the example and source of inspiration for the design of constructions for improving his living conditions ? This human being would be nothing without his skeleton, giving his body rigidity, without which he would collapse like a pudding. However, only a skeleton would look forbidding and reduce him to a ghost from the realm of the dead. But the teamwork of body and skeleton, combined with his gift of feeling and sense and his relation to the Creation makes the psalmist sing of his praise and the praise of his Creator (Psalm 8)

In relation to this, the skeleton of steel structures for greenhouses and buildings is not selfsupporting. The steelconstruction would not stand upright without more body, because of the hinged connections, specially with prefabricated buildings. In the greenhouses more rigidity can be achieved by means of windbraces. A sufficient rigidity however can only be achieved in the greenhouses with the glass and in the buildings with the wall panels and roofing. With these we have a hundred percent construction, suitable to serve for foodproduction and for accomodation and protection.

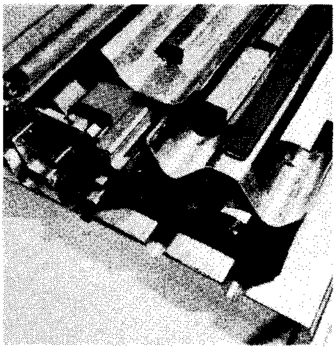
2. GENERAL: STEEL PROFILED BEAMS

Steel beams form the loadbearing construction for greenhouses and buildings. They give the necessary strength and rigidity. Because the beams are in different positions, such as in the foundation, walls and roofs, they are also loaded differently; besides these various demands will be made on the beams considering fastening of glass, walls and roofing. Therefore each beam has its own specific design. The actual loads and moments are generally speaking rather small, resulting in relative small steel sections

To be economical in steel - also steel, i.e. iron-ore, will not be infinitely available - the steel sections are designed in such a way that their form will be optimal, considering:

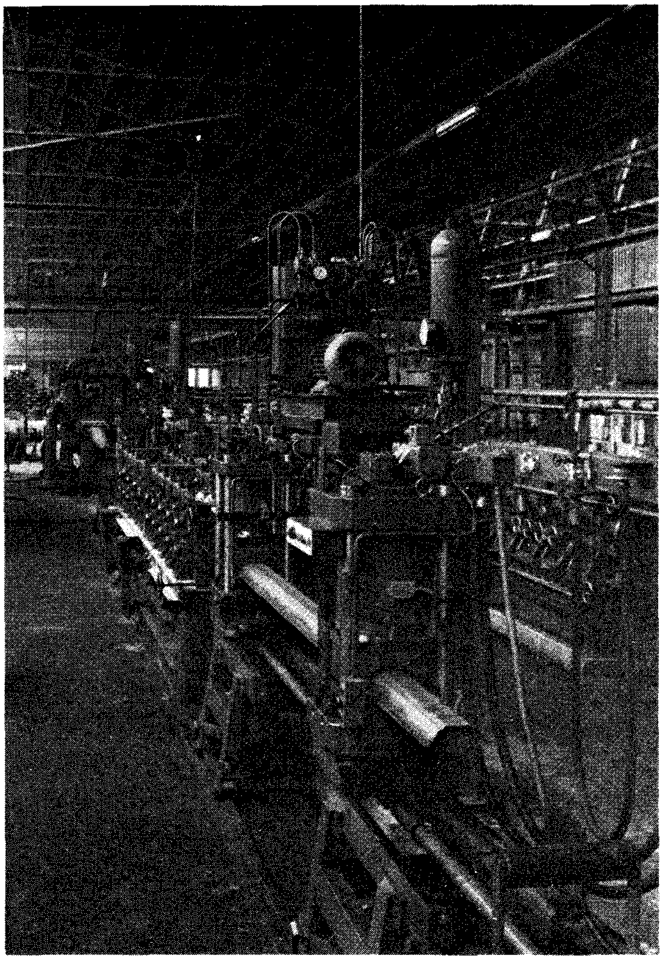
a. the amount of steel being used as little as possible, but still being able to transmit the maximum loads
b. each section can function optimally in the position where it is assembled.

To meet the above mentioned criteria steel sections can be produced by means of coldroll forming.



2.1 Further consequences

Coldroll forming is a continuous process in which standard sections in large quantities are produced. In the process the sections can be provided with holes, impressions, cut-outs, etc. and also cut-off at a pre-adjusted length. One ought to realize that as soon as the system is standardized and ready to produce, it is not a simple operation to make changes.

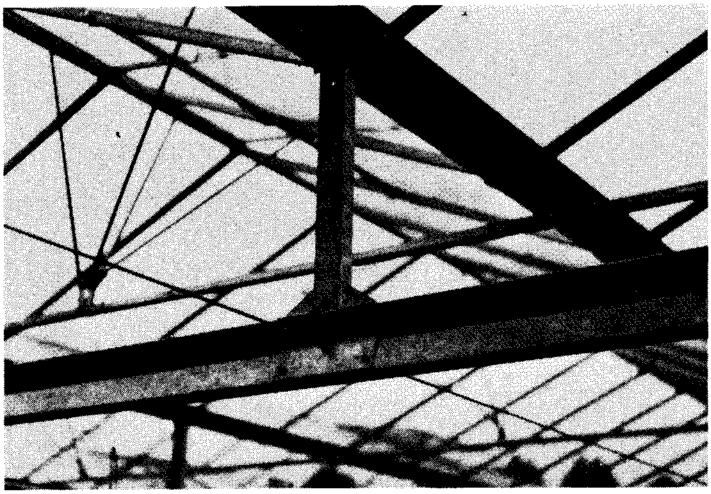


This involves changes of equipment and therefore extra costs.
The same applies for punch- and press equipment necessary to make the parts for connecting the different beams. These parts too are made in large quantities after the inevitable research to establish their optimal form.

3. GREENHOUSES

As mentioned before, the loadcarrying structure of a greenhouse consists of steel sections of sufficient strength and rigidity. Other materials that are or can be used are wood and aluminium. Because of the climate inside the greenhouse wood is not the appropriate material to use for its danger of rotting. Aluminium is a much used material, specially for those structures necessary for mounting glass to the loadcarrying construction. Often a specific form is required, that can be produced relatively easy because of the fact that aluminium can be extruded. Because of the explosive price increases in the last few years and also because of the energy needed to produce aluminium sections, Prins nv has since many years good solutions to place the glass in steel sections in combination with synthetic materials. These are competitive and will be even more competitive in the future compared to the ever increasing aluminiumprices. Inside greenhouses the climate has a high humidity, therefore the steel structure is hot-dip galvanized. This gives a good protection against corrosion while practice has proved that such greenhouseconstructions have a life expectance of some decades. The construction of a greenhouse is such, that specially at the joints of the various sections and beams no clefts occur where capillarity condensation of water can do its destructing work. This water is known to be very agressive. It is therefore clear that through experience no such details appear in the greenhouses of Prins nv

The conclusion can be drawn, that steel as construction material is quit suitable for greenhouses. Because of standardization greenhouses can be shipped easily and assembled on the site. If possible the glass can be obtained locally. Instead of glass also synthetic materials, single or double layered, can be used, they transmit less light however. This is in countries with high light densities not directly a disadvantage, but nevertheless a rule of thumb is that 1% less light transmission means 1% less yield.



4. PREFABRICATED BUILDINGS

The Prins Prefab System is designed in such a way that it is very easy to assemble the houses. Here a skeleton steel construction is used, but in itself not selfsupporting. The construction gets its strength and rigidity by means of the wall panels between foundation and frame, columns and wall plates and of the roofing material fixed to trusses and purlins.

The strength and rigidity in horizontal plane is achieved through ceiling panels fitting between the steel to give the ceiling a rigid layer. Here too the weight of the steelconstruction is reduced to a minimum; each part serves only its own specific purpose.
The construction can be divided in the following parts:
a) the foundation
b) the wall system
c) the roof, including the ceiling

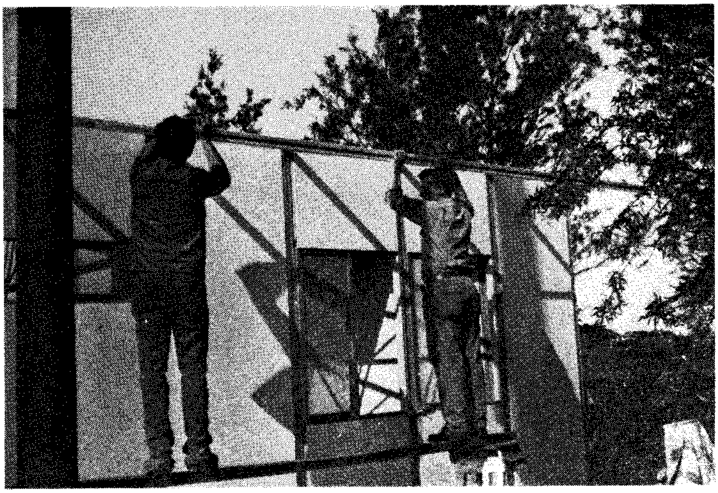
4. a) The foundation

The foundation consists of a number of steel members with the following functions:

a. they form the shuttering around the concrete foundationslab within which these light steel members also follow the pattern of the internal partitions.

b. the steel foundation members, cast in the slab, are partly projected above the concrete floorlevel in order to fix the steel columns and the wall panels, doorframes, etc. between the columns. The foundation members have standard lengths, connected together by means of standardized coupling items. Because of this way of construction, virtually each building can be designed

4. b) The wall system

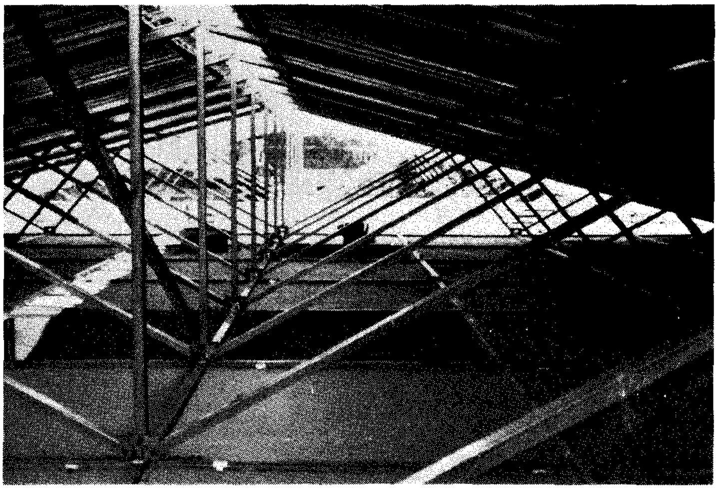


Walls are constructed with columns, fixed at every meter to the foundation framework. These columns consist of two cold-rolled U-members bolted back to back, enabling wall panels to slide in four different directions. The composition of the wall panels depends on the requirements of the client and on the climatic conditions in the country concerned. There is a wide range of possibilities, sometimes depending on the availibility of raw materials; or in some cases local production is to be taken into consideration.

4. c) Roofconstruction

a. the roof can be sloping or almost flat. The main beams of the roof construction are designed in such a way that the various parts, such as ceiling members, can be fixed to this framework quit easily.

b. the rafters are of course at the appropriate strength and rigidity, and are provided with cut-outs for an easy fixing and exact positioning of the purlins



c. the purlins are designed to allow fixing of almost all kinds of roofcladding.

d. the connection of the roof construction to the walls is very simple: the whole roof is fixed to the columns by means of wedges at every column.

e. the flat roof consists of a number of standardized girders, fixed to the columns by means of wedges. A slight slope is created to allow a good drainage.

Other properties

Apart from its strength and rigidity and functional design of the beams and other members, this design is also suitable to incorporate the electrical wiring. For each sanitary unit a standard way of fixing has been developed.

Traditional construction

The Prins Prefab System can also be used in combination with more traditional ways of construction. For instance where all internal partitions are made with prefab elements and the external walls of 11 cm brickwork. This gives the whole building a more permanent caracter while in most cases prescriptions of the building authorities will be met. With this system a second floor can be constructed, to accomodate bedrooms, bathrooms, etc.

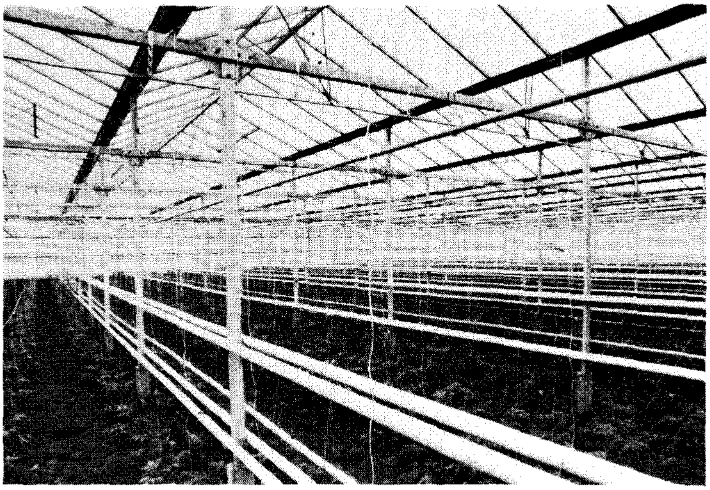
5. THIRD COUNTRIES

The function of steel for greenhouses and prefabricated buildings has been illustrated now. The following concerns the market: third countries.

Greenhouses

Traditionally the greenhouse is a construction, used in The Netherlands and in other European countries, to create an artificial climate for the production of vegetables, fruit and flowers. The advantages are that the products are fresh and of standard good quality to be sold in supermarkets etc. The last few years the greenhouse is gaining ground also in countries where because of climatic conditions and excessive sunshine, it looked at first sight not to be necessary.

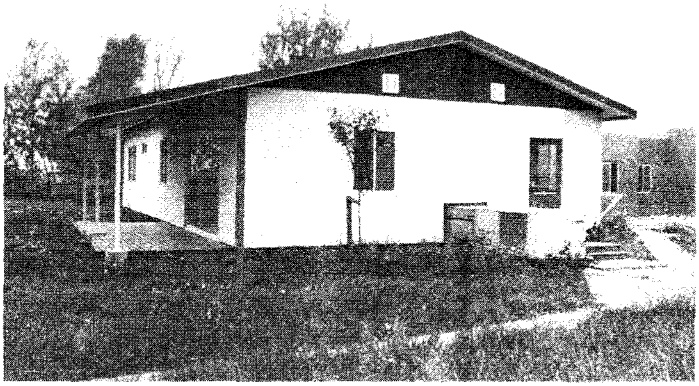
The conclusion now however is that not only sunshine is important, but also other important factors play a role to decide for greenhouses. The main argument being a constant equable climate that has to be realized. Because of this new development a new market has been created, where besides the cheaper shortlife greenhouses with poly-urethane covering,



now also the steel greenhouses with glass covering are increasingly being built.

Houses

The Prins Prefab System is originally designed to meet the needs of countries in the tropical and sub-tropical zones. Primarily the intention was to make a very simple system, in order to build cheap houses, but later higher demands were made upon execution and quality. The Prins Prefab System can be executed in various qualities and price ranges. The basic system of steel construction remains the same, only the type of wall panels doors, sanitary, roofing, etc. varies. The advantage of the system is that work on site can be done by mainly unskilled labourers under supervision. In a relative short time large quantities of houses can be erected. Because steel retains its form and the possibility to deliver the standardized materials on site, no problems will occur with the assembly.

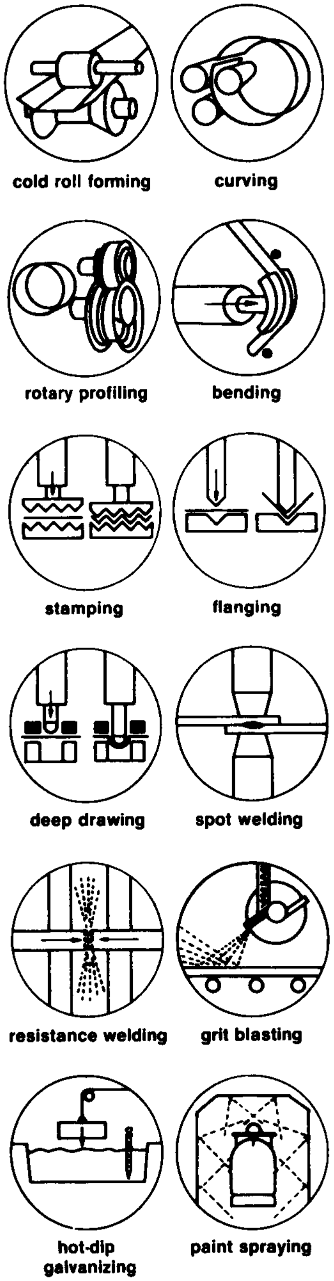


The use of the Prins system

The speciality of the Prins prefabricated houses is the form of the various beams and steel members and the way in which they fit together. In case larger quantities of buildings must be erected in a certain country on a certain site, there is in principal the possibility to produce part of the materials or even the whole system locally. This of course depends on the availability of the materials, but certainly for wall panels various alternatives are possible. For local production of the steel structure, one ought to realize that a considerable investment in machinery and know-how is necessary for the roll forming of steel and for further processing of the sections to ready products.

In such cases the steel structure can first be delivered from The Netherlands, bearing in mind that this structure makes up 15 to 20% of the total value of materials, excluding assembly. In a second stage standard sections can be delivered from The Netherlands and processed locally to ready products. For this of course a more limited investment is required. In a third stage one can roll form the steel members, either in a new mill, or in an earlier stage in an already existing mill. The only investment in the last case is some equipment. Specially in countries with high transport costs from Europe, or in countries were local involvement is stimulated, local production should be seriously considered.

Prins: specialists in 1001 techniques



CONSTRUCTION OF INDUSTRIALISED HOUSING

G. Vanhaekendover

Architect at the Académie Royale des Beaux-Arts de Liège, Belgium, specializing since 1958 in research on industrialized building.

Summary

A subject such as this can be approached from either a technical or a philosophical standpoint. The latter approach has been adopted in the belief that there is a more urgent need to convince the public of the social importance of steel in the construction industry than to recite well-known facts which may be found in the specialist literature. The experience gained in the so-called "developing countries" has had a positive impact, but we should bear in mind that all countries must continue to develop if they wish to avoid falling behind. Industrialized architecture is the philosophical response to the art of construction in our age. The steel market leaders must be converted to this view and should do their utmost to foster the principle, difficult though the path may be.

The subject of my talk today is steel in the service of the developing countries.

However, before entering into the substance of my talk I should like to make a preliminary remark: it is essential to bear in mind that all countries in the world are or should be in the process of development. Those which are not are stagnating, and stagnation may lead to a decline towards small, badly organized and antagonistic communities which are petty and narrow minded and which are the cause of wars, destruction and famine. As a Belgian born in Wallonia with a Flemish name, I regard myself in every respect as a citizen of the European Communities. The talk which I am about to give concerns all the countries of the world and is addressed to all who regard themselves not only as nationals of their own country but also as citizens of a territory extending well beyond its frontiers.

Since I have been asked to speak specifically on the construction of prefabricated dwellings, I think it worthwhile to redefine the basic tenets of the problem, since the value of a conference such as this is surely to enlighten those who are still wondering whether the time has come to embark on the industrialization of architecture, in particular with the use of steel. I shall therefore attempt to do this. The dictionary definition of architecture - "the art of constructing and decorating buildings in accordance with set rules" - has scarcely ever changed.

To the observer, architecture is primarily a decorative art. While we may admire the technical features of a building which is pleasing to the eye, we seldom admire the technical points of an ugly building. On the other hand, we always admire a pleasing design, even if the building in question is technically a total failure. While observation persuades us that architecture is primarily decorative, analysis proves that technology is essential for the creation and preservation of these decorative features. We can therefore conclude by saying that <u>architecture is a decorative art closely allied to a science</u> and by paying tribute to the builder who turned the flying buttress into a work of art.

But we are discussing the construction of houses, not cathedrals, in other words architecture to meet man's fundamental and not so fundamental needs.

Architecture of this kind must satisfy the three facets essential to the individual's well-being - the spatial, psychological and economic facets.

The spatial and economic facets can frequently be satisfied on the basis of technology. However, the psychological facet, which varies from one civilization or culture to another, raises the difficult problem of catering for personal tastes, which ideally should always be given scrupulous consideration.

Although the classical definition of architecture - the art of constructing and decorating buildings in accordance with set rules - has remained unchanged, we should not forget that the rules have changed. They have changed as a result of so many inter-related factors that it would be difficult to assign to them any order of priority - population patterns, psychological and philosophical factors, technological changes, economic theories, ecological anxieties, democratization and the more rapid flow of information have been instrumental in varying degrees in giving rise to new rules which we have not yet had time to digest, thus frequently causing friction between bureaucrats and builders; they also frequently provoke bitter reactions from those who think nostalgically of bygone ages and who are convinced that the industrialization of building is the death of architecture. If the artist who so admirably decorated the Lascaux caves had said that the hut was the death of architecture, it would have been because he did not have the inspiration, the courage and the will to tackle and resolve the problems caused by this development. We have moved from caves to houses, but we know that each intermediate stage had always displeased a section of the population affected. Here we are reminded of the famous psychologist Kurt Lewin, whose name is associated with studies and experiments on resistance to change. It is my belief that industrialized architecture, so often maligned, calls for a complex and painstaking mental effort and that no one now doubts it is the only way to solve the economic and social problems which conventional architecture is no longer able to overcome.

Why is this so? Mainly for two reasons.

Firstly, in the centuries which we generally regard as landmarks, technical problems often boiled down to the closely connected problems of resistance and sealing. In columns or walls, the load-bearing material provided the seal, which was thus necessarily external.

The desire to improve appearances led to the attempt to incorporate all decorative features in the load-bearing material. The capital was a larger stone than the others, while the columns, lintels and piers, which were almost invariably sculptured, fulfilled both a load-bearing and decorative function. This mattered little, since there was abundant cheap labour and materials.

Out of conservatism we tend too often to adopt or imitate this approach, and the contemporary builder still frequently extols the virtues of integrating decorative with technical features, forgetting that techniques have diverged since and that we can now achieve much more effective sealing without having to rely on any of the load-bearing elements. Since the seal was necessarily the outer cover, it became the decorative element and this aspect has always been incorporated with technical features.

Since then architecture, which was originally fairly simple, has required the cooperation of two or three types of building trade, and has been supplimented by a host of new technologies, which, paradoxically, have been added on rather than integrated: we have continued to build walls, in which holes are now drilled and channels cut in order to hide the special techniques employed 'and we have doubled them to incorporate insultation material. Structural elements have also been added - rabbet frames with lintel, fixed frames, mobile frames, panel frames, and frames for glazing insulation, and when the techniques of building skeleton construction were discovered, they were filled with bricks or blocks, thus adding two load-bearing materials with sometimes very different charcteristics. And this whole muddle was created by a host of very different building trades which were often totally unaware of what the others were doing. Clearly, the problem had to be rethought.

We have now arrived at the industrialization of architecture, that is architecture is planned as an entity in which all the components and materials are examined on the basis of a single technology and controlled by a small number of perfectly coordinated building trades. These entities, as in the past, may be tailored to the requirements of building projects and users. They are thus designed in the form of structures which are adaptable both in overall design and in the design of their components.

These structures are flexible, manageable and compact so as to meet the requirements of the largest possible number of programmes and decorative schemes. This brings us back to the problem of catering for individual tastes.

I shall give you a simple example of the design of a component: suppose we had to design a wall element of about 3 m^2 (and here I am talking about the equivalent, in our age, of a small megalith) and that this element had to be designed for a project in which insulation was not the determining factor but ventilation was (I mean the internal ventilation of an outside wall which prevents it heating up and encourages cooling). Clearly, such an element would have to be designed to ensure that the ventilation space was sufficient to allow for the possibility of insulation provided for under a different programme. To achieve this, we clearly need a structure to which decorative elements can be added without impairing ventilation; the more flexible and adaptable the structure, the more effectively it will be able to accommodate a wide range of decorative elements and additional features; and the more compact the structure, the wider the range of such elements and features. In addition to these characteristics, we should also mention the qualities of lightness and sturdiness, which are important in meeting the problems of storage, handling and transport which industrialization inevitably entails. And if we consider the population explosion, which increases our needs, and the acceleration of progress, we shall have to design adaptable buildings which can be disassembled and re-used, constructed with materials which can be recycled to avoid pollution.

To sum up what I have just said, industrialized architecture should ideally be conceived as a complete structure based on sub-structures which can be adapted and tailored to construction programmes and which must at all costs be flexible, manageable, compact, light, robust, adaptable, dismountable, re-usable and recyclable, and designed on the basis of a single technology which may be assimilated by a small number of perfectly coordinated building trades.

Perhaps one day other materials may be invented which can resolve this many-faceted problem. But I am convinced that steel is the right material today, and this is neither a bet nor a challenge but rather a statement of fact which we shall have to recognize and accept.

However, I have remained within the confines of a very traditional conception of architecture in regarding it as an inert assembly of materials, just as sculpture was inert before Calder.

What if we wanted to alter the positions of our houses? A house which turns with the sun or turns its back on bad weather can, according to preliminary studies, save 70% of heating costs. Houses which turn to face the landscape, or turn away from an unpleasant environment and houses which are dominated by the layout of their gardens are at last possible.

A house which may be the philosophical architectural expression of our age, which would liberate man from the blinkered constraints of the past and of all the inbred prejudices according to which houses should always be like castles. Architecture in which extravagant use is made of materials which are often useless and create a false sense of security would be replaced by the controllable dynamism of mobile architecture.

In Belgium, the architect Julien Massau holds the patents for this kind of house; he has constructed two prototypes using traditional materials, and he also helped in the manual assembly work. He is fully aware of the problems to be overcome, and has suggested that I should cooperate with him in constructing such houses in steel. Obviously, when we have the good fortune to witness the transition from the horse-drawn carriage to the motor car, it is an opportunity not to be missed. But we may well find that we are pressing ahead too fast.

I now turn to the developing countries, that is to those countries which feel an urgent desire to improve their economic futures. I have been called upon to design for Saudi Arabia not only dwellings but specific projects such as palaces, mosques and halls for wedding feasts. I was never prevented from using steel, and it turned out that only the use of lightweight structures, permitting the use of multiple ventilated walls, provided a substitute for the thermal comfort of the heavy and economically impracticable old buildings. It was also found that the same structure could accommodate traditional or contemporary decorative features, and in particular everything made of steel was more reliable, controllable, easy to transport and assemble than any other material and required 10 to 20 times less manpower.

Another marvellous example of a country which has been willing to use steel is Japan, which was devastated by the Second World War. A very penetrating market analysis carried out by Mr Degrelle, Head of the Development Department at Hainaut-Sambre, reveals that in 1976 55% of prefabricated dwellings in Japan were based on steel as against 22% in 1972.

The Sékisui Prefab Homes Group alone, which comprises three factories employing 7 000 workers, apparently produced 37 000 units in 1978.

A large proportion of its production was absorbed by the national market, but the group has been marketing a model adapted to the German market.

In Cockerill revue No 255, the Company Director, Mr Julien Charlier, stated that he believes that Japanese productivity is a very real threat to the European economies, and the technology and productivity gap between us was continuing to grow. He added that if we do not act we run the risk in the next few years of being beaten once and for all in the economic race.

There again, we are being fooled by old wives' tales: the age-old myth of the "yellow peril" still evokes for some people an image of snarling pitiless faces of blood-thirsty barbarians. The truth is that we have here a noble, cultured and disciplined race which in 20 years, thanks to its determination to improve its lot, has attained the enviable position of the second world economic power. We should bear this fact in mind.

At a conference organized by the inter-industrial study group on construction (the ICIB) I described the technical features which make steel an excellent construction material. I shall not repeat these, since I feel this will be unnecessary before an audience of specialists. I think it would be more useful to spend the closing minutes of my limited speaking time in urging that these observations should not be ignored. It is high time that the steel market leaders took these ideas to heart and entrusted their implementation to people who believe in them and who are not content with merely writing reports, but who accept their responsibilities and the risks invariably connected with the establishment of a market.

The shortage of housing adapted to the conditions of modern life is constantly growing almost throughout the world; abundant markets exist, and these must be opened up, studied and developed. I need not remind you that many steelworks are steadily losing money trying to hold their heads above water in markets which have been dead for years. When will they have the courage to open up new ones? Surely it is better to gamble than to allow the situation to get worse and worse. Are we going to allow the situation to worsen while we wonder whether it is commercially advisable to contemplate the prefabrication of steel houses when the evidence in favour of this has long been available of here and elsewhere?
Are we going to persist in ignoring the efforts of researchers except when we need to take advantage of their experience to resolve one or two specific problems where money is at stake or to fill conference halls? Are we going to persist in attaching less importance to the statements of those who have proved their cases than to the ambiguous and over-cautious reports of those who try to hold up developments for fear of getting their feet wet. It is our duty, now that most people in the lower income brackets cannot afford to buy their own homes, to bring about this change in the art of building, difficult though it may be. Not only would this improve the quality of life, but it would also bring into circulation savings which are stagnating because they have been inadequate and would create new jobs. They say that when the building is sound, so is everything else. Traditional building methods are no longer sound, and it is up to us to make this fact clear.

So far I myself have produced about 70 steel buildings and have developed two prefabrication programmes.

I am not making any bets or challenges. I believe in the idea, I put it to the test and go on from there. I appreciate the honour bestowed upon me in allowing me to speak, and I would like to thank those who have been listening to me and have understood what I have said.

PREFABRICATED BRIDGEWORK FOR DEVELOPING COUNTRIES

R. B. BREACH

Balfour Beatty Power Construction Limited,
Thornton Heath

Summary

A vital element in the progress of a developing country is the improvement of its road and rail communications.

Roads and railways in such territories, as elsewhere, frequently need to cross rivers and other natural barriers. Bridges, therefore form a most important part of the communications network.

Economic, geographic and various other factors peculiar to a developing country present a number of problems likely to be encountered in the planning of a bridge building programme.

For instance, difficulties of access mean that bridge components must be easily transportable; erection must be possible with unskilled labour and without sophisticated plant; subsequent maintenance must be kept to a minimum.

This paper details these requirements and other desirable qualities and establishes beyond doubt that the established prefabricated unit construction steel bridge is the ideal type of structure for the applications described, for the following reasons:-

- Established and proven design
- Quality controlled components
- Components easily transportable
- Can be erected by unskilled labour
- Maintenance free
- Adaptable to future requirements.

1. COMMUNICATIONS

One of the most vital elements in the progression of a developing country is the improvement of its communications, for better communications means a more cohesive nation.

The term "communications" can refer to many differing activities, all of which have their place in a developing situation, but it is the improvements in transport communications that we are specifically concerned with here.

Many developing countries contain vast areas of land rich in minerals or capable of growing enormous quantities of agricultural produce. These could be a source of immediate local benefit to the people and, as exports, would be of benefit to the nation as a whole.

Such land, however, is either remote from any transportation system or has a system which has not been developed sufficiently to accommodate a continuous flow of modern vehicles. Before such areas can be effectively utilised, therefore, the primary task is to install a basic system of roads supported, where appropriate, by a railway network. Such a scheme would facilitate the movement of commodities from the area of production into the area of most effective sale in another part of the country or to a port or railhead for shipment as exports. Similarly, other commodities, vital to the production of the home produced goods or to the well-being of the people, need to be brought into the area.

Every nation, therefore, seeking to achieve a high standard of prosperity and security must develop its internal communications on a permanent basis. It is almost inevitable that a developing nation engaging in such a programme will need to seek technical assistance from other nations and considerable foreign exchange expenditure could thus be incurred.

It should be possible, however, for this expenditure to be recovered, eventually, from the export trade that would be generated and it is vital, therefore, that the development of the infrastructure should proceed as rapidly as possible.

Any road system will, of course, involve the crossing of natural barriers such as rivers, gorges or depressions. Some rivers are dry for part of the year and can be crossed easily at that time; some may be easy flowing and therefore either fordable or suitable for crossing by pontoon or ferry, with the delays that such crossings entail; some depressions, also, may be traversible only in good weather.

The only effective, long term answer to such natural obstacles is the provision of bridges which will ensure that crossings can be made safely and speedily at all times of the year, by day or night, under any conditions.

2. THE PROBLEMS

Each country has its own particular problems which will affect the development of its communication system - problems due to climate, geography, labour problems and finance.

Let us examine these problems as they might relate to an extensive bridge building programme.

2.1 Climate

In many parts of the world, extremes of temperature or excessive rainfall limit the number of weeks in the year during which construction work can be carried out. In such circumstances, the time available for a contract to be completed could therefore be severely restricted, particularly where work would be affected by flash flooding.

2.2 Geography

The very need for a new or improved road system high-lights a major problem that must often be faced - lack of accessibility. Seldom are the roadworks advanced sufficiently to permit easy access to bridge sites. The bridge components must, therefore, be transported to the site in manageable loads in respect of both size and weight, without loss or damage. Similarly, the transportation of heavy plant to the site may be quite impossible, even if such plant exists in the country at all.

2.3 Labour Shortage

Although developing countries do not, as a general rule, suffer from a shortage of labour, the vast majority of the available local workforce will be completely unskilled and very often poorly educated. The need for skilled work on the site, therefore, must be kept to a minimum wherever possible. Even in the pertinent Government Engineering Department, the number of staff capable of designing a large number of bridges in a limited time may be quite inadequate. Any bridge, therefore, based on an existing, proved design, would have a distinct advantage as it would release local engineers for other work, such as the design of concrete pillars and side abutments.

2.4 Finance

Most developing countries require assistance of one kind or another to finance their capital projects. This can be obtained either in the form of a preferential loan from a Western Government at a special interest rate of 7½ - 7¾% over a period of say 7 to 10 years, or it may be in the form of a direct aid grant. Some countries do provide finance without restrictions, but others are likely to make loans or grants conditional upon the finance being in the form of materials for the project, supplied by the financing country. The use of steel prefabricated bridging is particularly useful in this respect.

Such assistance would not normally cover subsequent maintenance costs which would need, therefore, to be kept to a minimum.

3. PRINCIPAL REQUIREMENTS

The three principal requirements considered essential for a bridge building project in a developing country are:-

Easily transportable components.

Simplicity of construction.

Minimum maintenance.

It is also advantageous if the following requirements can also be met:-

Financial assistance available.

No delays in either design or construction.

A high standard of quality control of the components.

Design allows for future up-grading.

Bearing these requirements in mind, we are now in a position to examine the options open to a developing country embarking upon a bridge building programme, either as part of the overall development of its infrastructure, or to replace old bridges which have become unsafe, inadequate or, as so often happens in tropical countries, have been washed away by floods.

For bridges with spans of up to 120m there are two possible systems - reinforced concrete or prefabricated steel and it can be shown beyond any doubt that the steel system has the advantage over concrete in meeting the stated requirements.

3.1 Easily Transportable Components

The components of a prefabricated unit construction steel system present no problem in shipping from their country of origin and likewise can be easily transported overland to the site of erection by normal road transport. Even the use of pack mules is not unknown! At the site, all but the vary largest components can be manhandled into place and the larger items require only basic lifting gear.

3.2 Simplicity of Construction

With the supervision of only one Engineer, the construction of a prefabricated steel bridge could hardly be more simple. It involves simply the bolting and/or pinning together of a limited number of basic components in accordance with the design instructions and this can be carried out by unskilled labour without the need for sophisticated plant. There are four basic methods of erection:-

Construction in-situ, using falsework or temporary intermediate piers.

Launching out complete structures either with or without the use of an erection tail.

Cantilevering out using an erection tail.

Floating into position using barges or pontoons.

3.3 Minimum Maintenance

It is vitally important that, once construction has been completed, subsequent maintenance cost be kept to an absolute minimum. The ability of bridges to resist deterioration is, therefore, of paramount importance and an advantage of the steel bridge is that, suitably protected, it can be expected to last for at least 20 years before needing attention.

In the author's experience, by far the most effective way of protecting steel bridge components is by Hot-Dip Galvanising, normally to a thickness of 0.60Kg/m^2.

It is well known that the cathodic protection provided by zinc means that, even if the integrity of the coating is destroyed during transit, further corrosion is inhibited. The bond between the zinc and steel cannot be destroyed. A zinc/steel alloy layer between the materials has the same resistance to corrosion as the outer layer. Even when this outer layer has been attacked and removed in places, the steel is still protected.

3.4 Financial Assistance

As already indicated, financial assistance, in the form of a preferential loan or a direct aid grant, is very often made in the form of payment for materials and technical expertise supplied by the country providing the finance. This arrangement is particularly appropriate to the prefabricated steel system which employs comparatively small components designed and manufactured in a developed country.

The beams of a pre-cast concrete bridge, on the other hand, would obviously need to be manufactured in the country where the bridge is to be built.

Another particular economic advantage of the prefabricated steel system is that the project cost can be precisely identified at the outset and can, therefore, be immediately related to the amount of money available.

3.5 Speed At All Stages

Here again prefabricated steel system scores heavily at every stage:-

3.5.1 Survey

A concrete structure requires a complete and thorough survey prior to the commencement of any design work to establish precise distances, levels etc. Where, on the other hand, it has been decided that a prefabricated steel system is to be used, its very flexibility is such that a comparatively simple initial survey is quite adequate for tender documents to be prepared. A more detailed soil survey can be carried out at a later stage, prior to the commencement of foundation work. In the case of a package deal involving a number of bridges, the saving of survey time can be most significant.

3.5.2 Design

Although a pre-cast concrete bridge may employ standard beams, each individual structure will usually require more detailed design work than that called for with a prefabricated steel bridge. Therefore, on a large project the work load may well be greatly in excess of the capacity of the local design team.

Design work for an established prefabricated steel bridge system is virtually nil. The basic design exists and has been proved on many occasions. All that is required is to establish the type and the overall dimensions.

High strength steels, with yields of up to 450 N/mm^2, to give both weight saving and economy are often used.

The resulting lighter structure may produce higher deck and span deflections than normal but this can be accepted, particularly in remote areas where the occasional heavy load is subjected to a speed restriction while crossing the bridge.

Should unexpected problems be encountered when constructing foundations, then variations in span length can be easily accommodated by the addition or reduction of standard components.

3.5.3 Manufacture

The number of different components in a prefabricated steel system is kept to a minimum to permit a high degree of interchangeability. It also allows the manufacturer to build up stocks in advance of orders as the same basic components will be used for a series of projects. The period of time between the placing of a contract and the despatch of components can, therefore, be kept to the absolute minimum.

3.5.4 Erection

The prefabricated unit steel bridge can be erected quickly, regardless of weather conditions. A particular hazard encountered in many developing countries is the flash flooding of rivers, very often with little warning. Under such conditions, the use of temporary works in the river, as would be required for the construction of a concrete bridge, is inadvisable. The steel bridge, on the other hand, can be cantilevered or launched, without risk, irrespective of the state of the river.

3.6 Quality Control

This is another area where a prefabricated steel system is shown to advantage. In a factory continuously producing bridge components, a high standard of quality control over steel specifications, dimensions, machining and galvanising is a matter of routine. Quality control of concrete beam manufacture under comparatively primitive conditions in a developing country may well be open to suspicion. It is not unknown for reinforcing rods to be omitted or a sub-standard concrete mix to be produced, due to a false sense of economy, carelessness or personal dishonesty.

3.7 Capacity For Up-Grading

A well designed prefabricated system will have the capacity for up-grading to accommodate a higher traffic volume or greater individual loads. The addition of extra lanes to a deck type structure presents no problems, provided the necessary abutments can be made available. The provision of greater load capacity involves no more than the addition of standard parts as determined by simple design calculations.

This capacity for up-grading also means that an existing bridge can be dismantled and re-erected in a strengthened form at another site where the loading requirements are higher.

A striking example of this versatility was demonstrated a few years ago in Canada where a prefabricated steel bridge had been built on a remote road to provide access to a paper mill. This bridge was designed to carry a large logging truck with load, to a specification which amply covered all foreseeable traffic requirements. Some years later, however, extensive development of the mill included the construction of a power station. In other circumstances, the transport of the very heavy transformers required would have necessitated the construction of a new bridge. However, a simple strengthening scheme was devised which involved no more than the addition of some extra standard parts. The installation of the extra parts was completed in less than two weeks, during which time traffic flow was able to continue. The transformers were safely carried over the upgraded bridge and apart from the avoidance of considerable time loss the cost of the additional parts was only US $4,000.

Another instance occurred where circumstances required a change in bridge structure after a purpose-built steel girder bridge had been supplied.

The bridge was to be a 50 metre purpose designed steel girder bridge to carry a 6 metre roadway, and was urgently required. When the installation of the foundations was nearly complete, it was found that through a site error, the foundations had been installed 55 metres apart. The steel girder structure, already delivered, was therefore unsuitable.

The problem was solved using a prefabricated unit steel bridge composed of parts drawn from stock which had been held for use elsewhere at a later stage. Had it been necessary to obtain a replacement purpose designed bridge similar to that originally supplied, a delay of many months would have been incurred. As it was, the final completion date was very little behind schedule and the original 50 metre span was utilised elsewhere.

4. A TYPICAL PREFABRICATED STEEL BRIDGE

Typical of the available prefabricated steel bridging systems is the British Callender-Hamilton system which is based upon the gusset plate and multiple angle design. Angles of standard length and section are bolted together, linked by gusset plates to form a rigid structure constituting the load-carrying main girders of what is a warren-girder truss type bridge.

In a through-type bridge, standard cross beams link the trusses forming the base for road or rail traffic. In a deck type of bridge a series of these trusses are equally spaced, relatively close to one another, being linked by much lighter sway bracings and the top chords of these girders also act as the longitudinal members directly supporting the road or railway. By doubling up on the angle structure of the load-carrying beams, the strength and, in consequence, the permissible span, is increased. The design, material and finish specifications are such that the installed bridge may be regarded as being in all respects permanent. This type of bridge is normally used in permanent applications with single spans up to 120m, but it can be dismantled and re-used, in similar or suitably modified form, when emergency situations demand.

5. To summarise, the prefabricated unit steel bridge is a high quality, versatile structure fully comparable with a purpose-built design with added advantages:-

   It is adaptable. No longer must the engineer adhere rigidly to his original scheme. The system is flexible and, therefore, permits the span or loading to be altered as requirements dictate.

   It is re-useable. Although in every way a permanent structure, it can be dismantled and re-assembled at another site if circumstances demand. It can be moved to suit changes in traffic patterns or changes in paths of rivers. This ensures maximum utilisation of the capital employed in its construction.

   It is mass-produced and therefore capable of providing economies of a scale not found in the conventional one-off design.

Likewise, the bridge is capable of being designed to meet whatever combinations of span lengths constitutes the optimum having consideration for foundation requirements and river flow.

It is obvious, therefore, that the prefabricated unit steel bridge can play a vital part in the rapid, economical and efficient development of road and rail communication systems in a developing country.

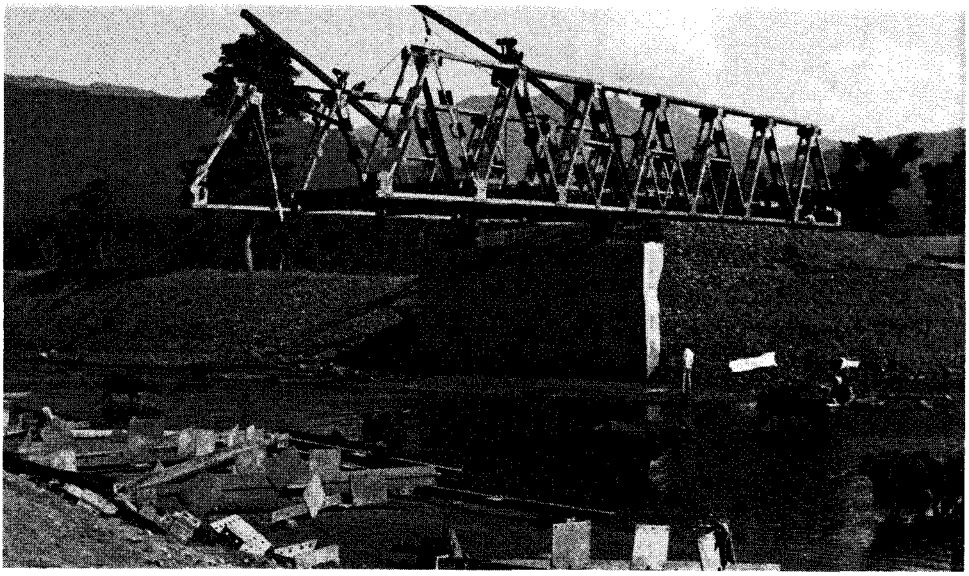


Photo 1

Cantilever erection of a Callender-Hamilton Type B15 Bridge in Nepal using basic erection equipment and local labour.

See section 3.2

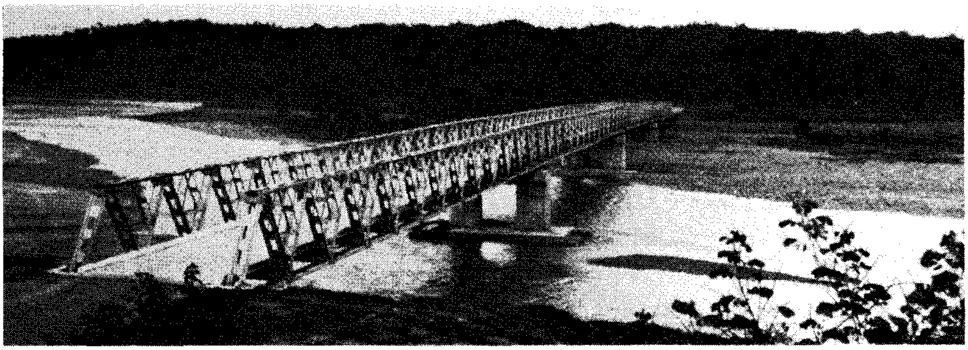


Photo 2

Four span continuous Callender-Hamilton Type B15 Bridge across a flood plain in Nepal. This Bridge was cantilever erected due to the tendency of the river in the area to flash flooding.

See section 3.5.4

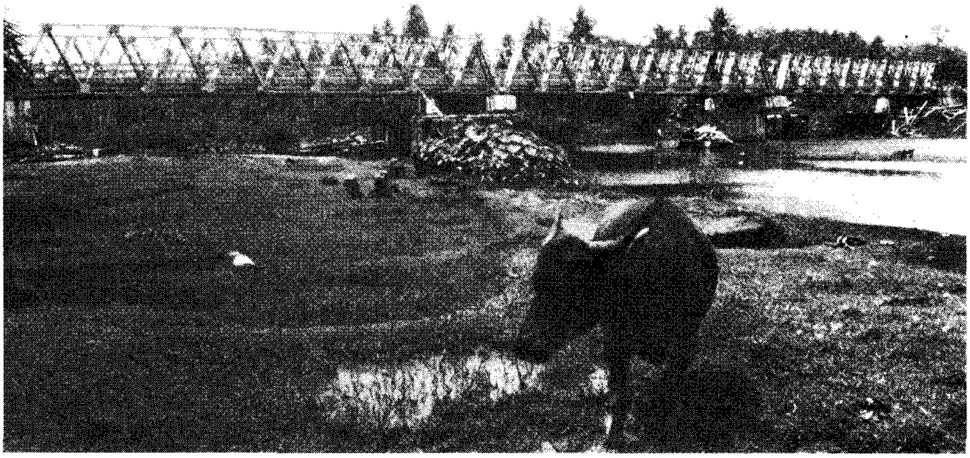


Photo 3 Three span Galvanised Callender-Hamilton Type B15 Bridge under construction in a remote area of Indonesia. The simply supported spans were necessitated by the earthquake potential of the area. The centre span floated into position by barge. See sections 3.2 and 3.3

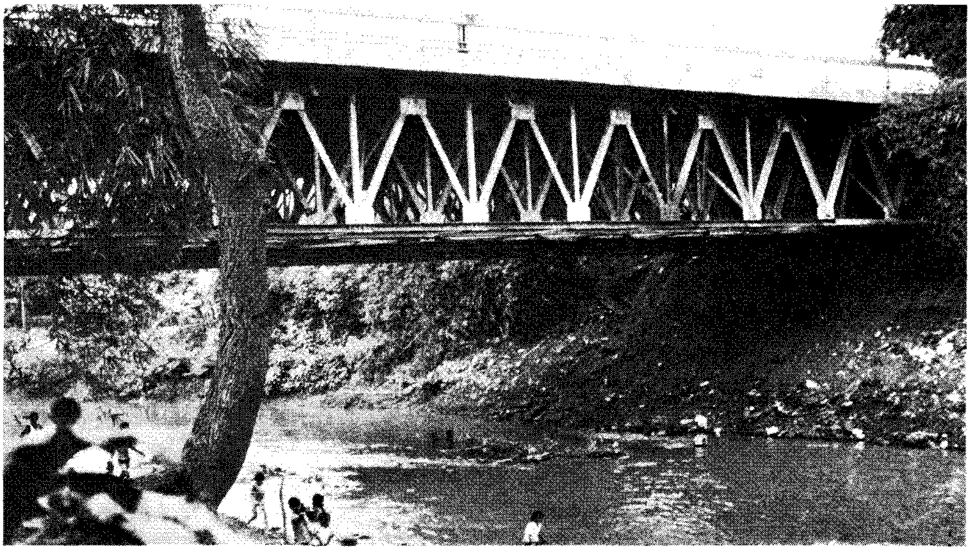


Photo 4 A four lane Callender-Hamilton Type B deck Bridge in Indonesia. This structure can be simply upgraded as traffic flows increase by the addition of extra trusses. See section 3.7

BUILDING WITH COMPONENTS: AN OPPORTUNITY FOR STEEL

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Summary

Industrialised building in France has experienced four phases: prefabrication, model buildings, construction-kit systems, and the components method. The last phase is just beginning. It involves putting 'open-ended' components on the market, produced by manufacturers quite independently of their on-site assembly. General cooperative agreements (of recent date) and special agreements relating to assembly (in process of being drawn up) are intended to lead to component compatibility without the need for fine adjustment on site.

Steel has a very clear place in this development:

- in the compoenents of the second order, which play an important part in industrialised methods and for which steel is the most effective material;
- but also in the metal framework which will have to be designed to accommodate the components as easily and cheaply as possible.

Industrialised building in France has passed through a number of phases:

The first phase consisted of the prefabrication of an element of construction in factories situated at a distance, great or small, from the site (metal fabrication, heavy prefabrication).

In the second phase, the intention was the series production of identical elements for erection according to a building model (identical buildings with only very small opportunity for variation): schools, private houses, sports facilities, swimming baths, hospitals....

These models still exist, but are tending to give way (especially with regard to schools) to systems, or the construction kit approach, involving standard elements capable of combination in a large variety of ways, producing different buildings; this is the third phase of industrialised building.

Finally, the present approach is to develop 'open-ended components', i.e. standardised prefabricated elements produced independently of one another, and capable of very free combination by the architect. These components are no longer bound by the system rules, but by the 'coordination rules'. In France, such rules are in the course of being worked out by working parties of a group specially created for the purpose, the Association Composants Construction (ACC) which combines experts from all disciplines participating in building:

- those from industry, grouped as the Association des industries de matériaux et composants de construction (AIMCC), representing all the materials and processes involved;
- the building companies, forming the Fédération nationale du bâtiment;
- the architects;
- the engineering consultants
- the Centre scientifique et technique du bâtiment, a study and research organisation for new technology.

Steel participates in the work through representatives of the steel-producing industry (Office technique pour l'utilisation de l'acier), through the Centre industriel de la tôle d'acier galvanisée (centre for galvanised steel sheet), the Chambre syndicale des fabricants de tubes d'acier (the trade association for steel tube producers) and Comtube, the research organisation for the use of hollow sections.

Recently appeared is a collection of 'General coordination agreements' relating to industrialised components. This sets out the rules for positioning common to all components of all materials in relation to a square horizontal 300 x 300 mm frame and a vertical module of 100 mm (ISO module). The object of these rules is to enable modular components to be planned for right from the time of conception of a project. Still in course of being worked out are the 'specific agreements' defining the rules and standards of assembly of components of diverse origin, termed 'external assemblies'. Parallel with this work, study groups are engaged on codification of specifications of the components, with regard to: tolerances for fabrication, layout-plan, and fixing, assembly types, batteries of components, and quality criteria for the components.

It is not, here, a question of 'standards', which are the concern of special conventions and agreements, but of codification of descriptions and specifications, i.e. the creation of a common language.

The presence of steel representatives on these working parties avoided the danger from the start that the general agreements did not only contain dimensions (wall and floor thicknesses, etc.) and design criteria typical of traditional or reinforced concrete building methods.

Heavy prefabrication methods have, in fact, made considerable advance over lightweight metal systems. For example, of the 20 systems at present authorised in France for the construction of dwellings (11 for blocks of flats, 9 for private houses), only two relate to steel frames in the correct sense of the term, and two refer to concrete-filled hollow section columns with solid ground floor in reinforced concrete; all the others refer to heavy systems with the sole exception of one which makes partial use of timber.

This is, indeed, a paradoxical situation, since metal construction adopted prefabrication methods well before reinforced concrete. But this is explained by the fact that the builders were led to adapt themselves to a 'custom' market, especially for industrial buildings where programmes are very diverse and restricting, by:

- fabrication methods permitting the supply of unit elements or of very small series
- a commercial network and an organisation of companies and not of industrial interests

There are now, in France, manufacturers of reinforced or prestressed concrete, which supply components, which they do not put up, to the firms which make use of them and usually handle the general contract.

This practice does not exist in metal construction, or only vary marginally ('finished' elements used by metal erectors who also carry out factory fabrication).

Certainly, the 'open-ended' components will probably be mainly second-order components, for which the value added by fabrication will be quite significant, and which represent 80 to 85% of the cost of a shell of a non-industrial building.

However, the main enterprise, which is the erection of the building, should be conceived according to the 'rules of the commonplace' which will permit the use of second order components without fine adjustment on site. The frame systems themselves, which are intrinsically 'closed' but open to the second order, should preferably move towards becoming open-ended also, if, over the next few decades, steel is to keep its competitive position in relation to other materials.

Metal construction should be represented in the working out of the specific agreements, with the objective of ensuring that the second order components which are to be offered 'open' on the market are just as adaptable (if not better) to metal frames (industrialised or not) as other materials and processes.

Steel has just such a direct interest in the development of second-order components: panels for facades, interior partitioning, floors, ceilings, roofing, hardware and metal fixtures.

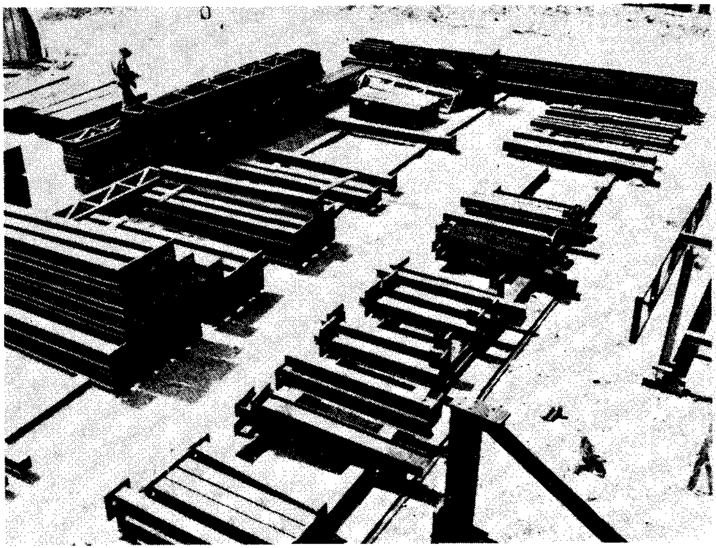
It seems necessary that some 'metallic' constructors should convert themselves into manufacturers and suppliers of open-ended components; this without becoming involved in erection, but leaving that part of it to others who will combine components from many sources and use a variety of materials and processes; that is, leaving to others the business of 'custom building', and restauration, renovation, conversion, and maintenance of existing structures - an area in which steel also has its place.

Of course, this reorganisation of traditional professional arrangements poses some important problems:

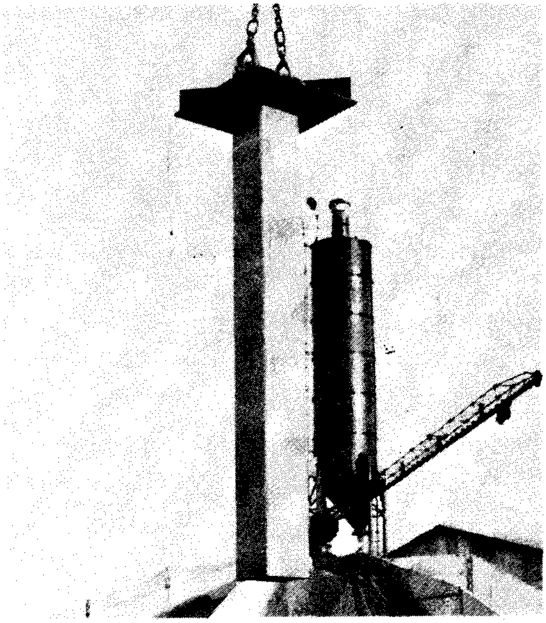
- of organisation: studies, manufacture, a commercial structure for the products
- of responsibility: a new law in France makes joint the manufacturer and contractor vis-a-vis the client; a special insurance system is now being introduced

On the other hand, the relationships between the various bodies involved in the business of building should become clearer, especially in the area of subcontracting, where practice leaves a great deal to be desired.

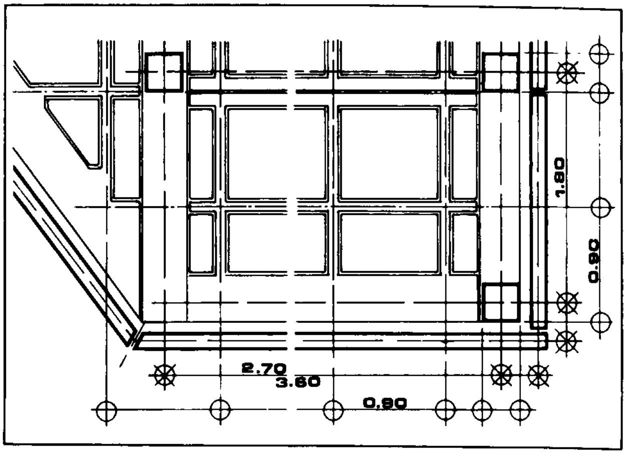
Moreover, one can hope for better productivity in both manufacture and utilisation (a great deal of the value added arising in the factory), a reduced erection and especially finishing time, a better finished building quality, and a better price/quality ratio. That is why the public authorities in France are encouraging the development by various positive actions aimed at public and quasi-public works bodies, architects and civil engineers, manufacturers and contractors.



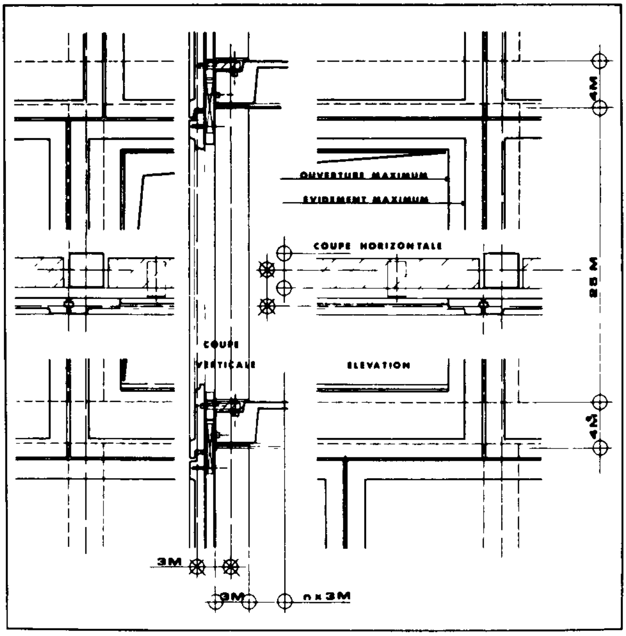
1. FIM system industrialised components; site storage of components



2. Column component of ETOILE system in course of site erection



3. GBA2 system: mounting components on horizontal frame according to ACC recommendations



4. GBA2 system: mounting components on vertical frame according to ACC recommendations

THE USE OF SELF-SUPPORTING BUILDING COMPONENTS

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Summary

One of the objectives of the construction engineering division of IMAG in Wageningen is to develop farm buildings which are functional, well built, aesthetically pleasing and reasonably priced. The research which led to the development of unsupported building systems began in 1978 with the question of whether the strength and rigidity of building materials were being exploited to the full. Further research showed that prefabricated structures, composed of standard panel materials such as corrugated cardboard, Swedish Masonite, and profiled steel sheet, in some cases combined with insulating materials, could serve a load-bearing function. These panel materials were used in more conventional structures as non-load-bearing roofing, wall cladding or insulating material.

Standard building components and existing production facilities can be used to make structures which are of adequate size and consistent in quality, and which combine the functions of support, partitioning and insulation. The use of these building components makes it possible to improve the material/labour cost ratio on the building site from 70:30 to 90:10. The effect is to shift the work to the factory, which ensures higher quality standards and considerably reduces the amount of time spent on building.

An effort is being made to make building materials perform a combined function rather than one specific function as in conventional building methods.

IMAG has filed a patent application in respect of the unsupported building system using profiled steel sheet which is described below.

1. DESCRIPTION OF THE SYSTEM

The structure consists of long roof modules which can be joined together along the length of the building. These roof modules are supported on triangular lateral frames. The frames transmit the forces from the roof to the concrete foundation. The roof elements are joined at the apex and the lateral frames are also hinged on the concrete foundation. No struts, cross-beams and other load-bearing structures are required.

This gives a continuous structure lengthwise with three piano-type hinges. The design incorporates panels which are inserted along the length and at the ends of the structure and which act as partitions, insulate the building and give rigidity.

2. STRENGTH AND RIGIDITY REQUIREMENTS

Requirements concerning the strength and rigidity of buildings for the Netherlands market are laid down in standards NEN 3850, NEN 3851 and NEN 3852. The standard load for low-rise agricultural buildings with a roof pitch of less than 30° is a snow loading of 0.5 kN/m^2 of ground covered. For roofs with a pitch exceeding 30° the parameter for calculating or testing strength is the wind load plus over- or under-pressure in the building, depending on the height of the gable. In this case the load is approximately 0.4 kN/m^2 of roof area.

These standards contain requirements on the rigidity of building components which are mainly applicable to residential and public buildings. For agricultural buildings standards can be relaxed, although not so far that any dynamic forces represent a hazard to the safety of the structure. There are minimum safety margins for individual building materials, which are laid down in the above mentioned standards.

When building materials which are not conventional, and which therefore have not been covered by regulations, are used for load-bearing components a safety factor has to be determined. This is done by determining the properties of the materials and assessing the element of risk in using them. A safety factor of 1.5 is normally applied to the building components described in this article.

3. DESCRIPTION OF THE COMPONENTS

The roof modules consist of sandwich panels faced with steel wall cladding sheet. The standard steel sheet selected is like sheet piling in section, and the profiles are 35 mm deep. The sheets are rolled from galvanized steel flats 0.75 mm thick. The steel is given a 20 m coating of epoxy primer and the outer face is given a coating of polyvinylidene film. The core of the panel is expanded polystyrene foam 90 mm thick. The density of the polystyrene foam is 20 kg/m^3, and has been granted a KOMO-keur (test certificate). Since flat slabs of polystyrene foam are used for the core and the panel facings consist of steel sheet piling sections, the two can only be bonded together at certain points. The adhesive is a moisture-retaining polyurethane bonding agent.

The long sides of the panels, which are approximately 1 m wide, are so made that the steel plates fit into each other. The foam core is grooved to minimize air losses (at the joint) from the shed.

The triangular lateral supports are made by welding together steel box girders. They are then thermally galvanized. The side walls are made of sandwich panels faced with a 5 mm thick layer of high-density asbestos cement and a 50 mm core of polystyrene foam (15 kg/m^3 KOMO-keur).

4.1 TESTING

When the first prototype of this building was constructed in 1977 as a tool store, approximate calculations of its strength were made. These were based on the assumption that the two profiled sheets joined face to face would function as a composite castellated sheet. Since it was feared that the thin sheet (0.75 mm thick) might tend to buckle in the area under pressure, it was decided to carry out a full-scale test. A horizontal panel was set up as a guide. The type of sheet required (a standard section) and the type and amount of bonding agent necessary were determined. The strength/rigidity ratio of the roof structure was then measured on the slope by applying the static load. The failure stress was established by applying a load which was 1.53 times greater than the bending load. There was some buckling in the area under pressure, and transverse forces were generated directly above the point of contact with the wall. The actual flexing appeared to be greater than the calculations had indicated. This indicates that the combined performance of the two sheets is not ideal.

5. SECOND PROTOTYPE

A second prototype was delivered in 1978. The main features were :

roof span : 12 m
length of building : 50 m
height : 5.4 m
height of side walls : 1 m
pitch of roof : 40^{o}.

The health authorities as well as the building and housing authorities commended the building when they approved the plans. Later calculations and loading tests have shown that it is possible to have a span of 21 m which does not require any other load-bearing structure such as struts, cross-beams or wind bracing.

At present under construction are a riding school (with a span of 21 m) and a potato store (with a span of 16 m).

The strength of the sandwich panels was determined by carrying out a full-scale preliminary test (see diagram).

An approximate idea of the following safety parameters was obtained. The structure gave way because the profiled steel sheets buckled in the area under pressure directly above the side-wall upright supports. The load at this point was 15.69 kN at right angles to the panel combined with a normal force of 10 kN exerted along the lengthways axis of the panel. The moment at the point of collapse was thus :

$$M_A = 10 \times 1.35 + \frac{1}{10} \times 15.69 \times 0.5 = 14.28 \text{ kNm}$$

The normal force in the underneath plate was $\frac{14.28}{0.13} + \frac{10}{2} = 114.9$ kN

The compressive stress $G_{d\ max} = \frac{114900}{994} = 11.56\ N/mm^2$

The shear stress $T_{max} = \frac{15690}{4 \times 994} = 3.95\ N/mm^2$

The total force exerted on the steel was therefore approximately :

$$G_{tot} = \sqrt{11.56^2 + 3 \times 3.95^2} = \underline{13.43}\ N/mm^2$$

The prototype building with a 12 m span had a top loading of snow in accordance with the Dutch standard NEN 3 850 of :

20 x 0.17 + (12 + 2) x 0.5 = 10.4 kN/m' building).

The horizontal resolved force exerted by the side-wall upright supports on the foundation is then :

$$H = \frac{10.4 \times 12}{8 \times 5.4} = 2.89\ kN/m'\ \text{building.}$$

The support reaction is $\frac{10.4}{2} = 5.2$ kN.

The bending moment in the roof panel directly above the side-wall upright support is:

$$M_A = 2.89 \times 1 + 0.67 \times 0.5 = 3.22\ kNm$$

The transverse at that point is = $D_A = 5.2 \cos 40^o + 2.89 \sin 40^o = 5.84$ kN

The normal force at that point is: $N_A = 5.2 \sin 40^o + 2.89 \cos 40^o = 5.55$ kN

The normal force in the underneath plate (area under pressure) of the panel is:

$$N = \frac{3.22}{0.13} + \frac{5.55}{2} = 27.54\ kN$$

$$G_d = \frac{27540}{994} = 2.77\ N/mm^2 \qquad T = \frac{5840}{2 \times 994} = 2.93\ N/mm^2$$

$$G_{tot} = \sqrt{2.77^2 + 3 \times 2.93^2} = \underline{5.78} \text{ N/mm}$$

On the basis of the failure of the structure caused by the buckling of the profiled steel sheet the factor of safety for the structure is approximately:

$$v = \frac{13.43}{5.78} = \underline{2.32}$$

For this kind of building these calculations may be regarded as adequate.

6. Energy balance

Many sheds in the Netherlands have so many seams in the walls and roof that there is more ventilation than is strictly necessary. When additional heating is necessary, as in the case of buildings for breeding sows and chickens, this results in a waste of energy. When steel sandwich panels are constructed this problem of heat loss is overcome to a great extent because of the size of the building modules, so that the precise amount of ventilation considered necessary can be built in. Furthermore, the roof structure has a K value which is approximately half that for conventional types of shed, which is intrinsic to the structure. This type of construction may therefore be described as energy-saving.

The second prototype incorporates a section for piglets which is kept warm at all times, and has no heating installation. The body warmth of the animals, combined with a minimum of ventilation and very good thermal insulation of the outer walls of the building, reduces the amount of heating required, as calculated in accordance with the ninth publication listed in the bibliography, so far below that required for conventional sheds that expenditure on a heating system is unneceesary.

7. Design

Hitherto the development of commercial agricultural buildings in the Netherlands has been on a schedule of requirements which are exclusively concerned with guaranteeing efficiency. On grounds of economy little attention is paid to the aesthetic merits of these buildings. One of the requirements IMAG set itself when developing buildings without supports was that the structures should be well designed. Standard structures had to be developed which would easily fit into large-scale as well as small-scale surroundings. It is incorrect to suppose that "pleasing buildings" fit into any surroundings. Each individual building has to fit in with the scale of the landscape and with the other buildings in the vicinity.

The variety in height and roof pitch obtainable with unsupported building systems can be a real asset as regards the architecture of agricultural buildings, since harmonization with the landscape is thereby made easier. The exposed load-bearing structure along the side-walls is also decorative, and can enhance the architectural merits of the building.

8. CONCLUSIONS

We have seen that even with simple trial buildings it is possible to obtain sufficient calculation data to develop a new building system to the point of being a practical possibility. It is easy to transport the light-weight roof modules to the building site, even when the location is remote, and to assemble them with the aid of simple hoisting equipment. No further work is needed on either the outer or the inner face of the unsupported modules; they offer good thermal insulation in most cases and require practically no maintenance. The dimensions and pitch of roof can be varied, thus offering a great variety of internal designs for different agricultural buildings.

When plans were submitted for approval the authorities commented favourably on the design of the buildings. The interest shown by the business world in this kind of system indicates that there are good prospects of making it commercially viable.

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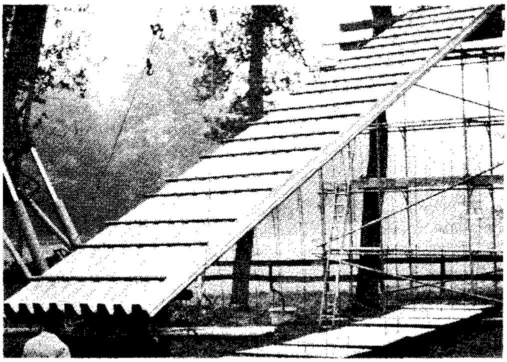
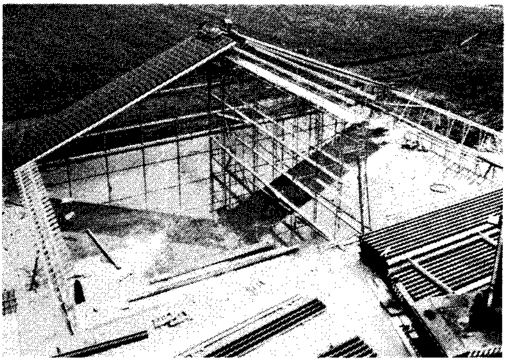
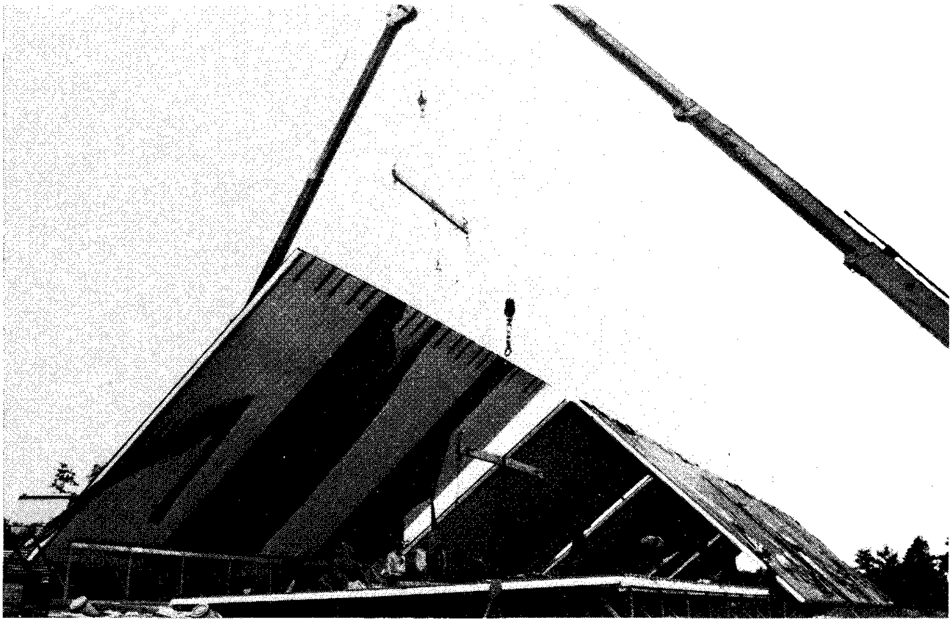


1. Full-scale test loading of modules for the first prototype. The picture shows two profiled steel sheets which have been bonded face to face being used as a composite castellated plate.



2. When the first prototype was being constructed a temporary scaffolding was used in the middle under the apex.

3. In the second prototype the triangular frames were hinged to the concrete foundation.



4. Second prototype - two cranes are used to hoist the roof structure which has been assembled on the ground. The roof area is some 100 m^2

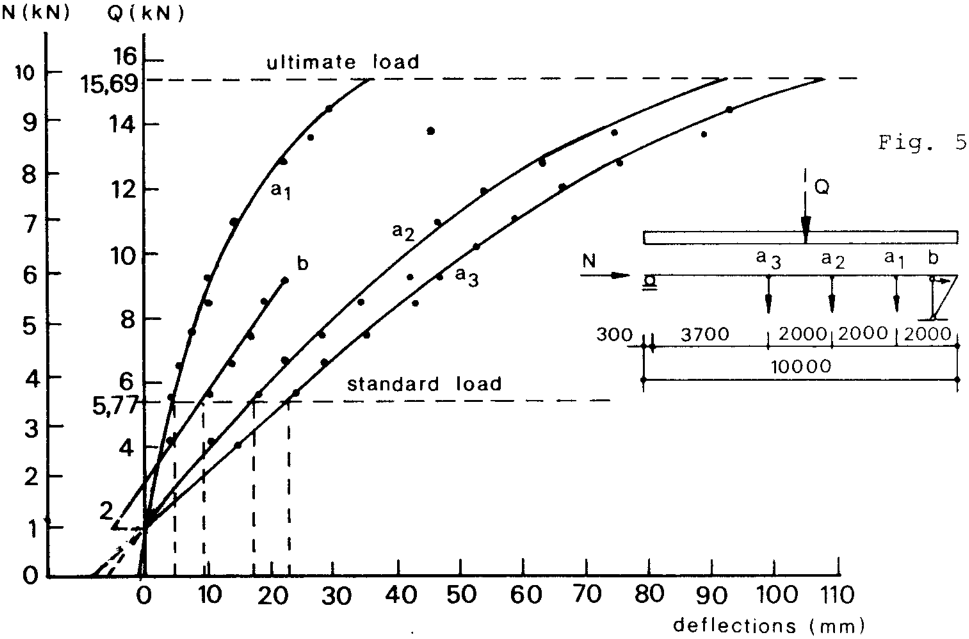


Fig. 5.

SOLAR ENERGY AND THE USE OF STEEL FOR A NEW ARCHITECTURE

V. BACIGALUPI

University of Rome

Summary

The energy crisis and the predicted depletion of fossil fuel reserves has led to a policy of attempting to reduce both consumption and dissipation and of moving towards renewable energy sources, the most important of these being the sun which provides earth with a quantity of energy 10 000 times greater than present consumption.

Not all that energy can be effectively used, but systems which can be applied in building offer not inconsiderable economies in the heating of space and water for domestic purposes.

Solar collection and concentration panels introduce new elements into the language of architecture. Steel is the material best adapted to put into effect the elements of design and form in the new architecture, quite apart from considerations of energy components.

Given a system of solar panels providing about 60% of the heating requirements of a building, some 88 kg of steel per user over and above that needed for conventional purposes can be foreseen.

Moreover, the use of steel is indispensable for the support pylons of large (up to 50 m high) wind-powered generators and for MIUS (modular integrated utility systems) producing electricity and heat with great efficiency.

1. THE ENERGY CRISIS

Man has satisfied the energy requirements of his activities over the centuries in a variety of ways, from human and animal muscular energy transformed directly into mechanical energy, to the various forms of combustible fuels of greater or lesser accessibility (wood, coal, hydrocarbons) as well as the natural power sources such as wind and water. Quantitative and qualitative availability has determined both the economics of its exploitation and the form of installation and equipment. In certain cases, the effects have also been felt on the environment. One only has to mention the extent of deforestation to provide wood for burning, dykes and dams for hydro power, fume and gas from chimneys, thermal power stations, pylons and wire for high-tension transmission of electricity.

Furthermore, the form of buildings has echoed the various technologies for the conversion and use of energy supplies, and construction techniques have come to reflect the cultures and societies which have used them.

The first industrial revolution undoubtedly changed the traditional relationship between man and his environment, and between natural and artificial environments, giving the illusion of the ability to dominate the natural environement through the series of discoveries, inventions and innovations, without taking the broader view of the problems created or perception of the interactions which exist between elements of an apparently diverse nature.

The politically inspired energy crisis which began in 1973 has not only affected the whole world, and especially the industrialised countries, it has also highlighted the fundamental questions concerning the utilisation of the world's existing energy resources.

The quantity of coal mined and consumed from 1940 to the present day is almost equal to the total consumption of all time up to that date. The total production for the period 1860 to 1970 was about 133 thousand million tons; before 1860 it was about 7 million tons - a ratio of about 19 000 : 1.

The situation is very similar with respect to oil. During the 80 years from 1890 to 1970, output grew at an annual rate of 6.94%, doubling over a period of about ten years. At the end of 1969, total production was 277 thousand million barrels, of which:

- the first half had been produced 1875-1959 (84 years)

- the second half had been produced 1959-1969 (10 years) (1)

What has happened has been a frantic depletion of traditional energy sources, regardless of what is to happen when those sorces are exhausted and without consequent research on alternative and renewable sources, still less reduction of the annual rate of increase in consumption.

The same situation prevails for other technologically indispensable minerals (Fig. 1).(2)

RAW MATERIALS	Know reserves	Static index years	Predicted growth rate, % year			Exp. index years	Exp. index assuming 5 x reserves years
			max.	moy.	min.		
aluminium	1,17 x 10^9 t	100	7,7	6,4	5,1	31	55
chromium	7,75 x 10^8 t	420	3,3	2,6	2,0	95	154
coal	5 x 10^{12} t	2300	5,3	4,1	3,0	111	150
cobalt	2,2 x 10^6 t	110	2,0	1,5	1,0	60	148
copper	308 x 10^6 t	36	5,8	4,6	3,4	21	48
gold	11 x 10^6 kg	11	4,8	4,1	3,4	9	29
iron	1 x 10^{11} t	240	2,3	1,8	1,3	93	173
lead	91 x 10^6 t	26	2,4	2,0	1,7	21	64
manganese	8 x 10^8 t	97	3,5	2,9	2,4	46	94
mercury	3,34 x 10^6 bottles	13	3,1	2,6	2,2	13	41
molybdenum	4,9 x 10^6 t	79	5,0	4,5	4,0	34	65
natural gas	32,3 x 10^{12} m3	38	5,5	4,7	3,9	22	49
nickel	66,5 x 10^6 t	150	4,0	3,4	2,8	53	96
petroleum	455 x 10^9 barrels	31	4,9	3,9	2,9	20	50
platinum group	13,3 x 10^6 kg	130	4,5	3,8	3,1	47	85
silver	170 x 10^6 kg	16	4,0	2,7	1,5	13	42
tin	4,36 x 10^6 t	17	2,3	1,1	0	15	61
tungsten	1,32 x 10^6 t	40	2,9	2,5	2,1	28	72
zinc	123 x 10^6 t	23	3,3	2,9	2,5	18	50

Fig. 1

> "Recent, rather speculative, discoveries must not cause it to be forgotten that there are very few areas which can be searched for new mineral deposits; indeed, many geologists doubt whether such prospecting can be successful. It seems unwise to make long-term predictions about the discovery of rich new deposits of basic raw materials." (3)

The more serious and immediate problems are those faced by those countries which are not coal or oil producers, such as Italy, whose energy requirements must be largely satisfied without domestic primary resources (80% of consumption being covered by fuel imports). The slogan of the times, reflecting a very real objective, is 'save it'. Energy conservation in general, and especially with reference to the traditional 'exhaustable' resources, can be achieved in a number of ways:

- reduction of consumption
- reduction of waste, i.e. of the energy quantity consumed but not used
- the use of alternative and renewable resources

Still taking the broader view, the building industry can make a contribution to the conservation of energy. Domestic space and water heating in Italy accounts for about one quarter of all energy consumption, so that any improvement there brings tangible results. Consumption reductions can be achieved by technological, political, and economic methods and by standards and practices (fuel prices, regulation of heating periods, maximum temperatures, etc.). Reduction of waste affects both planning for new structures and corrective action with regard to existing ones. Wastage is primarily due to design defects, poor materials, and equipment inefficiency.

Any move towards renewable energy sources tends to reduce the consumption of fossil fuels (particularly coal and oil) by way of the construction of specialised plant, but more especially through a new approach to the planning of buildings.

A building must, as a whole unit, give off the minimum quantity of heat to its surroundings, and take the maximum quantity from alternative sources by planned use of equipment or the structure.

2. SOLAR ENERGY

The annual delivery of energy to the earth from the sun is about 10^{18} kWh. In a single month, energy arrives which is equivalent to 10^{13} tons of coal, which roughly corresponds to the total fossil resources presumed to exist.

Taking the annual energy consumption of the human race at the present time to be 10^{4} kWh (i.e. 10 thousand times less than the solar contribution) the justification for paying special attention to those systems based on solar energy is evident. Numerous examples already exist of installations in use in buildings with positive results.

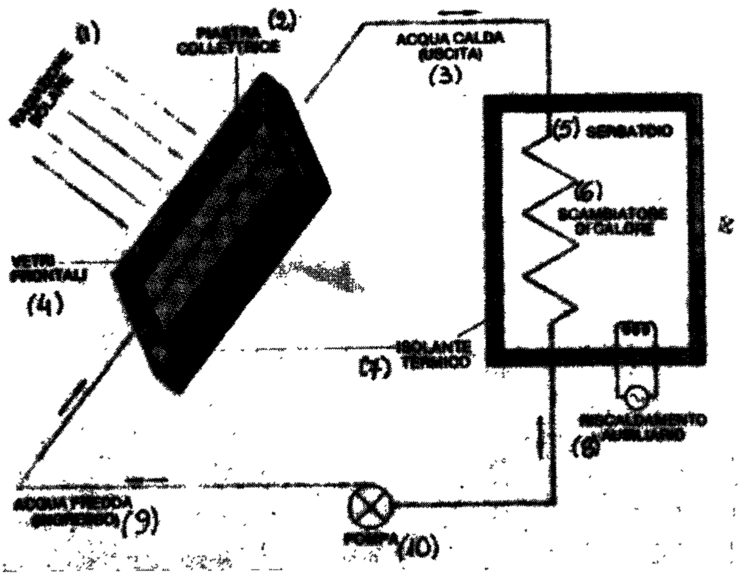
The sun's energy (delivered free and without pollution), is not uniformly distributed over time and space; it varies according to latitude, season, meteorological conditions, atmospheric haze, etc. Figures for various locations can be provided on the basis of mean monthly tables of:

- external temperature
- hours of sunlight
- hours of daylight
- mean radiation (kcal/m^2 per day, south facing surfaces)(4)

Naturally, not all the available energy can be used, due to the efficiency of the equipment and the inevitable thermal losses. Moreover, radiation is not continuous day and night, summer and winter, so that storage during periods of superabundance for use during the shortage periods is a most important problem.

The energy of the sun can be 'captured' by active or passive systems to produce high- medium- or low-temperature heat.

An active system can be one of two main types: collectors (for low and medium temperatures) and concentrators (for medium or high temperatures). The collector system consists basically of a dark-coated panel of metal to which are welded (or otherwise connected) ducting for the fluid (usually water) which is to be heated. Above the metal plate, at a distance of a few centimetres, is a transparent surface, such as glass, and below it is an insulating layer. Solar radiation (at a wavelength of 0.48 microns) passes through the transparent layer and strikes the dark plate which absorbs it almost entirely and passes it through to the circulating fluid. The dark plate, once heated, starts to radiate heat at a much higher wavelength (about 7 microns) and this is to a great extent unable to pass back through the transparent layer. The heated fluid can be passed directly to a heating installation or can give up its heat via an exchanger to the water or air of that installation (Fig. 2).



1. solar rad.
2. collector panel
3. cold water (out)
4. frontal glasses
5. reservoir
6. heat collector
7. insulation
8. auxiliary heate
9. cold water (in)
10: pump

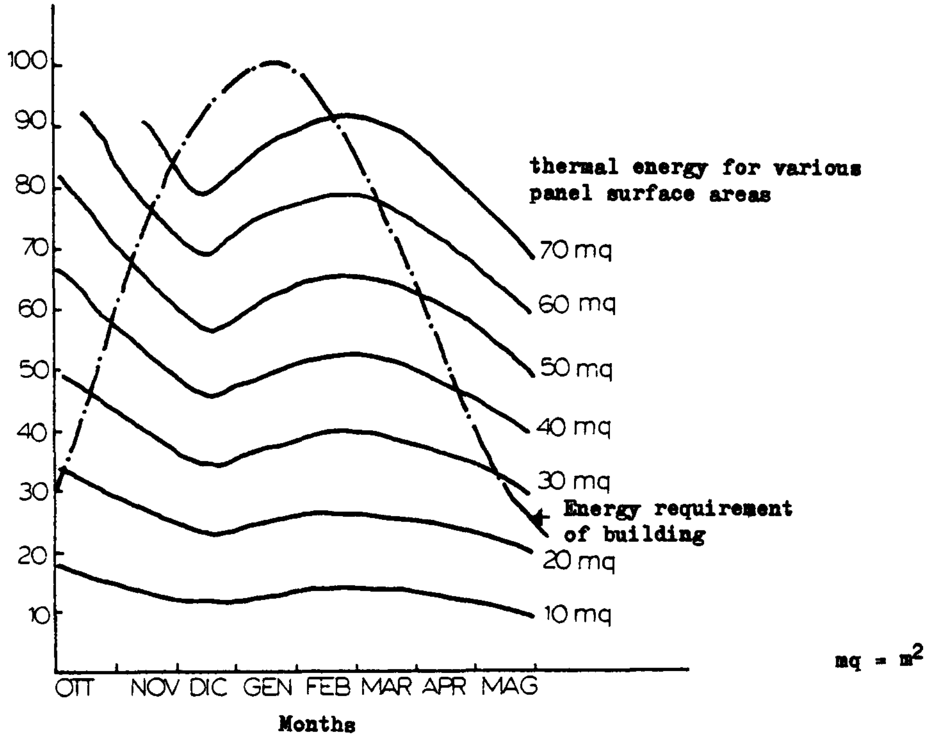
Fig. 2 : Diagram of solar water heater

In order to optimise panel performance, they are oriented towards the south and are inclined in accordance with the latitude at which they are located so that as afr as possible the sun's rays fall perpendicularly onto the surface. One of the more difficult problems with these installations is the calculation of the surface area of the panels; too great a surface area could only be used for a small part of any year and could, therefore, prove uneconomical in terms of cost and depreciation. (Fig. 3).

Another problem relates, as mentioned above, to the storage of heat. In general, water systems have been adopted, in which the temperature is raised during the hours or seasons of exposure to sunlight so that the heat thus generated can be held and released during other periods. The size of the water reservoir can need to be very large to ensure the integrity of the plant even in the absence of sunlight.

Solar energy installations are generally integrated with those of conventional type in order to minimise the dimensions of the collector surface area and of the water storage system.

Solar equipment of the concentrator type consists essentially of a reflecting surface (a mirror) which is rotatable or sliding and which concentrates the sun's rays onto a point or along a line to produce very high temperatures (above 1000°C).



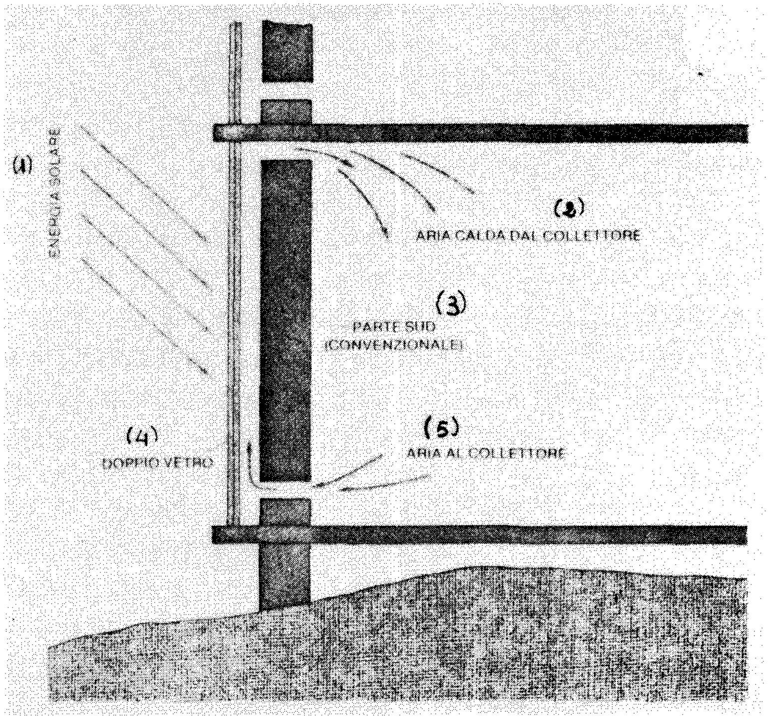
Such systems are especially applicable where superheated steam is to be produced; they are a greater problem than the former type in terms of reflecting surface, maintenance and operation. In fact the best efficiency is obtained if the concentrator is turned permanently towards the sun either manually or by means of a sensitive mechanism.

Passive systems are of the same general design in terms of collectors and accumulators of heat; they do not incorporate mechanical means of movement of the fluid.

Air conditioning in a building is normally achieved by means of natural circulation of warm or cold air using fairly simple devices according to the design and concept of the building.

A noteworthy system for the use of solar energy is the Trombe method. Glass is placed in front of a fairly massive wall, oriented towards the south and coloured black; it makes use of the glasshouse effect involving the opaque (absorbent) and transparent (receiving) surfaces.

Apertures in the walls at floor and ceiling level create convection currents of cold air moving upwards. The glass surface also has apertures allowing warm air to escape to the exterior in summer (Fig. 4).



1. solar energy
2. cold air from collector
3. south face
4. glass plate
5. air to collector

3. THE USE OF SOLAR ENERGY AND THE FORM OF BUILDINGS

Throughout the history of the building industry, atmospheric and meteorological conditions have normally influenced the choice of the general shape and form of the building. That has been the case, and may still be so today, where the internal environmental conditions are only partly or in a localised manner 'adjusted' in relation to the external conditions; i.e. the adjustment is not integral. For example, the rainfall in a given locality or the likelihood of snow affect the slope of the roof and the roofing materials.

Lengthy exposure to strong sunlight, such as is typical of southern regions, leads to thick roofing of stone or tile (i.e. of high thermal intertia) and whitewashing.

The profusion of new materials and technological solutions for making a basic 'correction' to the external conditions has moved building form away from the influence of meteorological conditions. Thermal insulation layers and weatherproofing have made flat roofing possible anywhere and large expanses of glass are theoretically admissible (cost and energy saving apart) even in very hot or very cold climates.

The utilisation of alternative energy sources (especially solar) has put the problem in new terms, bringing a variety of specialised elements into the technological repertoire. These new elements are, by their nature, of considerable dimensions and are externally placed. When a building is planned for energy self-sufficiency, either total or partial, by means of solar energy (and that appears to be the best solution in terms of technology and architectural convenience), the collector elements must behave, in terms of form, like the other elements of the structure. In view of the scale of technological innovation, the solution cannot be in the usual synthetic form.

A far-from-complete review of the possibilities is provided by the following, which indicates the extent of the questions facing the planners:

a) inclined panels: can be assimilated into the roofing geometry even if the inclination varies; it is different with regard to colour and grain of transparent collector or dark absorbent surfaces

b) concentrators: generally elements which are integral to the building but not excluded from considerations of form, especially from the viewpoint of urban appearance; an interesting example of integration of collectors and the building structure is provided by the offices of CNRS solar energy laboratory at Odeille-Font Romeau, France, built in 1971, in which the long-range parabolic collectors form the north facade of the building on nine levels.

4. THE ROLE OF STEEL IN A NEW ARCHITECTURE

What is the place of steel in this new branch of technology which is so much attracting the attention of the planners and builders of the 80s?

Above all, the social and economic necessity of industrialised building has shifted the emphasis from commissioned design to large-scale concepts.

Serially produced materials have to be arranged in systems allowing for prefabrication of components; this implies dimensional standardisation of assembly systems, and not just straightforward qualitative standardisation. Today, it is not only possible to 'construction components', 'energy components' can also be specified; given uniform technological characteristics specification from the viewpoint of energy criteria is possible, plus assembly with components of current type.

In this respect, steel is the ideal material, in view of its wide possibilities in terms of finished products:

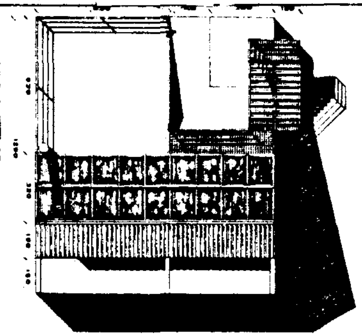
- good dimensional tolerances
- adaptability throughout the building process by virtue of the many interfacing and joining methods
- lightness in terms of strength, with consequent transportation and handling advantages (5)

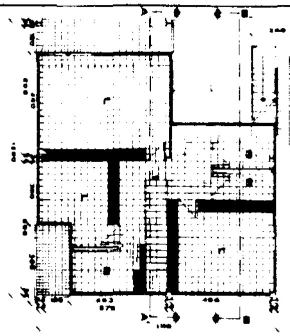
Steel structures, moreover, with their statics and design characteristics provide the ideal solution for the new range of forms. Inclined surfaces, of modest weight, are integrated with the structure and require simple design criteria. and they can be pre-assembled outside the main work. An example is provided by a rural residential project, heated by solar panels and using steel, which has been studied by a working group of students and academic staff in the Technology of Architecture course at the University of Rome (Figs. 5 and 6).

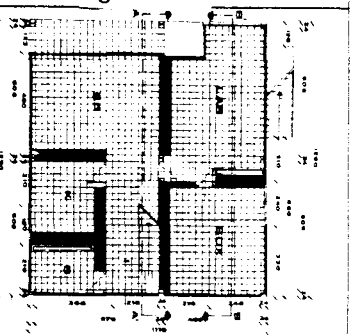
Secondly, it is useful to take a quantitative look at the possibilities for the use of steel in the various solar energy utilisation schemes described above. The basic component of the panel is the collector plate made from an Italian common steel, which material represents the greatest proportion by weight. For 1 m^2 of panel:

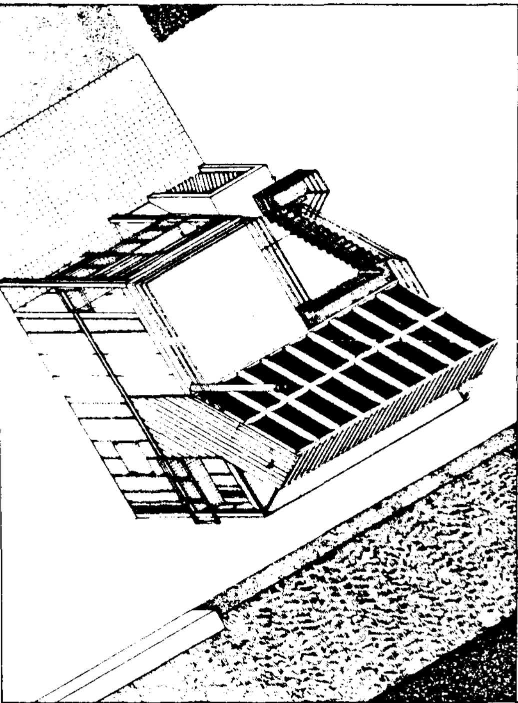
PROGETTO DI MASSIMA

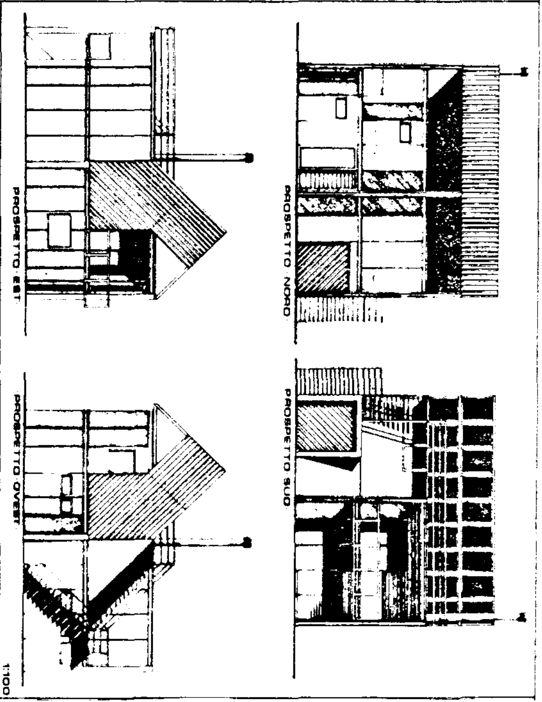
:100 **Roof** **first floor** **ground**

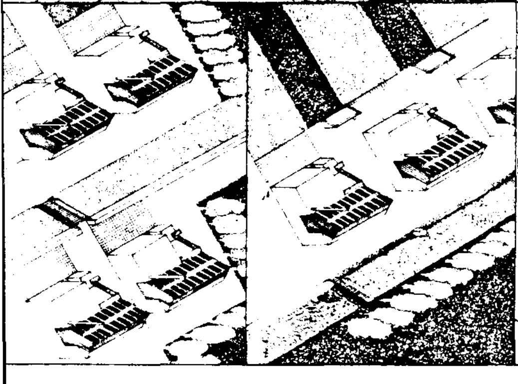




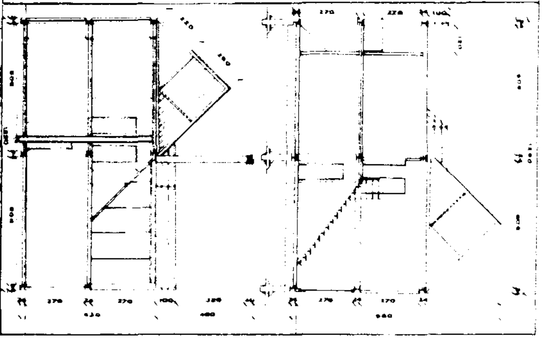


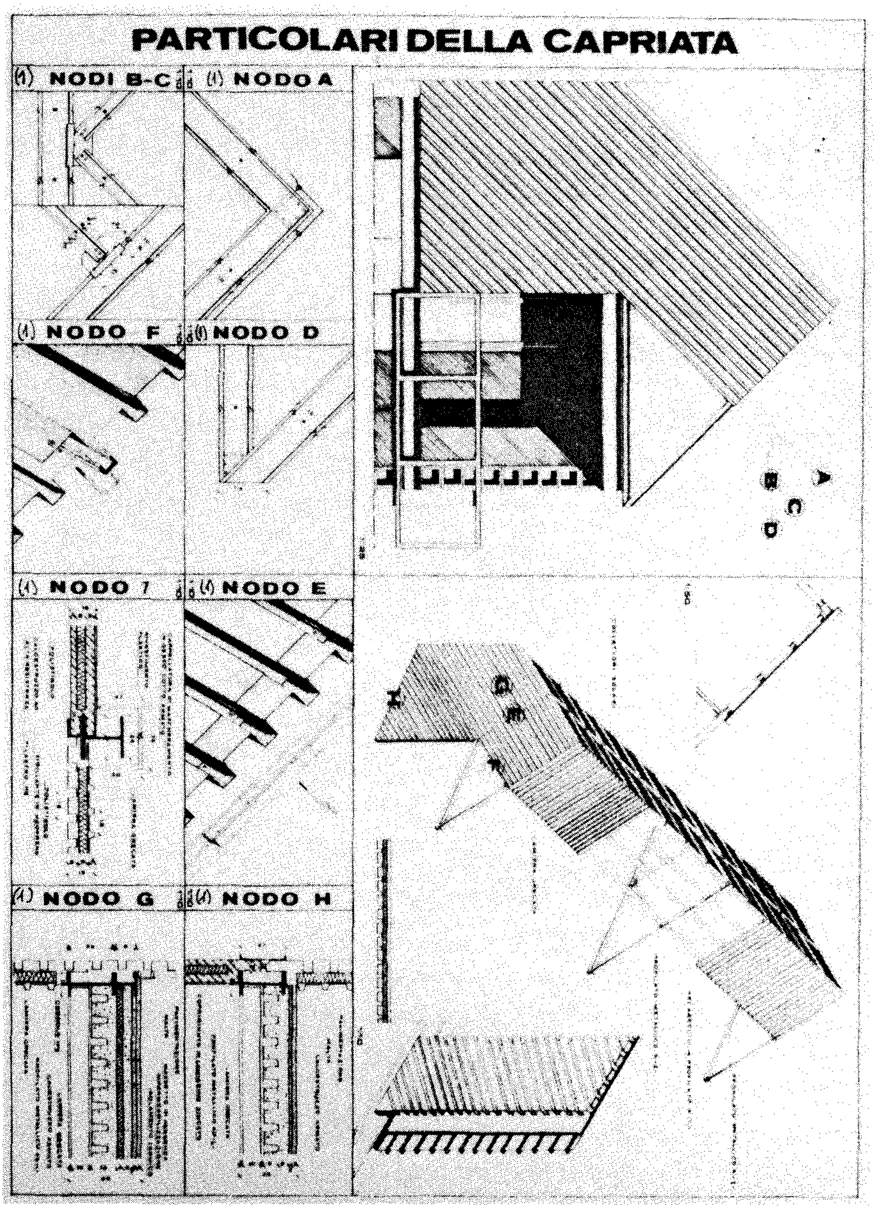






SECTION B-B **SECTION A-A** 1:100




PARTICOLARI DELLA CAPRIATA
(1) NODI B-C
(1) NODO A
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(1) NODO D
(1) NODO 1
(1) NODO E
(1) NODO G
(1) NODO H
A
B
C
D

aluminium	3 kg	(14%)
glass	7	33.2
steel	8	38
insulator	2	9.5
accessories	1	4.9
Total	21	

Important here are the mechanical strength and thermal conductivity properties of steel (50 kcal/m h °C).

The obvious consequence is the consideration of the use of steel in solar equipment on a large scale, i.e. leading to tangible economies in the consumption of fossil fuels. The following example, using very broad figures, shows the relative orders rather than precise quantities. A population of 1 million, in the central region of Italy
and assuming a volume to be heated of 10^6 m^3 has these annual needs:

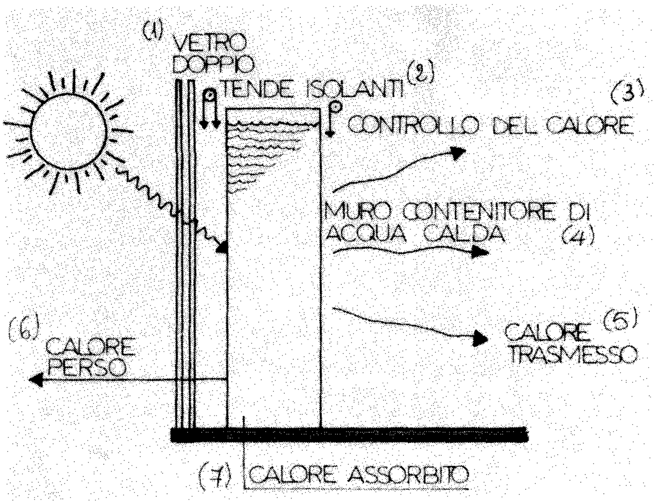
for heating	2.02×10^{12} kcal
for washing	0.65×10^{12} kcal
losses in generation and transport	1.00×10^{12} kcal
Total	3.67×10^{12} kcal

Assuming the solar plant to cover 60% of the requirement and that each m^2 of panel provides approx. 300×10^3 kcal annually, there is a resulting saving of about 220 000 tons crude oil; the requirement is then for about 7 340 000 m^2 of panel which assumes some 58 720 tons steel.

To this must be added the material needed for the storage tanks (capacity about 70 l for each m^2 of panel) making a total volume of 513 800 m^3. If the capacity of each tank is 26 m^3 and the weight of the steel components is 1500 kg, the requirement is 29 600 tons steel. The use of solar panels for domestic heating and washing purposes means about 88 kg steel for every person, without those quantities involved in ducting and radiating.

Apart from the solar panel systems themselves, other methods have been tested which unite the collector and storage systems into modular energy packs in the external structure of a building. In the case of water systems, the Trombe wall has already been mentioned. This has steel walled tanks working with heating elements with external surfaces blackened and glass covered and with stores (Fig. 7).

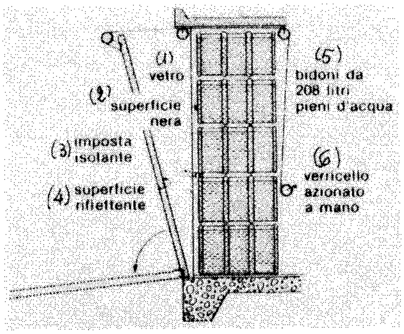
Experimental buildings using this concept have been constructed using standard steel components normally intended for other purposes, such as 160 litre petrol drums.



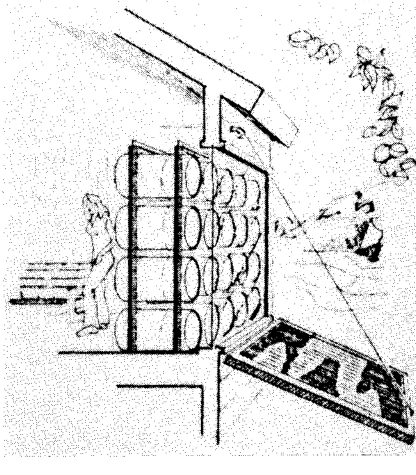
1. double glazing
2. insulation
3. heat control
4. wall containing warm wa
5. heat transmission
6. heat loss
7. absorbed heat

In the example in Albuquerque, New Mexico, the drum walls, filled with water, are exposed to sunlight during the day, are protection from excess heat and store thermal energy. During the night and cloudy days, they are protected from heat loss on the exterior by an insulating layer and restore heat internally.

The corrugated or louvred sheet steel cladding, appropriately oriented and dark-coated, can be used for active and passive systems. In water systems, the fluid is contained in the concave parts which are coated with transparent surfaces; in air systems, the air circulates beneath the cladding and delivers heat through ducts and vents (Fig. 8 and 9).



1. **glass**
2. **dark surface**
3. **insulator**
4. **reflective surface**
5. **208 l drums water filled**
6. **manually operated hoist**



Steel also plays a central role in the generation and use of alternative energy forms such as wind or organic refuse systems.

Wind power is proportional to the cube of its velocity, velocity which is affected by a range of orographic and geographic factors as well as by the height of the generator. The generator is basically a rotor (with vertical or more usually horizontal axis) and a two or three blade propellor. The mechanical energy is converted into electricity by means of an alternator and then passed to batteries; alternatively, pumps can draw water or compress air into natural or artificial reservoirs.

Clearly, the larger the rotor diameter, the greater the power obtainable, hence the height of the supporting structure. The supporting structure is subject to static stress resulting from the weight of the apparatus and its own weight, as well as to dynamic stresses (wind force, propellor rotation).

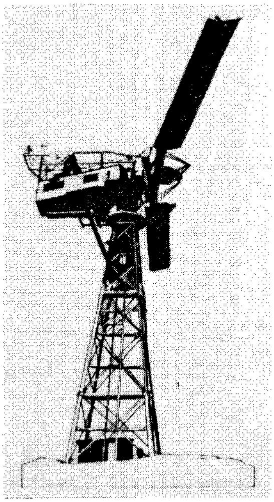


Fig. 10 The Smith-Putnam windmill of 1250 kW rating, built in 1941 at Grandpa's Knob, Rutland; Vermont; note scale of human figure at base

It is usual for the propellor to be adjustable for wind direction, so that the generator must move around a vertical axis (Fig. 10). In order not to present an obstruction to the wind, and thus cause vortices which can affect the operation of the machine, open steel frames are generally used, especially in large-scale applications. The shape and size of the supporting structure and of the sections from which it is composed, must take account of the direction of horizontal stresses. Figure 11 shows some of the characteristics of actual installations; the weight of the supporting structure is obvious - amounting to about 40% of the total, and with a maximum of 70%.

Denomination	diameter m	blades	height of support structure; m	total weight kg	rotor weight kg	support structure weight kg	power, kW, from wind at 12 m/s
Vime	5	3	15	1875	135	1300	6,4
Neyrpic	8	3	15	3860	500	1800	17
Zvei	12	3	16	5497	1129	2553	40
Neyrpic	13	3	15	7265	1600	2500	45
Gusmp	18	3	20	16000	3240	6655	88
Neyrpic	21	3	20	29000	7300	8000	120
Zage	30	3	25	49070	-	15070	230
Zwel	50	3	50	226000	48000	92000	640
Putnam	53	2	35,5	348000	100000	110000	750

Fig. 11

Energy recoverable from organic waste should not be ignored. The waste is fermented in the absence of air, through various stages and under predetermined dosage, temperature and acidity conditions. The result is biogas - a mixture of methane and carbon dioxide. This gas has good thermal characteristics (5500 kcal/m^3, roughly equivalent to 6.4 kWh) and can be produced in large quantities, especially in association with farming, where animal waste can be used. The 'digestor' basins are made of steel since they must be watertight, have good mechanical strength, and be of considerable size. Also steel are the gas collector hoods, storage tanks, and gas and slurry discharge pipes.

Obviously, these are not examples of architectural elements in the formal sense of the expression; the combination produces a different organisation of territory, with decentralised units having a high level of self-sufficiency in which individual productive activities, agriculture, industry, craft, as well as dwellings and services, are integrated into renewable energy systems.

Finally, MIUS (Modular Integrated Utility Systems): this is the generic term for those basically simple systems producing electricity and heat simultaneously and with a good level of efficiency.

Among these is TOTEM (total energy module), developed by FIAT and combining the engine of a 127 car (fuelled by petrol, methane or biogas - which can in turn be produced from animal waste) with an asynchronous electric motor. The electric motor delivers 16.5 kW, while the heat recovered from the cooling water, the oil and the exhaust amounts to 33000 kcal/h. The overall capacity is 92% and the heat produced is enough to provide for four medium size dwellings in the climate of northern Italy. TOTEM is fairly compact (about 1 m^3) and its total weight of 390 kg is distributed:

frame 90 kg; sound-proofing 60 kg; i.c. engine 70 kg; electric motor 100 kg; heat exchanger 70 kg.

About 90% (350 kg) of this is constituted by steel components, whether common or alloy; they represent the basic elements in rational and efficient use of traditional energy resources and integrated sources.

5. CONCLUSION

In the face of the energy crisis now confronting in some degree or other all the technologically advanced countries, steel is taking up the challenge in proportion as alternative energy sources are increasingly used in the building industry. The 'new architecture' which is being derived from this unpublished but dramatic situation is more conscious of environmental conditions and which is being integrated with the environment both in form and in technology, cannot exist without steel. This material provides the way to solutions for planners and builders.

NOTES

1. from 'The world's energy resources' by M. King Hubbert Le Scienze , 1971, Dec. no. 40 (Italian edn. of Scientific American.

2. The data on known reserves are from 'Mineral facts and problems', 1970, US Bureau of Mines. The static index is defined as the number of years availability of verified reserves on the basis of present consumption. The exponential index is the number of years of availability of verified reserves on the basis of an exponentially increasing index of consumption (average rate of increase is used in the table); the exponential index ref. to reserves multiplied by five is the number of years of available reserves five times greater than those existing, on the basis of an average rate of consumption.

3. 'First annual report of the Council of environmental quality', Govt. Printing Office, Washington, 1970.

4. For example, about 100 m^2 surface inclined to the horizontal at an angle equal to the latitude of the location, receive, for the month of July:

location	latitude	kcal	litres fuel oil equiv.
Turin	45°13'	12068000	1371
Rome	41°48'	15069000	1712
Naples	40°51'	12710000	1444

5. Ratio of specific weight: safe load for various materials:

brick	200
reinforced concrete	34
wood	10
aluminium	5.4
steel	4.4

Weight of normal structure with reinforced concrete frame: about 250 kg/m^3 calculated as is without openings, corresponding to a residential block with 20 tons per inhabitant (about 20 average cars). A column of 30 x 40 cm, 3 m high weighs as much as an average car; a building of 500 m^2 ground area 20 m high weighs about 2500 tons, or about the same as 9 fully loaded jumbo jets. The structure of a building in reinforced concrete weighs about 120-125 kg/m^3, in steel the weight is about 15-18 kg/m^3.

NEW DEVELOPMENTS IN THE USE OF STRUCTURAL HOLLOW SECTIONS

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Summary

The growing use of hollow sections is a result equally of developments in range and applications as well as of the aesthetic effect of expanses of structural steelwork. Research and development work under the leadership of the tube manufacturers on a national and an international scale has provided the bases, recommendations and standards for reliable application in structures of all kinds. A wide range of hollow sections in many sizes and qualities is available to the architect and the engineer for the realisation of their designs and ideas. The paper provides some examples.

1. APPLICATIONS FOR HOLLOW SECTIONS

Steel can in general hold its own in building technology in relation to other materials as a result of the innovations in the area of hollow structural sections. Two outstanding characteristics of hollow sections account for their widespread use in recent years: the spatially economic use of steel supports and the progress made in fire resistance especially in view of the abandonment of insulating material on the outer surface. The growth in the use of hollow steel sections is also a consequence of the existence of universally applicable standards throughout the world which are the result of fundamental and specific applied research work undertaken and initiated by the tube producers. The aesthetic effect of the use of hollow sections is also essential to note. Correctly designed and architecturally thorough buildings using hollow sections have encouraged many architects and structural engineers to make, to an increasing extent, the hollow sections visible - with by no means insignificant economic advantage. Hollow steel sections are there to be seen and not hidden under walls and cladding and so on.

Along with the research and development work, economic studies have also been undertaken. Some of the prejudice existing among builders, architects, authorities and even structural engineers has been swept away. Many questions have been answered and some are still being investigated, with a view to making steel tube structures better resistant to corrosion and fire and to improve the economics of their use in respect of other materials. The optimum use of sections, shapes and strengths has made a contribution to the economic application of hollow sections. One method of improving the economic aspects is the judicious mixing of open and closed sections and concrete components in situations where the properties of the different components complement one another.

An encouragement to the use of hollow sections is the prefabrication of supports, trusses and tie beams in the works for subsequent joining in larger units on site.

Hollow sections used as supports have great technological and economic advantages, as a result of their excellent buckling and torsional rigidity and their good joining properties. Knowledge of the load-bearing properties of concrete-filled supports and of their fire-resistance has led to their more extensive use. All conventional fire protection methods, such as cladding, sprayed asbestos, etc., are of course available. The space-opportunities offered by hollow sections as supports leads to a more economical utilisation of the building volume, an advantage which will be increasingly sought.

A particular advantage of the use of steel, and certainly, of hollow sections, has been evident in recent years in terms of rebuilding and demolition. The short periods of time necessary for the enlargement or size reduction of schools, stores, and leisure centres, as well as administrative buildings makes for a decided advantage over other building materials. Furthermore, the value of the scrap should not be ignored.

One still little used advantage of hollow sections appears in connexion with heating and air conditioning.

Of considerable significance is the use of labour-saving joining methods such as thread or socket joints in place of high labour cost welding. Progress is evident here in terms of structural design, load-bearing properties and architectonics.

2. PRODUCTION PROGRAMME, THICKWALL, SPACE-SAVING HOLLOW STEEL SECTIONS

New opportunities for building applications are opened up by the recently available hot formed tube with very thick walls.

Table I shows the dimensions supplied by a producer; other sizes and wall thicknesses up to maxima of 1200 x 1200 x 100 mm are supplied to order (1).

Thickwall hollow sections are important for use in high-rise buildings, structural work below ground level, tunneling, and bridges. New possibilities are also provided in heavy engineering applications.

The steel tube producer provides, as well as round-profile tube, hollow sections with square or rectangular profiles in various strength categories. The number of tube shapes and sizes is constantly increasing (Fig. 1). Use is made of the excellent strength and rigidity properties in doors, windows, facades, partitioning, radiators, vehicles, furniture, and many more areas. The continual growth in areas of application is not least the result of the progress made in corrosion resistance by means of galvanising, plastic coating, and materials-oriented design (1).

3. FIRE PROTECTION

The need to protect structures against fire is a decisive element for all building components, materials, and designs. The fire resistance of hollow sections has been considerably improved over recent years as a result of systematic research.

Cooling systems for supports have been widely applied and frequently described. The economic aspect in comparison to other building methods has been emphasised. The use of hollow sections for this purpose is increasing. While, in earlier reports, the few examples were discussed repeatedly, the worldwide application has increased, though not yet part of the general knowledge of all architects and structural engineers. There are no problems, but considerations of economy are still at least a talking point between builders and architects. A recent example is provided by the Institute of the Landesanstalt für Umweltschutz (the Land office for environmental protection) built in Karlsruhe in 1975. (Fig. 2). The 48 outer supports are of 180 x 100 mm^2 rectangular hollow sections in weather-resistant ACOR 37-2 steel.

Building licenses have been issued in a number of areas for the use of this fire protection technique, so it is to be expected that permission for individual buildings will become easier in the future.

A new development is the use of hollow sections with concrete filling, in which under certain conditions the outer protection of the hollow section by means of coating or jacket can be dispensed with up to and including fire resistance class F 90 (fire-resistant) (Fig. 3). The special measures which have to be taken are the correct selection of the cross-section ratio steel/concrete, increasing the steel cross-section by means of floating longitudinal reinforcement, the use of twin-tube supports, and the reduction of the permitted compressive load. The first buildings using concrete-filled supports without external protection and with fire class F 90, are now under construction (1).

4. LARGE SPANS

Hollow sections can be used economically for large spans, even more than 30 m. Examples are numerous. Figure 4 shows the roof structure of a warehouse accentuated by strip lighting, even if the goods in a major port obscure the picture. Figure 5 shows sections through a three-part sports hall with angled three-chord beams on the supports. Figure 6 shows the impressive size of the 24 x 36 m^2 span of a sports hall. Figure 7 confirms the well-known ability to roof large areas without support, as well as the advantages of a light, open construction favoured in southern lands, and which is architecturally satisfactory. Prefabrication at the works makes for easy and rapid assembly in a distant country with little need for skilled labour, or, in some cases, for a crane.

5. RESEARCH, DEVELOPMENT, STANDARDS

As a result of the research and development work undertaken in recent years by the producers of round sections, not only has extensive applied knowledge been collected, but also national working groups in several countries have produced standards and design recommendations. Some of these are here mentioned: DIN 18808, Feb. 1980 'Structural work in hollow sections under mainly static load' (2). This is valid for hollow sections with closed, circular, square, or rectangular hollow section with constant longitudinal and circumferntial wall thickness. Steels St 37 and St 52 should in general be used for members and welded joints.

In France, there is at the moment NF P 22-250 for circular hollow sections. In the Netherlands, there is directive RB '78 for the calculation of hollow section tubular structures, using circular or rectangular sections. The American Welding Society has issued AWS D 1.1-79 mainly for circular and partly for rectangular hollow sections. Other recommendations and standards will follow, since the research initiated by CIDECT (3) in the last few years has been completed and will be published in the monographs on welded tube joints under static and fluctuating load in 1980-81.

The many parameters for welded joints which have been investigated can be assumed from the accompanying illustrations.

In Figures 8 and 9 are given the data from numerous investigations on K and N joints under fluctuating loads. The investigations were financed by the ECSC and the tube producers' organisation CIDECT and were conducted in five laboratories (Delft, Karlsruhe, Liège, Nottingham, Paris). The fatigue limits for various stress conditions are incorporated with the network of dimensional parameters (3).

That is only one example of the large amount of work carried out in all areas of steel construction and steel applications.

6. OUTLOOK

It would appear that not all the properties of variously shaped hollow sections in relation to relatively small external surface area and inner space have been utilised. Fundamental problems such as increasing stability by concrete and steel reinforcement, improvement of fire resistance by concrete filling, and corrosion protection, have been solved. The data obtained by experts deserve the most widespread publicity. Further exploitation of the inner space for carrying fire protection or air conditioning media, or for services needs the attention of men with ideas.

7. REFERENCES

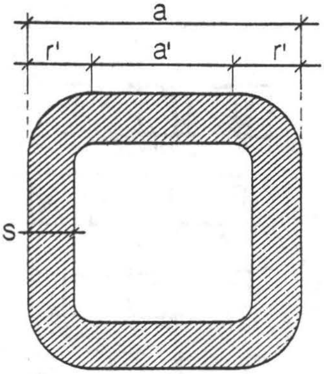
(1) Mannesmannröhren-Werke AG, Düsseldorf, publications:
No. 6116/1 'Hot extruded thickwall steel hollow sections' March 1980
No. 6085 'Tubes - range, systems, applications' 1980
No. 6101 'Mannesmann structural hollow steel sections MSH' Tech. Inf. 7 Dec. 1979.

(2) Symposium 'Hollow sections in structural steelwork - draft DIN 4116 (DIN 18808' Essen, 12 Dec. 1979.

(3) CIDECT - Comité International pour le Développement et l'Etude de la Construction Tubulaire; reg. off. Geneva; Tech. Sec. Croydon.

Table I

DIMENSIONAL RANGE OF HOT EXTRUDED,THICKWALL HOLLOW STEEL SECTIONS



uter ia. minal	Wall th.	Outer radius	Cross sect.	Mass	Area of cyl. surf.	Static values 2)					Plastic resis-tance moment
						bending axis 5) x-x = y-y			twist 4)		
a m	s mm	r mm	F cm^2	G ~ kg/m	U m^2/m	J_x cm^4	W_x cm^3	i_x cm	J_t cm^4	W_t cm^3	W_{pl} cm^3
200	25	37,5	164	129	0,736	8170	817	7,05	13780	1500	1060
220	35	52,5	238	187	0,790	13130	1190	7,43	22660	2320	1600
250	35	52,5	280	220	0,910	20940	1680	8,65	35720	3160	2200
	50	62,5	368	289	0,893	24230	1940	8,12	40920	3880	2700
280	20	30,0	201	158	1,070	22320	1590	10,50	35980	2690	1940
	25	37,5	244	192	1,060	25970	1860	10,30	42560	3220	2300
	50	62,5	428	336	1,010	37210	2660	9,33	62460	5170	3620
300	30	45,0	309	242	1,120	36700	2450	10,90	60700	4330	3070
	35	52,5	350	275	1,110	39960	2660	10,70	67000	4840	3410
	60	75,0	530	416	1,070	50240	3350	9,74	84840	6700	4670
320	30	45,0	333	261	1,200	45690	2860	11,70	75170	5000	3560
	40	50,0	427	336	1,190	55090	3440	11,40	90240	6210	4430
	45	56,3	469	368	1,180	58260	3640	11,10	96250	6720	4760
350	30	45,0	369	289	1,320	61760	3530	12,90	100900	6100	4360
	45	56,3	523	410	1,300	79950	4570	12,40	131200	8280	5900
	55	68,8	610	479	1,280	87220	4980	12,00	145200	9410	6630
380	25	37,5	344	270	1,460	71300	3750	14,40	114400	6270	4540
	45	56,8	577	453	1,420	106300	5600	13,60	173800	10000	7150
	60	75,0	722	566	1,390	121400	6390	13,00	202200	12080	8510
400	30	45,0	429	336	1,520	96230	4810	15,00	155700	8170	5880
	55	68,8	720	565	1,480	140800	7040	14,00	232300	12930	9180
	70	87,5	861	676	1,450	154100	7710	13,40	258400	14920	10450

) max. curvature r, see 'dimensional and shape tolerances'

) the static values are measured for these curvatures r in relation to wall thickness s
$r = 1.50\ s \quad s < 40$ mm
$r = 1.25\ s \quad s \geqslant 40$ mm
a' = a - 2 r', where a = outer edge length and r' = sight edge length

) J = moment of inertia; W = moment of resistance; i = inertia radius

) J_t = St Venant torsion resistance
W_t = torsion resistance moment

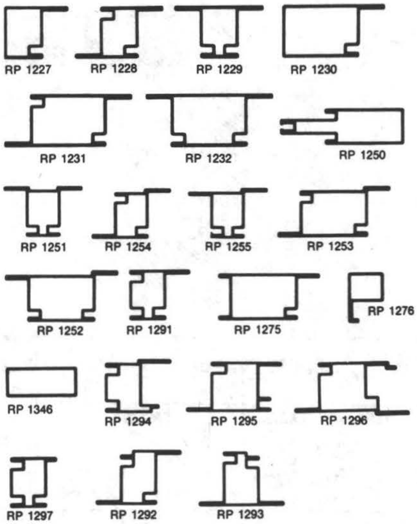


Fig. 1 Special hollow section for window and door frames

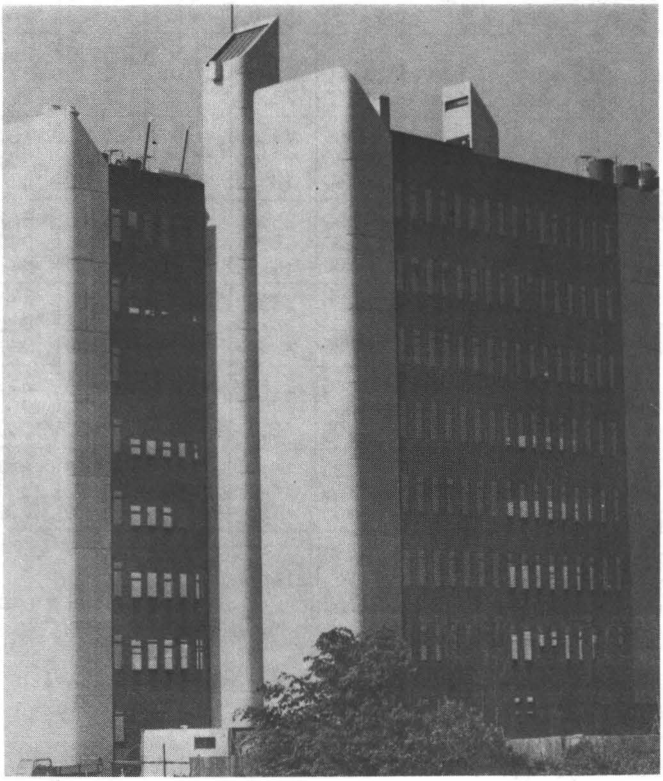


Fig. 2 Institut für Umweltschutz des Landes Baden-Württemberg, Karlsruhe. Water-filled outer columns in MSH 180 x 100 mm

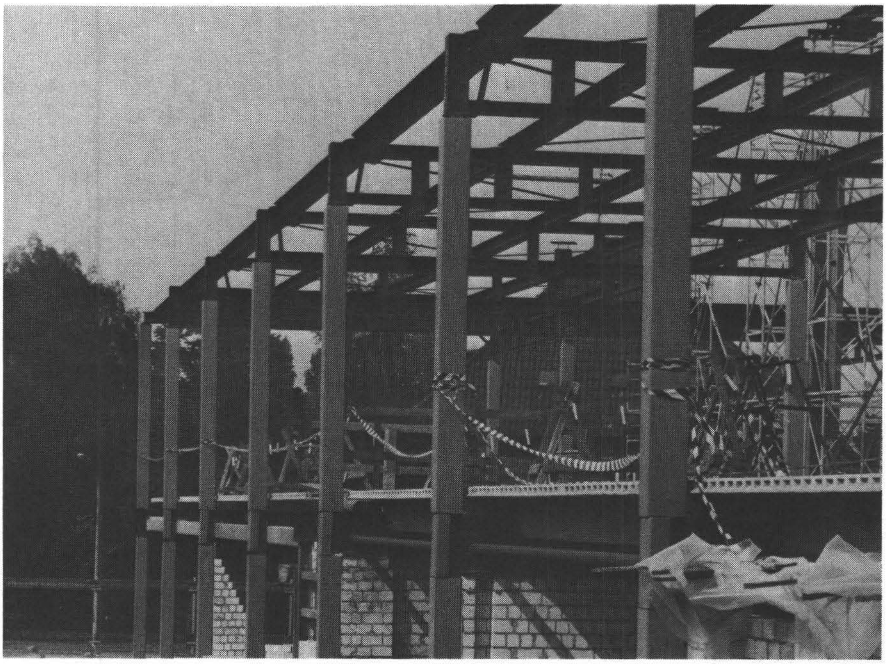


Fig. 3 Council House at Bottrop. Concrete-filled supports; F 90 at full load

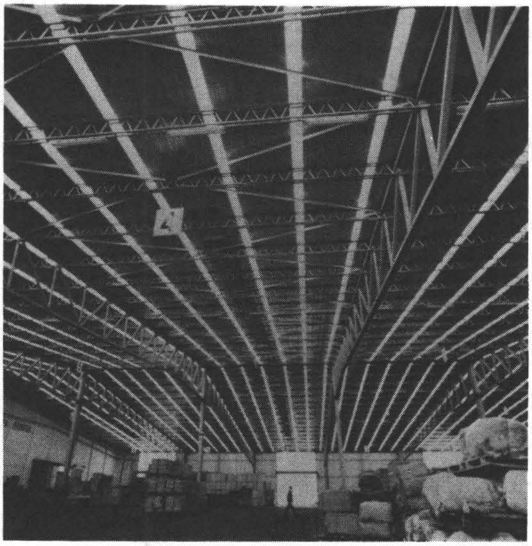


Fig. 4 Warehouse, port of Hamburg; span 2 50 m

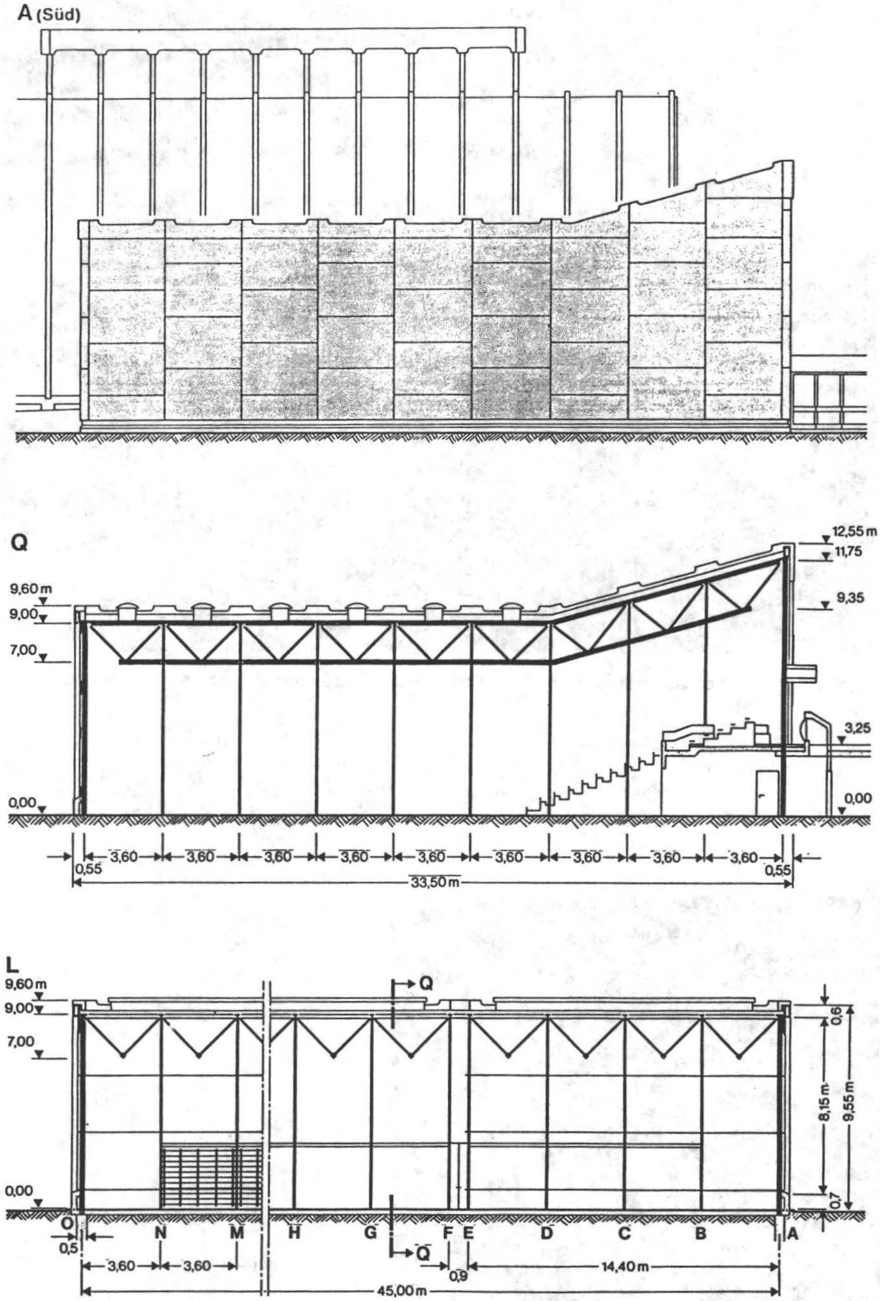


Fig. 5 Three-sectional sports complex, Sitten, Switzerland. Span 32.5 m; twelve three-chord beams

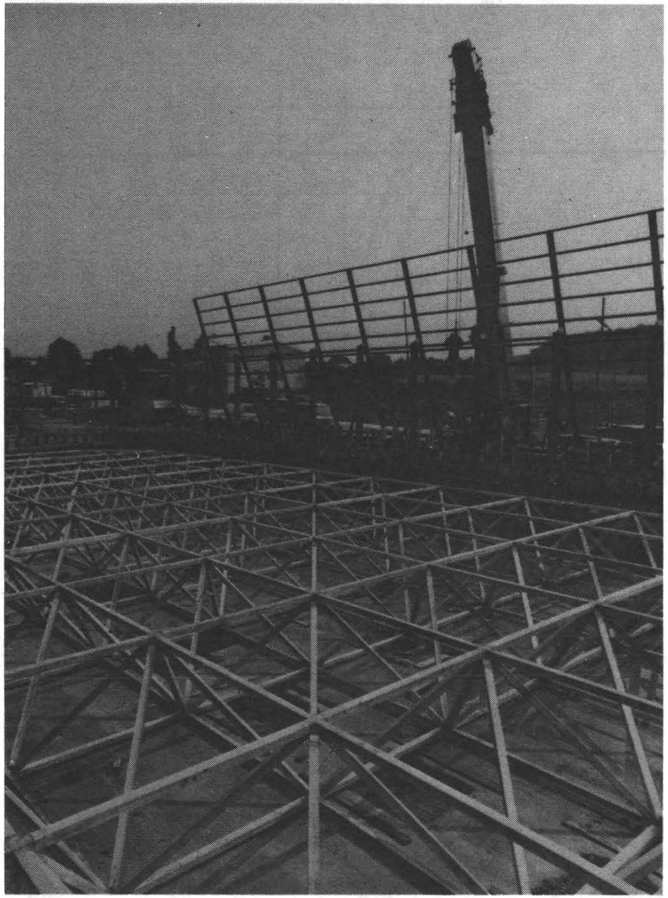


Fig. 6 - Multipurpose building 24 x 36 m; Dortmund

Fig. 7 - Shade-providing porch on supermarket un Doha, framework on square base.

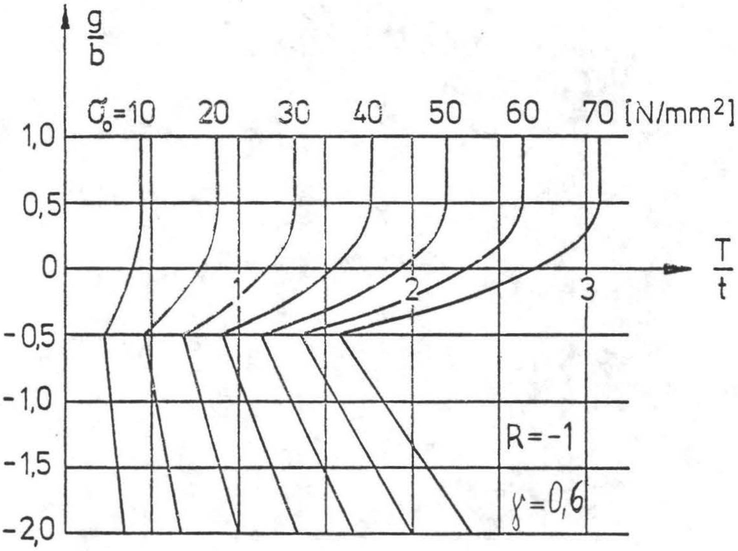


Fig. 8 Fatigue strength of K joints of round section

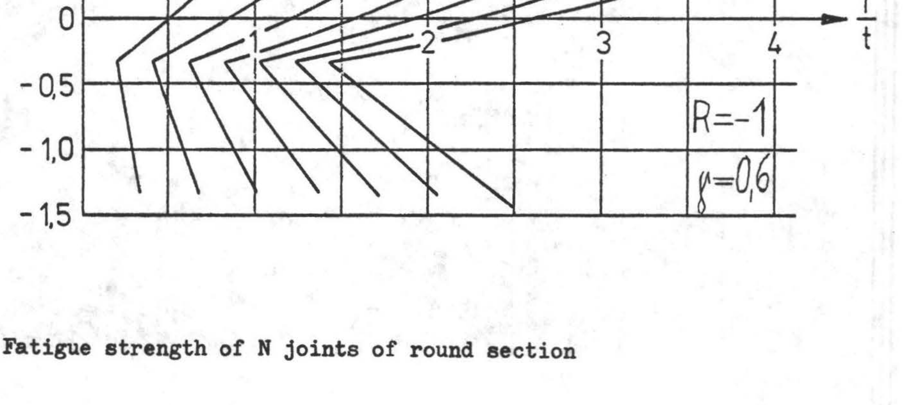


Fig. 9 Fatigue strength of N joints of round section

HEATED FACADES WITH HOLLOW SECTIONS

A TOPICAL USE FOR STEEL IN BUILDING

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Summary

The multi-facetted concept of the 'heated facade' offers the opportunity for the integration of a wide range of functions. The facades can be used not only for heating, but also for cooling, air conditioning and can take on the functions of framework and fire protection simultaneously. These diverse functions are carried out by means of water- or air-ducting in hollow steel sections which form the framework of the facade-forming windows and parapet panels. The large radiation element in the heat loss is the cause of the hitherto unknown comfort factor in this heating system. The cause is the reflection of the radiated heat onto the otherwise cold window surfaces. For low-temperature heating, the system offers good criteria for the economic installation of solar collectors, absorbers and heat pumps. On the other hand, water filling in the summer - even without special cooling, carries away large quantities of heat and prevents overheating of the facade. Even the low pressure system in the air conditioning variant is superior to the more common high pressure plant in efficacity. In that way, technically complex induction systems and the air and dust agitation detrimental to health are avoided. The operating fire protection of load-bearing design by the use of water filling reaches far beyond the hitherto conventional building technology and in no way represents an end to further development. That these simple, but enormously promising ideas still await universal acceptance lies in the new, interdisciplinary basic ideas which imply moving away from the well-trodden paths.

1. INTRODUCTION

'All architecture is imitation' was Schopenhauer's sceptical view of his own understanding that the basis of architecture - namely the interaction of support and load - had been comprehensively solved once and for all in Greece. It is equally valid today that by imitation and the adoption of conventional building systems and planning concepts there can be no progress, only stagnation. An evaluation of the scientific and technological bases and of the knowledge of building is only made to an insufficient degree and this is only to a limited extent the result of the very large number of research data.

Another reason lies in the change in architectural training: in former times, the master builder was in a position to approach and solve the aesthetic, technical and functional problems as a unified whole. This led to buildings at whose harmony and inventiveness we can still wonder.

Increasing academisation during the 20s brought about a change of direction. With the best of intentions, theories were put forward which were elevated to dogma so that no-one who did not follow blindly could count himself as a modern. In the field of city construction, for example, the Athens Charter of 1928 proclaimed the strict separation of the functions of living, recreation, work and traffic and this influenced all planning into the 50s. Our cities still suffer today as a result of this ordinance, no doubt sensible enough in certain circumstances. The symptoms are: absence of infrastructure, dormitory satellites, commuter travel problems and decaying urbanisation in the centre. The error has been identified and an attempt has been made to soften the desolation by a broader view of the complex of problems. As in town planning, so in high-rise planning. In this case the totality of the building is divided as:

primary structure = frame
secondary structure = cladding and space subdivision
tertiary structure = execution

The effect of this functional division of the building today is: The previously all-embracing master builder withdraws, according to inclination, to his task as artist or building manager and leaves the execution of the technical realisation of his conceived building shape to the various specialists. One of the rules of the game is the fulfilling of the technical requirements and standards. Each individual specialist, therefore, sees only his own task, his own part of the whole, and is blinkered to the neighbouring disciplines.

The expression 'specialist idiocy' is not here intended to define any given calling but, far worse but to the point, the deplorable state which results from this disasterous demarcation. The result of this cooperation, or rather, counteroperation, is evident in the buildings which are increasingly vulnerable as technology becomes more complicated. This orchestra lacks a conductor capable of seeing the harmony of the whole. This is a challenge to the inventive genius of both architect and 'engineer'.

Equally injurious to progress in building development is the imitation of well-tried methods, which are overlarded with fashion trends. Concrete is a good example. Without the seasoning of steel, cement paste would have remained the opus caementitium it was in Roman times. The paradox is that steel - shoved into concrete as life-supporting corset stays at great expense - there plays a shamefully retiring role; naked and without the voluminous covering of concrete its role is much more functional, graceful, and fascinating. What would the Eiffel Tower look like in concrete?

Yet concrete alone has maintained, with its properties, its occupying power position in our standards and in our acknowledged building rules. It does not take much effort to see that, for example, with concrete one can simultaneously fulfil the requirements of statics and fire protection. Hence the fashion for visible concrete. Sociologists will concern themselves with the brutalisation of form, and generations of our followers will be concerned with the timebomb in the form of slowly corroding steel which is ticking away in the concrete.

The challenge for steel is a real one; the chances are good. It is precisely steel that offers the possibility of breaking away from the disastrous separation of structure and function in a building and once again of coming back to a unity. As a material, steel, with its wide range of properties, is in the position to supply a solution to the complex problems.

How far one can go, given appropriate inventiveness and using all the properties of steel, in the direction of integration of frame, facade and technical execution, has been demonstrated by Gartner with his office building in Gundelfingen.

The frame is constructed of tubes. The water filling of the slim, unclad supports performs simultaneously the functions of basic heating or cooling and provides fire protection.

The facade, of rectangular steel sections, has ducted water and air and fulfils, to a degree of quality not hitherto reached, the requirements of heating, cooling, and ventilation. The low-temperature heating system leaves open all possibilities for energy saving through collector, absorber, or heat pump.

This example, the method of operation of which will be described in more detail later, demonstrates what is new in this construction principle, namely an integrated approach to the achievements in

statics
life (corrosion, fire protection)
building physics (heat conduction, storage, etc.)
heating and air conditioning (convection, radiation, transmission).

Also new is the viewing of capital cost, maintenance cost and operating costs as a totality in terms of general optimisation.

In the presence of increasing energy costs, the priority formerly given to capital cost has moved over to operating costs. A heated facade guarantees very low heating costs.

2. HEATED FACADE

The start point for integration, which must be approached quite comprehensively even in the anticipatory stage, is the bringing together of the shell of the building and its heating and ventilation technology: the heated facade (Fig. 2). This consists of vertical posts and horizontal members of rectangular steel sections to the outside of which can be attached windows or heat blocking panels. The hollow sections designed to carry the facade are connected to the hot water circuit and form on the inside of the facade a room height radiator with large surface area.

The physical advantages by comparison with the conventional unheated curtain walling, are clear from the illustration. Cold spots and associated condensation and frosting are avoided since the structural components are thermally separated by packing and Neoprene sections. These sliding joints easily accommodate externally induced lengthening of the components due to expansion.

In terms of heating technology, the heated facade is a low-pressure warm water pumping system. Room temperature control is effected in the conventional way by means of thermostat valves. While conventional heating systems operate with an initial temperature of 90/70°, the heated facade requires only 30 to a maximum of 50°C. On the one hand this is due to the relatively large surface area of the hollow section as the heated body, and on the other to the efficiency of the free-standing posts and cross members which give up most of their heat in the form of radiation. The radiated portion in this case is more than 50%, whereas, for example, the conventional radiator will only give 20% radiation since the parallel arrangement of the segments does not make for effective radiation.

3. COOLING

The heat radiated due to a facade heated by the sun is unacceptable in the summer. Conventional facades do not permit a solution to this problem. The water filling in a facade reverses its winter function and absorbs and carries away the facade heat and automatically cools the building. This effect can, of course, be intensified by boosting through a refrigeration plant. In this way, in summer as in winter, a comfortable constant temperature is achieved whatever the external conditions. It is possible to divert the externally arising heat or cold load before entry into the building.

4. COMFORT

The temperature sensitivity and degree of comfort of persons is largely determined by the air and radiated temperatures. Simplifying, it can be said that the detected temperature is the arithmetical mean of the air temperature and that of the surface of the surrounding partitions. The radiated temperature is directly dependent on that of the surrounding surfaces (Fig. 3).

Therefore, the best heating method is one which provides all cold wall surfaces with heated surfaces. This produces temperature and radiation conditions roughly equivalent to those in an unheated room on a pleasant summer day. The effect of the wall temperature is, however, also dependent on the position of the heated body and the standpoint of the people in the room. If a person is tanding, for example, right up against a cold window in an external wall, his own heat loss radiated outside will cause discomfort quite apart from the draught effect of the infalling cold air. By means of radiator heating in the area of the window, the effect of the cold outer wall surface will indeed be moderated, but the heat is in this case often too concentrated and can itself lead to discomfort. In both cases, an unsymmetrical thermal loading of the body is brought about and this is unsatisfactory. Differences of 19-29 W/m^2 are clearly detectable, and an unsymmetrical loading of more than 40 W/m^2 will cause discomfort. A good level of comfort can only be achieved when the difference between the wall temperature on the inside and the air temperature can be held to a maximum of 3°C.

In radiator and convector heating systems, the air is mainly heated by convection currents. The associated disadvantages of air and dust disturbance are well known. By using roof radiator or floor heating systems these disadvantages are indeed very largely avoided, but the radiation comes from an unusual direction as far as the person is concerned. This can lead to thermal loading for the part of the body nearest the radiation source.

The closest approach, therefore, to the rays of the sun, which are felt to be most natural and pleasing, is radiation which reaches the body uniformly: heating by means of a heated wall derived from a heated facade.

5. RADIATION

Investigations on heated facades have been carried out by means of infrared thermography.(4) It has been shown that the diffuse radiation going out from the facade is reflected by the insulating glazing. The reflection behaves basically according to the laws of optics and depends largely on the angle of incidence and the wavelength.(Fig. 4).

The reflected radiation is intensified by heat-protected or sunscreening glazing. Part of the radiation will be absorbed by the glass surfaces and will raise that surface temperature. In this way, the otherwise cold window surfaces are incorporated into the space heating and form, with the heated posts and cross members, a virtually homogeneous heated surface.

The consequence is that even under conditions of very low external temperature, no cold or draught effect is perceived in the vicinity of the heated facade. This degree of comfort is not to be reached by any other heating system, where, as has been shown, similar conditions only prevail at about 2 to 4 m from the outer wall (Fig. 5).

In the past, on energy-saving grounds, and especially in public buildings, air temperature maxima for heated spaces have been laid down. The adoption of heated facades offers the opportunity of maximum comfort at lower, and even more economical air temperatures, since on psychological grounds the perceived comfort due to radiated heat is more important than the air temperature itself. One has only to think of a cold winter's day on which intense sunlight causes the low air temperature to be forgotten.

6. HEAT INSULATION

Critics of the system have, in the past, and from the viewpoint of other interests, frequently asserted that the system contravenes German heat conservation regulations. A number of reports can be cited in this connexion. (1,2,3) The research data confirm quite clearly that the construction of heated facades does conform to the regulations. The energy loss from heated facade systems is even, depending on the design, to some extent significantly lower than that from a radiator heating system operating on a much higher initial temperature.

7. CORROSION

The inner corrosion protection means of the supports is the existence of low-oxygen water in an enclosed circuit. Greater protection is not necessary but can be obtained by small additions of K_2CO_3.

8. LOW-TEMPERATURE HEATING SYSTEM

As has been observed above, the initial temperature of the facade system is very low as a result of the large surface area. For example, given the average annual temperature of +5°C prevailing over large areas of Germany (FRG) the initial temperatures for heated facades are around 35°C.

This form of heating is, therefore, to be classified as a low-temperature system. This is of particular significance under the present energy crisis conditions, since only low-temperature systems guarantee optimum economics where heat pumps and solar panels are installed.

9. FURTHER EXAMPLES

The following examples will serve to represent the large number of applications of the system already in existence (Figs. 7-10).

As well as the water-filled steel design already cited, the facade can also be provided with air-ducting posts and cross members. The hollow section (Fig. 7) is designed as an air distributor and blower, so that hot or cold air can be blown direct onto the glass.

The design at Lauingen (Fig. 8) is specially intended for swimming baths since due to the greater level of humidity acceptable, smaller need for air change arises and hence the plant and operating costs are lower.

By a combination (Fig. 9) of water-heated and air carrying posts and cross members a further integral design with a large number of variants is produced. The hollow section frames round the middle row of windows are fed by hot water and form the static heating. The three sill cross members of the facade modules are designed as blowers for the heated or cooled air. This low-pressure system dispenses with the induction equipment required by high-pressure systems and which bring with them the health hazards of dust and secondary air circulation.

In the blower box (Fig. 10), air is blown through a slit perpendicularly upwards past the glass. Inside is a finned tube running through past which the intake air streams and is heated or cooled. The hot water for the facade modules yields part of its initial heat in the finned tube and is then passed to the facade frames. The surface temperature of the frame is correspondingly lower. A thermostat valve between tube and frame controls flow of hot or cold water and thus the room temperature.

An interesting feature of this design is the interaction of sluggish and very rapidly operating heating elements. The control valve is very rapid-acting, since the water quantity is very small in relation to the surface area. On the other hand, the large volume of water in the hollow section frame is relatively sluggish and will hold its temperature for a considerable time even if the hot water supply to it is cut off. The design has, therefore, the advantage of adaptable and responsive control which is very important where conditions change rapidly, such as in a classroom.

On the other hand, temperature conditions near the heated facade are steady and independent of the rapidly changing conditions and this is the reason for the unusual degree of comfort in that region.

10. FIRE PROTECTION

The forms of heated facade so far described have been clearly economical and efficient in concept. The integration of a number of functions in one structural component makes a positive contribution, by virtue of its versatility, to the economic viability of the structure as a whole. In this connexion, the possibility of incorporating a further capability is of great interest, namely the simultaneous provision of fire protection.

The first buildings incorporating water-filled components were started in the mid 60s. The objective of the water filling in case of fire is to provide for dissipation of the heat and maintenance of the structural integrity of the building. Similar projects were undertaken in Europe too. In all these cases the water filled steel components were outside the facade. The framework is connected to a water circuit by means of an upper and a lower main which is set in motion in the case of fire by virtue of temperature and density differences and which carries away the heat. A feeder tank replaces water lost due to vaporisation (Fig. 11).

The consequential development was that the water-cooled element should no longer be on the outside of the shell of the building but should become an integral part of the building and form an essential part of the facade.

In lower-rise buildings, the heated facade is part of the load bearing framework. In this arrangement, the hot water circuit can serve as a cold water circuit for fire protection purposes (Fig. 12). Naturally, building height limits apply if the size of the main supporting uprights is not to exceed feasible proportions.

This method of fire protection faces, however, a number of hurdles erected by the various authorities. The existing fire protection standards are concerned with the protection of the building from fire, i.e. in the absence of specific information, those fire protection devices are admissible which protect the load-bearing parts of the structure from excessive heat for a period sufficiently long to permit the evacuation of the occupants. Protective devices should not hinder firefighting attempts to break into the structure.

Fire protection by water-filling is an operational method which is made possible by the functioning of special equipment, such as the reservoir-fed water cooling circuit. Permission has been granted for certain experimental buildings of this type. Investigations have shown that given appropriate dimensions for the ring mains, improved and long-term fire protection is provided. Ways must be sought in a programme of tests of elevating the improved system into a set of standards and recommendations.

11. DIRECTIONS FOR DEVELOPMENT

By properly directed exploitation of the properties peculiar to steel, the development of a versatile and economic system is achieved to a level which is not attainable with any other system. The applications are unlimited, from single-family housing to any large-scale building for any purpose. Because of the degree of comfort which is attainable with this system, the following types of building are especially appropriate: dwellings, indoor swimming and sports facilities, hospitals, schools and administration buildings.

Despite the already proven design systems, new variants are constantly being put forward to confirm the versatility of the principle and the correctness of the route chosen. A representative set of examples of the future possibilities is given here.

The attempts so far made to utilise the rays of the sun for heating purposes have been confined to the solar panel, which is not capable at our latitudes of providing the year-round heating fuel requirements.

The solar absorber is no more than a solar panel which has dispensed with the insulating glazing. The main difference is that when the suns rays no longer enter, the absorner surface will become colder than the surrounding air. In this way the absorber system can make use not only of radiant heat but also of the energy content of the surroundings. A heat pump supplies the low surface temperature of the absorber and raises the intaken heat for usable purposes up to levels of 50°C. Absorbers of this type can be installed along the sills of facades and connected according to the system in use.

The examples provided have shown that the principle of the integrated facade not only answers all the earlier demands but also provides for the requirements of heating, ventilation, air conditioning and fire protection.

After this glance at the future possibilities, let us look again at the past and the opinion of Schopenhauer mentioned at the start that all architecture is imitation. If the Romans with their underfloor heating system created large radiant heating surfaces, is, then, the heated facade also only an imitation?

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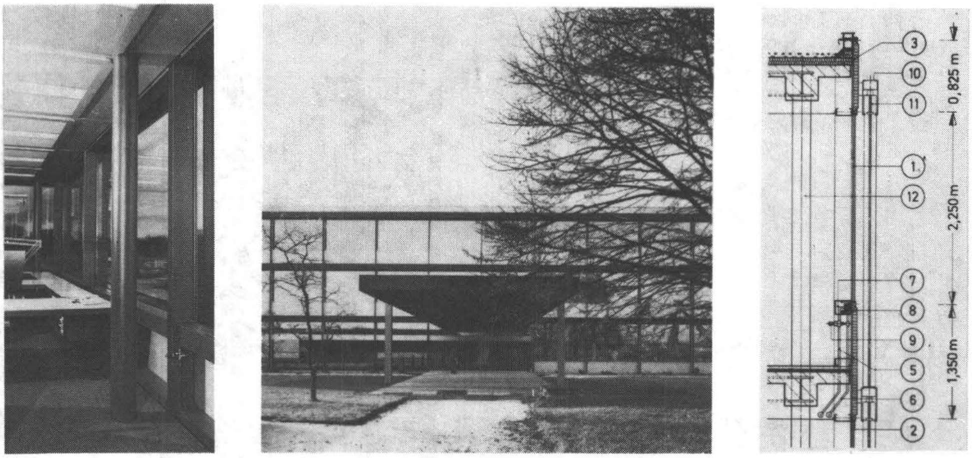


Fig. 1 - Office building by Gartner at Gundelfingen.

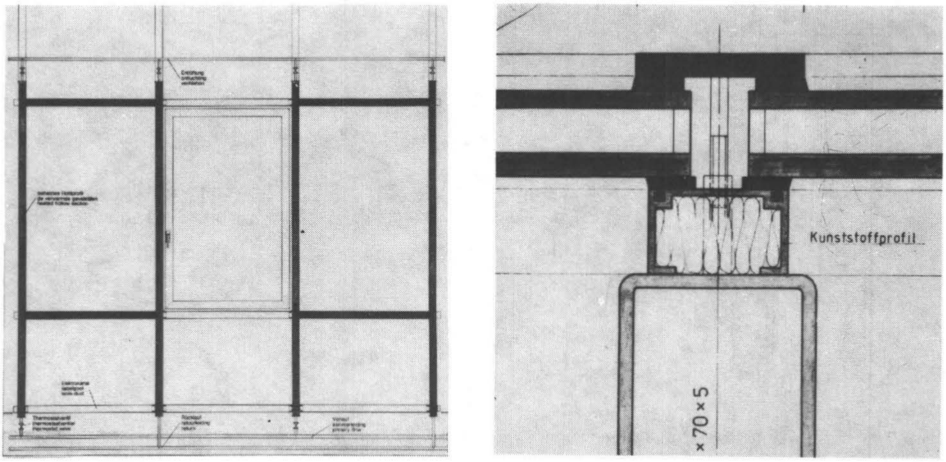
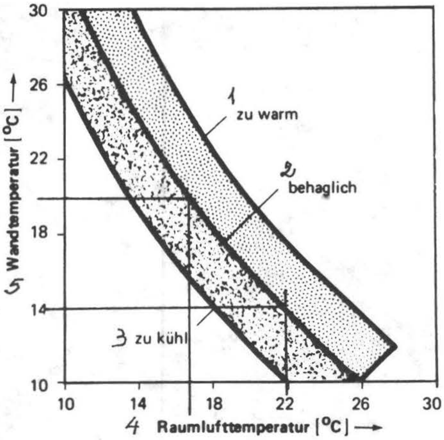


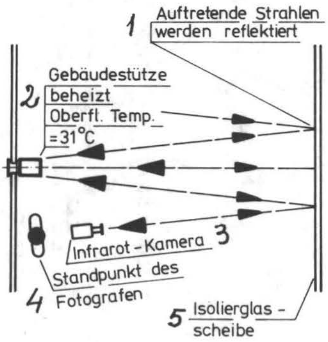
Fig. 2 - Components of the heated façade



1. too hot
2. comfortable
3. too cool
4. air temp.
5. wall temp.

Fig. 3 Comfort diagram

1. rays reflected
2. building supports heated - surface temp. 31 °
3. infrared camera
4. operator
5. insulating glass



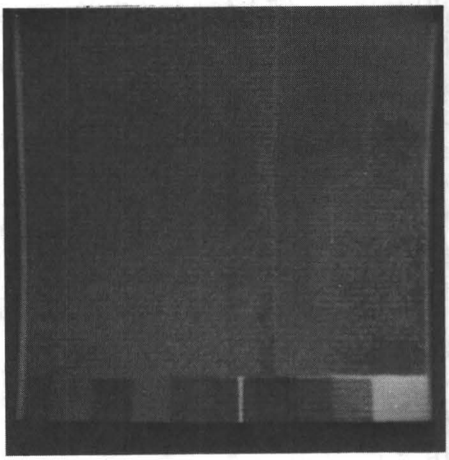
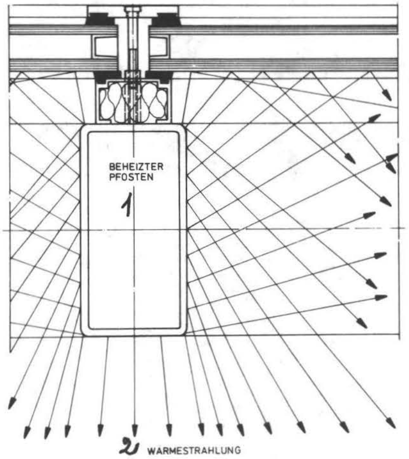
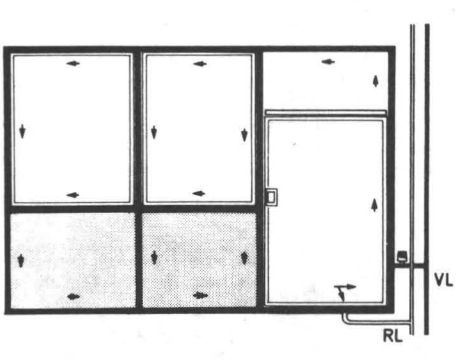


Fig. 4 - Reflection of radiant heat



1. heated uprights
2. radiatn heat

Fig. 5 - Effect of radiant heat for space heating



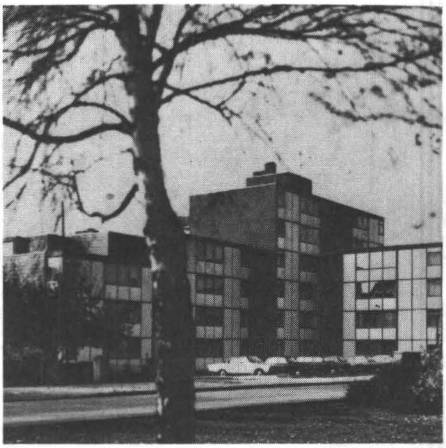


Fig. 6 - Block of flats, Dortmund

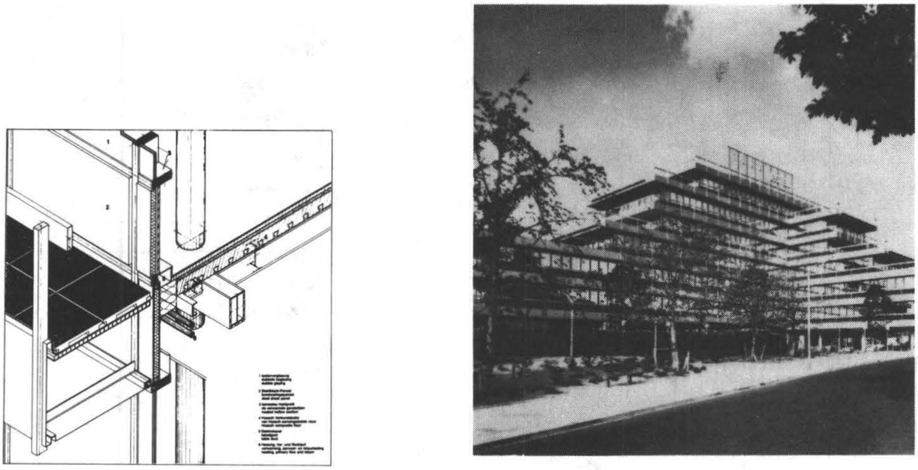


Fig. 7 - Administration building for ESTEL, Nijmegen

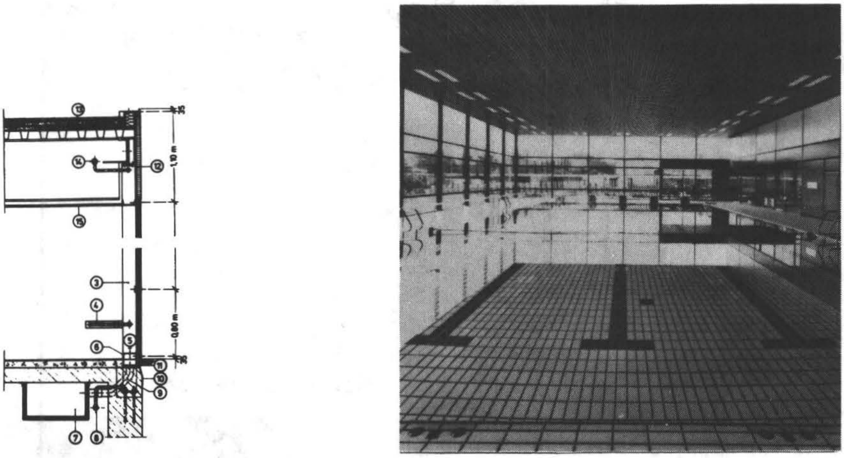
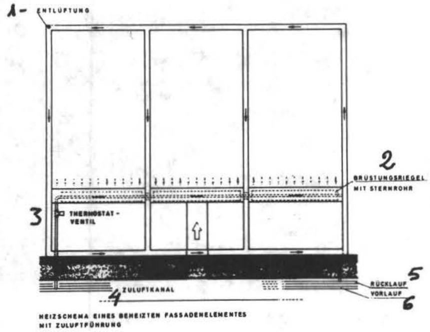


Fig. 8 - Swimming bath, Lauingen, 1971; uprights heated,
air blown by lower facade cross members



1. exhaust
2. cross member with finned tube
3. control valve
4. air channel
5 backflow
6. inflow

Fig. 9 - Combined water ad air system

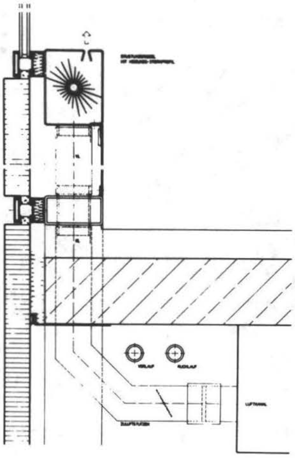
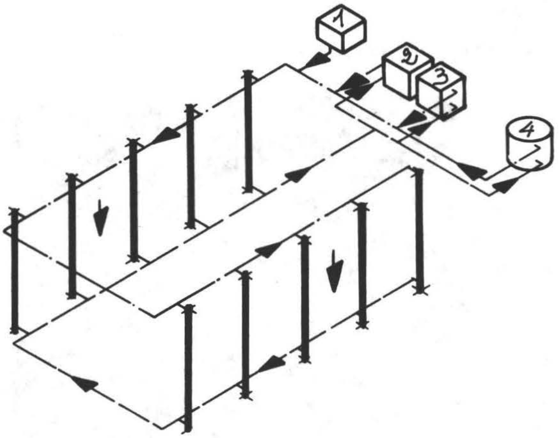


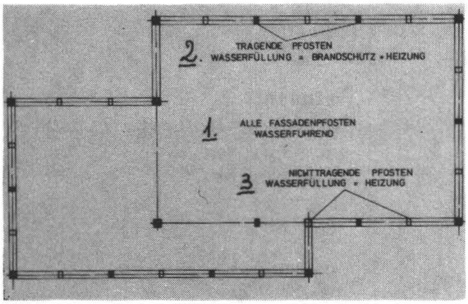
Fig. 10 - Blower box arrangement



1. header tank
2. heating plant
3. cooling plant
4. latent heat store for
   solar energy

Fig. 11 - Isometric diagram of fire protection scheme

1. all façade posts water filled
2. load bearing posts water filled =
   water protection and heating
3. non-load bearing posts; water
   filled = heating



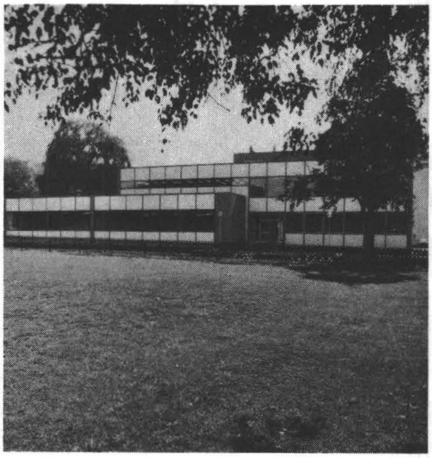


Fig. 12 - Data preparation and telephone exchange HSW, Siegen
water filled supports, si'ultaneous heat supply and fire protectio

STEEL: THE POWER AND THE TORMENT OF MODERN ARCHITECTURE

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Summary

Starting with the observation, not always sufficiently emphasised, that steel is the most representative material of the industrial revolution, the paper points to steel as the material of the first manifestations of the art nouveau movement and then considers the role it can play in stimulating development of the trends; in what way it can bring solutions to the many problems caused by the mass of information and confusion of direction of the present time (the near impossibility of the task is not underestimated, hence the danger of 'torment' as much as 'power'.

Steel has the special potential, perhaps exclusively, of restoring the seemingly lost human face of the art and science of building; each planner can express himself on a basis of formal constants which ensure lively coordination of the constructed environment.

By way of comparison of the Mies Crown Hall in Chicago with two recent structures, that of Mangiarotti in Majano del Friuli and that of Foster Associates in East Anglia (which are derivative to some extent), the paper shows how, using the same material and the same basic idea, the objective can be achieved of guaranteeing a new creativity for the individual and for the community.

This is not the place to investigate, or even to affirm, whether or not the time is ripe for the beginnings of an industrial civilisation which finds in steel the most congenial mode of expression, or whether this is to suggest too radical a change of course. As in many situations, cause and effect can be discussed endlessly; most factors are mutually interdependent. Suffice it to say that steel has always been synonomous with industrialization and its image is all pervasive in the world today, in industrialized, industrializing, and in non-industrialized countries. In the 18th and 19th centuries it was the obvious material for those seeking power and weapons; it is worth remembering that it was the material for the development of the railway system which is so outstandingly representative of human relations on the grand scale. It is most appropriate that it should be referred to as the iron road. (Fig. 1).

The material was first used in territorial programmes and in building, then in railways, bridges, and great roof spans. The Crystal Palace 1851 exhibition in London had a length of 1851 feet (the numbers may or may not be coincident) and offered a dream of Utopia which no other structure of the modern movement could equal - a fact that has led many histories to trace the origin of the movement back to the Crystal Palace. But in fact, nothing new has been added to the principle of light. It demonstrated the potential of the material for the realisation of high-quality buildings in great quantity. The almost contemprary Sheerness docks, UK, which were the project of a colonel, anticipated an architectural theme which seems unsurpassed even today; the military planner is no surprise, being heir to a functional way of thinking (Fig. 2).

The extension from an essentially structural material to one suitable for standardized, industrialized prefabrication was quite rapid. It is easy to trace the material's progress in the hands of the liberty architects bending it to the shape of the wisteria and softening the apparently excessive rigidity of the rectilinear outline. This development was short-lived as attention was turned to other problems; nevertheless, the liberty style, variously expressed in the different countries of Europe, had the merit of rediscovering the secular craftsmanship traditions, amply tested but looking for new expression. There are now many forms of joining technology (welding, bolting, structural adhesives) and many ways of treating and producing rolled products, so that steel can now give expression to the smallest detail in a building.

The role played by steel in the definition of industrial design over the years should not be forgotten. When, in 1925, Stam designed the first tubular steel chair, he showed definitively how the tube can be made to form a useful structure without the need for many joints (Fig. 3). Thonet approached the problem with wood, but it was steel which had the manufacturing and economic advantage over other materials (Fig. 4).

The broad range of applications possible remains exclusive to steel; this must be repeatedly emphasised, not only in terms of spectacular or monumental expression - tower structures with large or very large dimensions, tensostructures (Fig. 5,6) - but also in terms of items of more normal dimensions and free structures, those with very concentrated loading patterns, those in which construction time has to be curtailed, prefabricated buildings, rebuilding of historic monuments, reconstruction of communities, all shape and function issues most rationally executed in steel. This prerogative is well assured by a heritage and a present foundation (even if two centuries is not very long by comparison with the tradtions of other materials !). "We want to lead our students through the study of materials and the objectives of creative expression. We want to show them the sound basis of primitive methods of construction, where every blow of the axe had meaning and where every chisel cut had significance....Every material has its peculiar properties and these must be recognised if we wish to work with them. This is equally true for steel and concrete. We must remind them that everything depends on how the material is used. Each material has the value that we can draw out of it." So said Mies (from M. Bill 'Ludwig Mies van der Rohe, Milan, 1955, pp. 28-30), a man who can be reasonably considered to be the poet in steel of the modern movement. In conferring on every material its own expressive autonomy, he was surely correct, but it is significant that his choice fell on steel at the opportune moment. Steel discovered a kind of vocation in modern architecture. If one accepts that history is not so much a phenomenon of evolution but change, it is difficult to establish when a given series of operations is going in the historically correct direction; in scientific or technical terms, then in relation to the use of a material it is easier to say whether the steps taken have future potential or whether the chain has stopped at a fixed time. It follows that the use of an unsuitable material can be a barrier to progress. Given that errors of planning can occur with any material, then it is clear that steel has the most temptations. The towers which Johnson (a collaborator with

Mies on the Seagram in New York) has been putting forward in the most respectable architectural periodicals can only be built using the preferred if not exclusive option of steel. But if on the ground floor and in the coping, rennaissance ideas (Fig. 7) and eclectic neogothic or even neo-neogothic elements are called into play and it is evident that steel is not playing its most congenial part on a present or historical plane, then it also serves as yet another demonstration of its versatility. When speaking of the torment of modern architecture, the improprieties of style, technique or proportion which are still occurring should not be forgotten. The example has been cited to bring into focus the vitality and universality of the now well-known phenomenon of 'post-modernism', which appears to renounce all derivation from the modern movement, including that which Wright termed the 'truth of the material', a truth which all contemporary building activity respects, except architecture. If one sees post modernism as an enormous magma from which a new architecture is to be formed, then new materials may also appear (as steel did at the beginning of the century) which will enable planners to make the right decisions.

Turning to the main theme, and looking preferably at the positive aspects of the 'power' of steel, then given its characteristics and properties, it is a material which can be thoroughly recommended in terms of continuity of the human aspects of construction. Being a material produced by solidly industrial methods, it has an intrinsic expressive capability which excludes pseudo-creative forms which exceed the limits of sound judgment. The structural component (a standard section) has its own physiognomy, not bearing any relation to other components. It is rather like a word ready for a talk which is still to be given. It is, however, the correct word, and one which all can use. It is possible to see steel as a material, even if not the only one, on which a human architecture can be founded (an aspect which seems to have been lost at the present time). To continue the metaphor, each planner has freedom of expression but against a background of linguistic constants which produce coordination in what is constructed from the units.

One can move on from this to the larger and permanent aspects of architecture in didactic terms: the lesson of Gropius is always with us. He was one of the few of his contemporaries who understood the dilemma of Thomas Mann in respect of the relationship between the artist and society and who preferred the didactic to the conjectural as expression of individuality. The didactic aspect of architecture means that the experience is only significant if it can form part of a common heritage and if it is in some way available to successive experience, if it is able to suggest a content in which others can see themselves or into which others can fit, rather than reveal personal interests.

Let us attempt to illustrate the themes with some examples: the Crown Hall by Mies in Chicago (1955) better known as the faculty of architecture of the Illinois Institute of Technology, the exhibition building for an industrial company, by Mangiarotti, in Friuli (Udine) (1978), and the Sainsbury Centre for visual arts of the University of East Anglia, Norwich, by Foster Associates (1974/8).

The IIT faculty of architecture building is one of the first and most precise of Mies' designs, passing the derivative period of architecture from the figurative neoplastic and taking the definition of form as a priority. In this building, Mies asserted that space is not a kind of intangible material to be manipulated so as to obtain the desired qualitative and quantitative effects (in the way, for example, of Wright or Le Corbusier) but is the consequence of the use of structure. Mies did not take as his point of departure, therefore, an internal prismatic space but he thought of a sequence of four portals of single light with strongly differentiated sections upon which are carried the curve of the roof (Fig. 8). The space is a consequence. The symmetry of the structure is emphasised by the centrality of the entrance. With four portals, three follow the interspaces and the central one is most obvious: in an organism based on this concept the value of the components of the scheme is directed towards the reciprocity of the whole in absolute terms. In the Museum of Contemporary Art in Berlin, the last work of Mies, this scale of values remains unaltered on the four balanced facades, and with the tamponing carried more towards the inside, structure and space together are sufficient to make architecture.

In the Mangiarotti building (Fig. 9, 10, 11), the treatment of the base remains unchanged (though others similar cannot be cited), that is to say that the structure on the exterior and the dependence between it and the tamponing. Two identifiable 'facts' are added to the homogeneous treatment, the nature of the portals which continue the same in section of horzontal to vertical plane, and the definition of space related entirely to the structure. The space is the position marked by the nodes of the structure.

The Sainsbury Centre takes up the same theme, as can be seen from the illustration, with respect to the two 'facts'. There being a requirement for an absolutely free plan (Fig. 12) for the display area, and having been led to a structure of considerable thickness (2.4 m), the concept was to make not a homogeneous structure, but to use uniformity of section (Fig. 13); in this way artificial or natural light is transmitted along with the other services and power in a sort of continuous and changing game of projections. The panels on the exterior of the structure are visible on the two end frontages (Fig. 14), are interchangeable and can be opaque, grilled or transparent.

If these three examples are to be considered in sequence, we do not have a case of three variations on the same theme but with different ends in view; rather do we have three separate and autonomous examples of the expression of the personality of the designers (a statement of architecture as an image of perfection for Mies, the sense of structure for Mangiarotti, and the mechanical precision which is executed by assembly but which remains architecture rather than a mechanical display of the kind so prevalent today); all, however, lead back to the same theme in terms of unity, apprpriate use of materials, especially of that material with which alone large spaces can be spanned.

The resistance of the seemingly logical temptation to read these examples in chronological order is of significance in making the 'information' they offer evident; we can identify a community of heritage and a continuity of interest and intention in which material selection plays a decisive but not restrictive role.

The already large scale of architecture is a function of the possibility of building without joints and of an excessive specialisation of planning and calculation. It leads back to the perennial theme of architecture of defining a portion of space and allowing it to develop functions - along with the equally perennial desire to use less material for the same result and to span ever greater areas with ever fewer supports.

Naturally, the possibilities are wide open for architectural design studies by those with enough confidence in the material; a new and genuine building tradition is required.

Finally, we should draw our attention to a recent hypothesis - formulated by Mangiarotti - which seems to show very clearly the possibilities for exploring the promise of steel with continuity and with unforeseen results.

If one imagines a system of beams made up of sandwiches of metal and concrete which can be formed, with reinforcement in the concrete on the inside of the sandwich, so that the two materials carry the forces of traction and compression appropriately (Figs. 15 and 16).

To the planners engaged on the discovery of new solutions, the steel producers respond with new qualities and processes, using high productivity and automation to reach increasingly sophisticated ends at economic cost and with uniformity of properties. The challenge of steel as a building material is derived from this common effort.

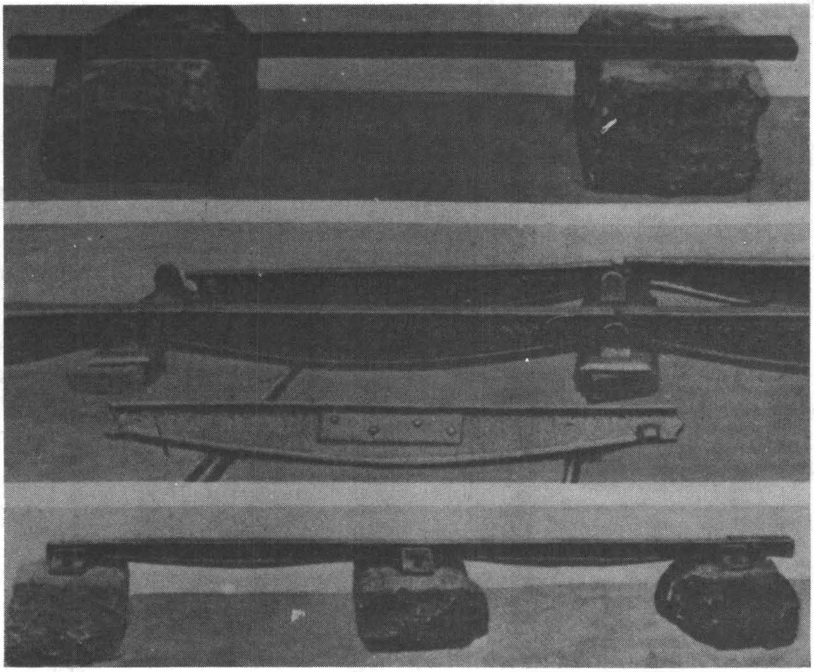

Fig. 1 - Some early examples of rails.

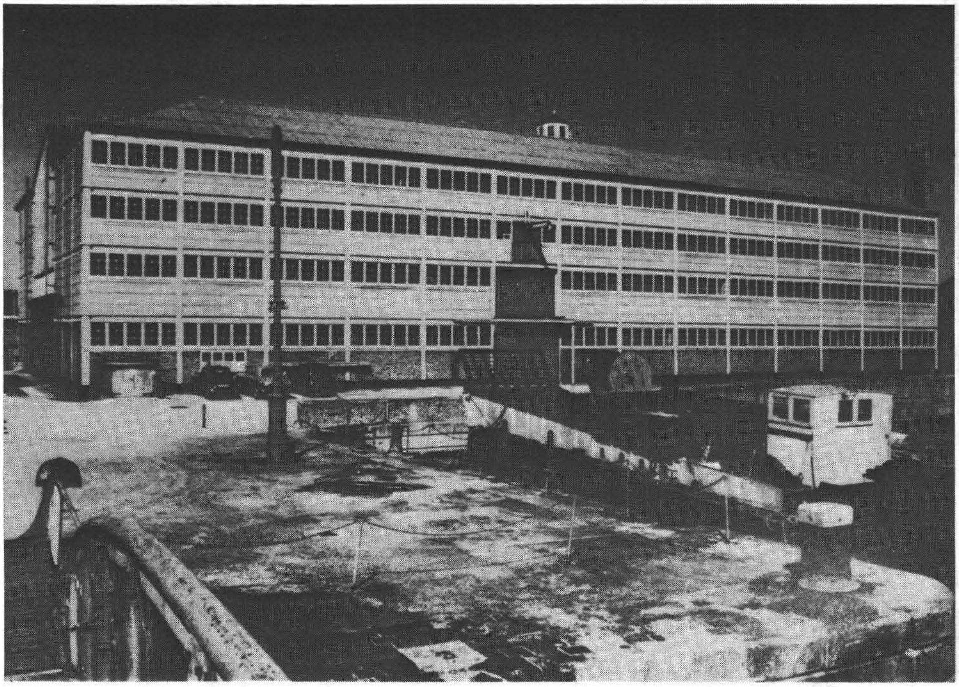

Fig. 2 - The Boat Store at Sheerness (UK) designed around 1860 by Godfrey To Greene.

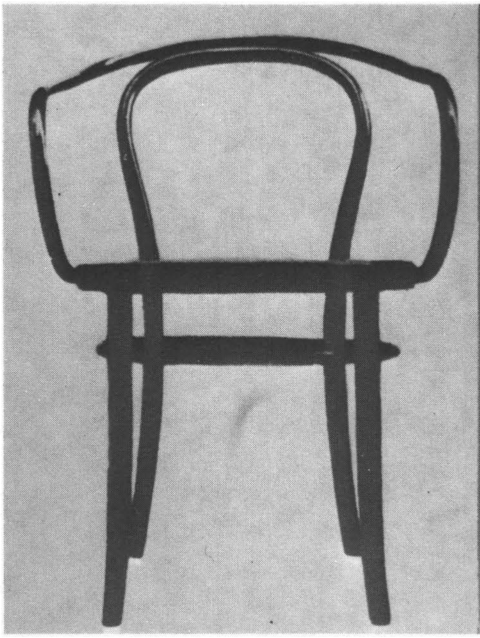

Fig. 3 - No Stam: the first continuous tubular metal chair (1925).

Fig. 4 - Thonet: a chair produced in the second half of the last century.

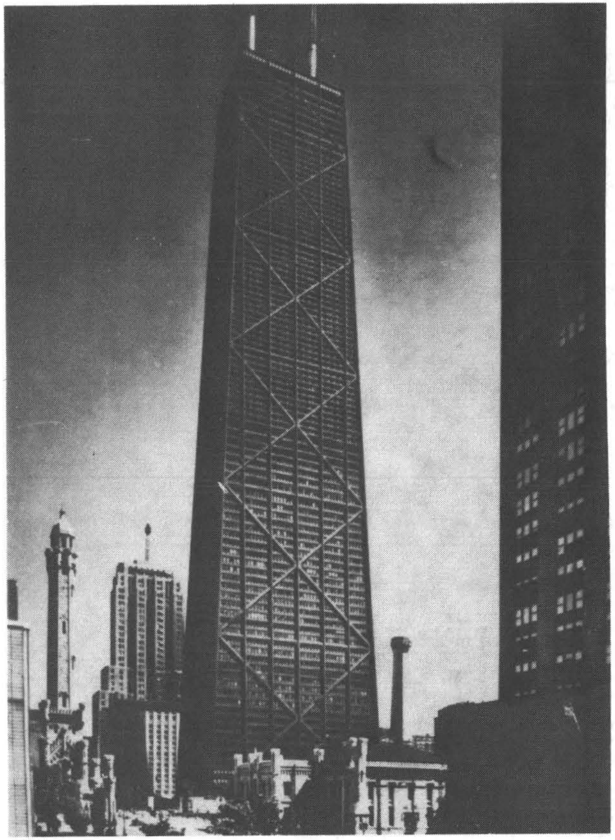

Fig.5 - The John Hancock Center in Chicago, Illinois (USA) by Skidemore, Owings and Merrill.

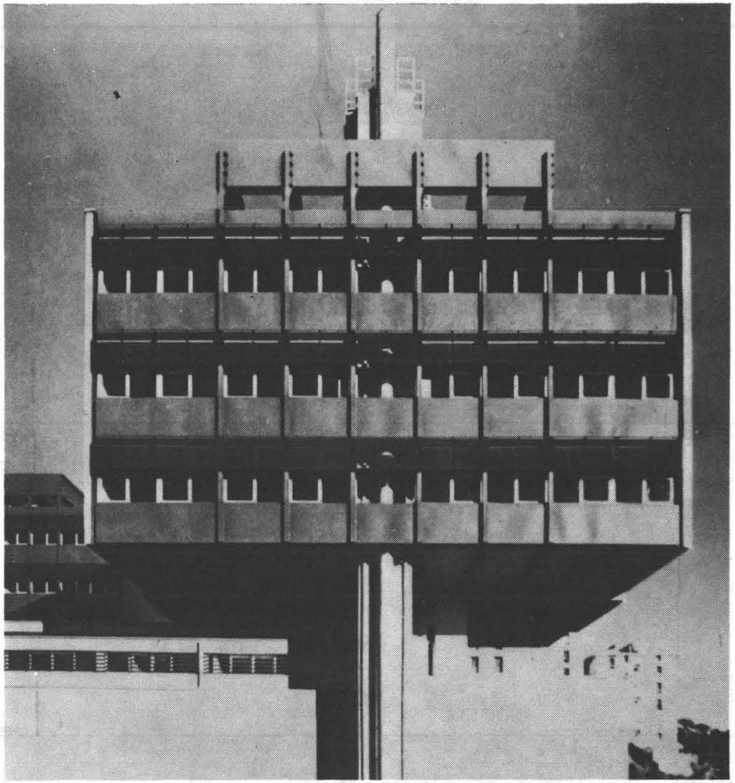

Fig. 6 - A. Rizzo: school complex at Genoa-Prà, featuring a classroom block atop a reinforced-concrete tower (medullary pillar).

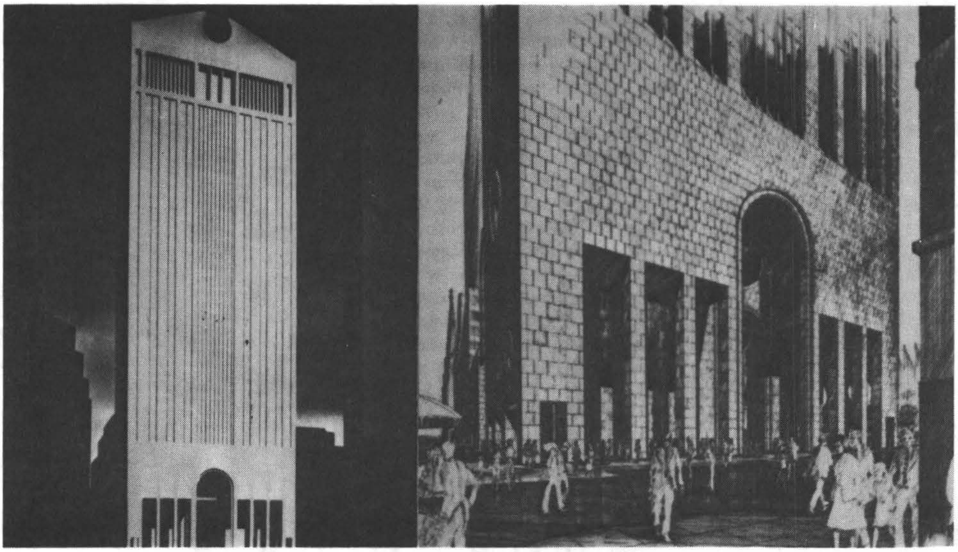

Fig. 7 - The AT & T Building designed by Philip Johnson for New York (1979).

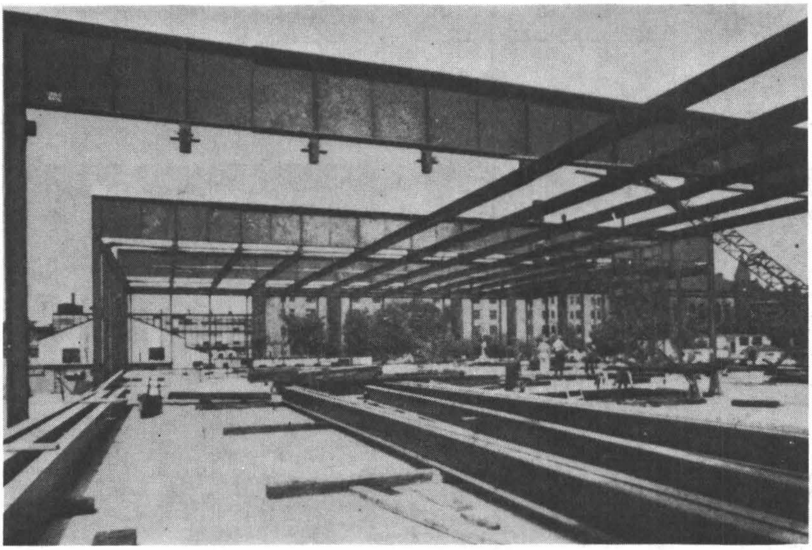

Fig. 8 - The School of Architecture on the I.I.T. campus (Chicago, USA), seen during assembly of the structure. The design is by Mies.

Fig. 9/10/11 Mangiarotti: showroom facilities for an industrial concern at Majano del Friuli, Udine. Perspective view of side with opaque curtain walls, front view of the side with transparent curtain walls, and assembly of the structure.

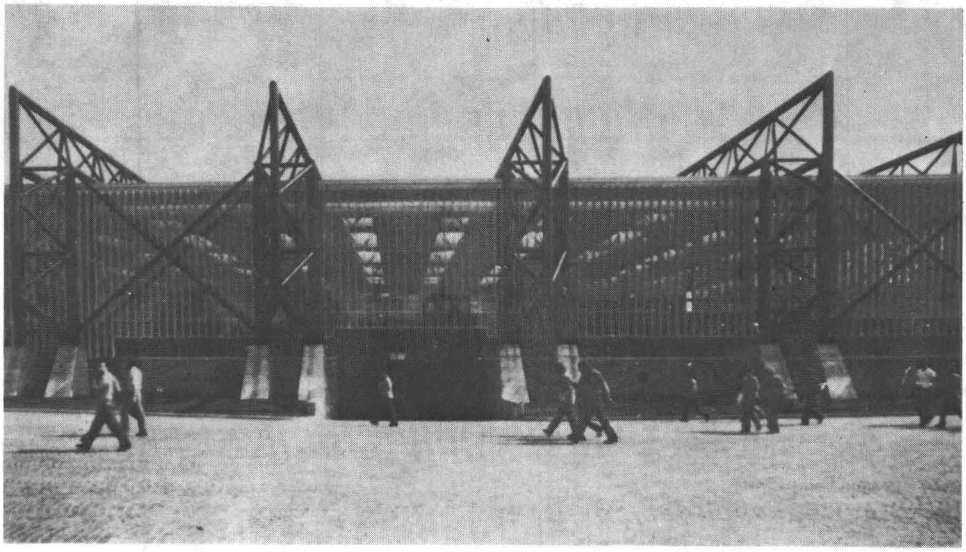

Fig. 9

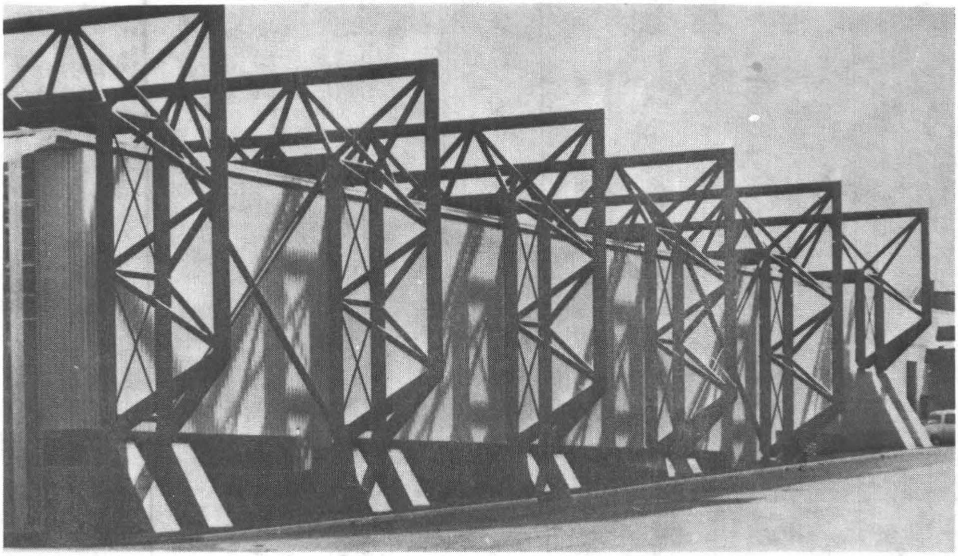

Fig. 10

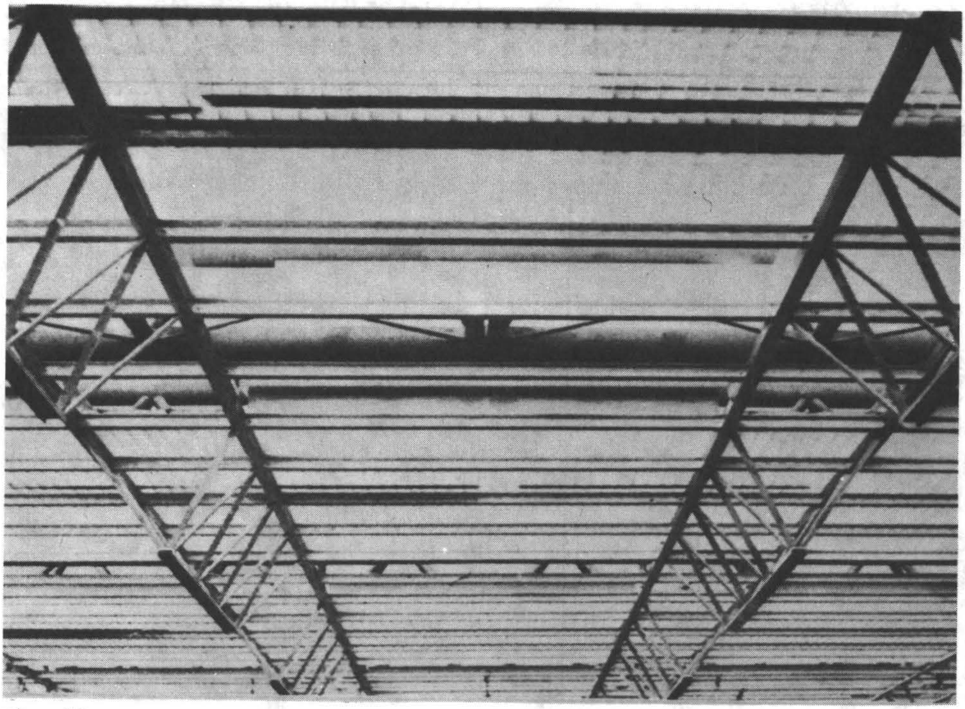

Fig. 11

Fig. 12 - The Sainsbury Centre for Visual Arts in East Anglia by Foster Associates. The interior is completely open-plan.

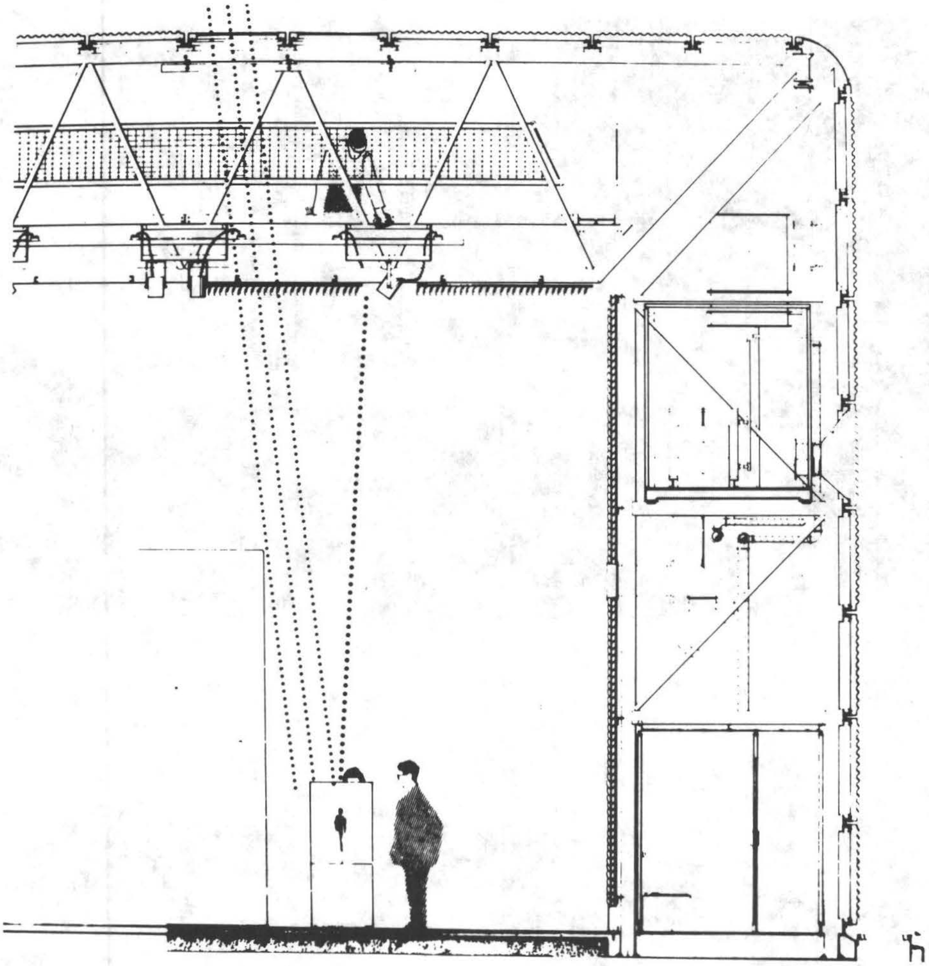

Fig. 13 - Sainsbury Centre: standard cross-section of the structure.

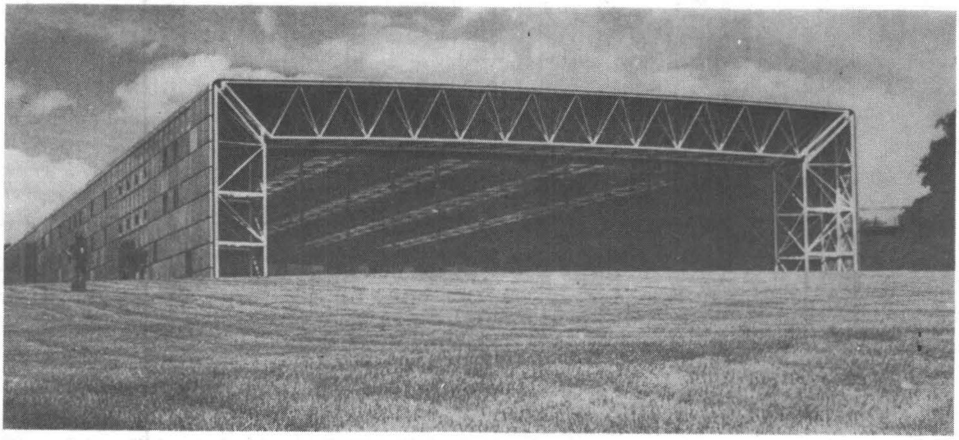

Fig. 14 - External view of the Sainsbury Centre.

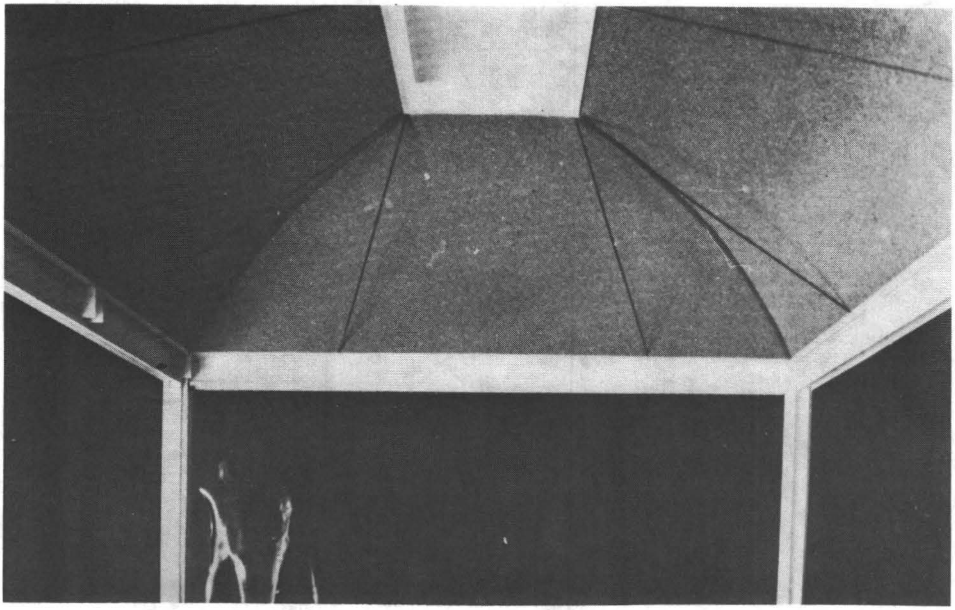

Fig. 15

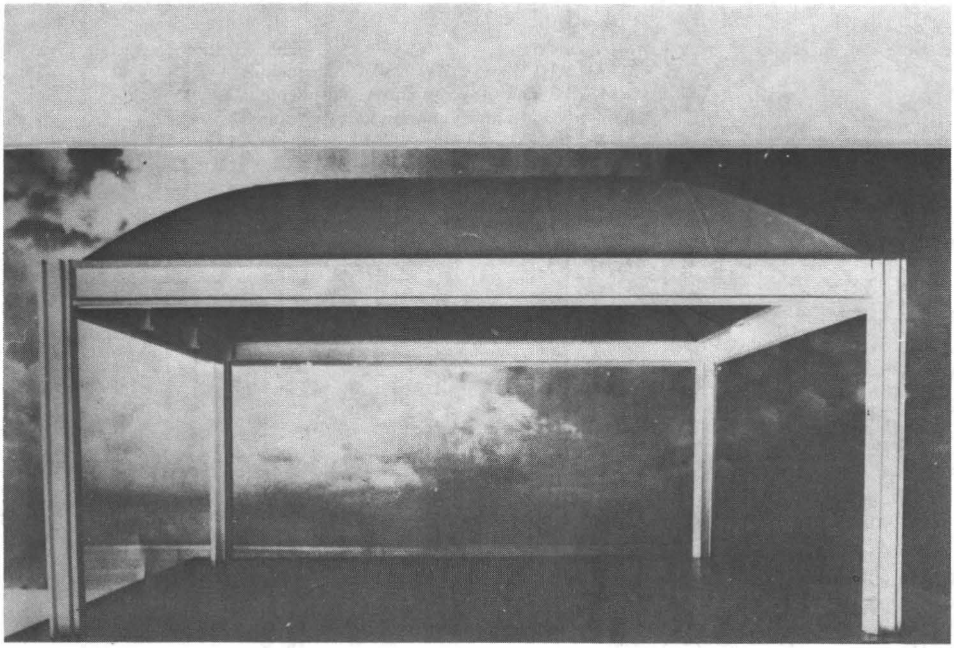

Fig. 16

Fig. 15/16 - Mangiarotti: vaulted roof system using sheet steel combined with a layer of cement-based aggregate. The vault is divided into four segments.
Model of a span seen from the inside and the outside.

ROUND-TABLE-DISCUSSION

Discussion panel:

- Dipl.-Ing. G.Th. WUPPERMANN, Chairman
  Geschäftsführender Gesellschafter
  Th. Wuppermann GmbH, Leverkusen

- J. RORET
  Director, Cie. Française d'Entreprises
  Métalliques, Paris

- P. LEFEVRE
  Director General, Administration des
  Bâtiments, Ministère des Travaux Publics,
  Brussels

- D. GARDIN
  Fédération Internationale européenne de la
  construction, Paris

- V. GANDOLFI
  Professor Architect, Milan

- W. EASTWOOD
  Eastwood and Partners, Consulting Engineers,
  Sheffield

Synthesis: G.B. GODFREY

ROUND TABLE DISCUSSION

G.B. GODFREY

The chairman, Herr Dipl.-Ing. G.Th. WUPPERMANN (Germany), in opening the final session, introduced his five fellow members on the panel and stated that, while he represented the steel industry, they would respectively speak on behalf of the architectural profession, consulting engineers, the structural steelwork industry, the construction industry and a specifier in the public sector.

It had been agreed that they would address themselves to one of the following two questions :

1. What do we expect from steel construction in the future?
2. What should be the objectives for steel in construction in the future?

Mr. WUPPERMANN said he wanted to talk about steel, not about subsidies, article 58 or the steel crisis. Some introductory remarks would be appropriate.

He belonged to a family concern which was active in the steel industry. Unfortunately, from some points of view, owing to the present crisis, they had diversified and were producing cold rolled sections for the building industry, other types of sections and forgings. He was also a member of the German Committee for Market Research and Development of the International Iron and Steel Institute which was concentrating on the structural use of steel. There were regular meetings and the delegates who came not only from Europe, but also from Japan and the USA, exchanged their experience. He suggested that on another occasion they might discuss the possibilities of exploiting the potential of such institutes. He was sure that the information exchanged at the IISI was of great interest and should be available elsewhere at other times.

In the reports they had been privileged to hear they had discussed the use of steel in building and housing. During these deliberations, little attention had been given to the question whether technical developments in steel production had contributed to the improvement or extension of the use of steel in building. They had been reminded of the first steel congres of the ECSC in 1954 and then, in 1964, that Mr Fritz HELWIG, who was a member of the High Authority of the Coal and Steel Community at that time, had said the use of steel in buildings and structures was about 25 % of total steel use and was declining slightly. The percentage had not changed since then. It was the same in 1980. Mr HELWIG also spoke about the changing processes, especially welding. He pointed out that the use of steel had been reduced by 3 % by plastics and aluminium and 3 % by concrete, timber and asbestos-cement products. Mr. WUPPERMANN said that although the share of the building industry was still about 25 % of all steel production, the substitution by other materials had risen from the 6 % it was sixteen years ago to 15 % at the present time. The production of the six Member States in 1964 was 80 million tonnes of crude steel. In 1979, it was 118 million tonnes, but the Community then had nine members and they consumed 140 million tonnes. Mr HELWIG had cited the following reasons for structural changes and the reduction in specific steel use :

1. Introduction of weight-saving sections
2. Manufacture of higher grade and better quality steels
3. More rational use of steel
4. Substitution of steel by competing materials
5. Technical advances in other areas leading to improved performance with less use of steel.

Mr WUPPERMANN asked his audience how they expected the situation with respect to steel use to develop in the next sixteen years and what challenges steel producers might face.

As far as steelmaking was concerned, the Thomas converter and the open hearth furnace had been replaced by modern oxygen converters and electric arc furnaces while a revolution had taken place in the pouring of liquid steel. Ingots had been replaced by continuous casting and the resulting products could be rolled directly into the well known sections, merchant bars, plates and strip. Continuous casting resulted, not only in an even distribution of the alloying elements, but also the less desirable elements, such as phosphorus and sulphur. This distribution applied to the length as well as the cross section of the product. The segregation zones which sometimes appeared with unkilled steels at the junctions of web and flanges in rolled sections were now a thing of the past.

All these developments had now led, for example, to Grade 1 steels being excluded from the latest German standard for structural steel. However, the standard for general steels did include more types of steel than those actually employed for structural steelwork. It was interesting that in addition to the conventional St 52.3 steel, there were now the fine grained building steels St E 47 and St E 70 used as flat products or for welded hollow sections.

When one compared the tensile stress, the yield stress and the minimum elongation of the various steels, one could appreciate the developments which had been made with building steels. There were also interesting developments in the continuous galvanizing and coating of sheets for use in roofs, walls and floors. Another significant outlet was steel for reinforced concrete. The Temcore process was a cost effective method for the manufacture of bars from 12 to 28 mm diameter. The quenching and tempering of the steels was one of the greatest economic factors in the new process, leading to toughness as well as high strength and weldability.

Mr WUPPERMANN then introduced Professor V. GANDOLFI, who could represent the architectural profession :

"Steel has now fulfilled a role in construction or, to be more precise, in that integrative concept of construction known as architecture, for some two hundred eventful years which have seen some of the most extraordinary and decisive developments in the history of civilization.

In architecture, these developments have ranged from the simple, linear impact of the I-beam to the intricate complexity - considered futuristic by some and extravagant by others - of the Eiffel Tower and present-day macrostructures. To describe how steel has so far risen to the challenge represented by man's socio-economic needs in construction is therefore to write the history of architecture during the past two centuries.

The present configuration and likely evolution of architecture must therefore be our starting point if we are to predict how steel will answer society's future needs. Rationalism is a chapter long since closed in architecture, but it has provided the basic guidelines for all architectural research. The most significant of these are the concept of creativity, which takes things a stage further than the mere repetition of hallowed forms, and the resulting freedom of architectural expression which is restricted only by the extent to which it is compatible with content and structure. There is no doubt that these criteria remain paramount and are clearly applicable in the most significant works.

The present configuration of architecture is very diversified as regards general trends and undercurrents, some of which are clearly defined while others are merely the manifestation of cultural or more idiosyncratic aspirations. Nevertheless, over and above the different conceptual approaches, one common feature of all recent and current trends is the quest for new forms of expression, so much so that the only common denominator in present-day architecture is to be found in its leitmotif, viz. experiment. Experiment is no longer a mere transitional phase but an essential and fundamental credo, the conscious vehicle of an architecture which will not even shrink before the temptations of yet another round of neoclassicism. The latter is wilfully ironic and profane, but nevertheless constitutes a revival - an end in itself - of forms which bear no relation to everyday reality, as can be seen at the present Biennale of Venice. This experiment-based approach does, however, bode well for a future which will be geared more closely, more perceptively and more sensitively to the real needs of man taken as society at large and as an individual, and, above all, to a more sincere, less hypocricital interpretation of these needs.

The question one is tempted to ask today is whether all this will help to smooth once and for all the relationships - so chequered to date - between steel production technology and architectural design, between structural analysis and the rapidity of aesthetic developments, and, in particular, between housing and industrial requirements. And whether at last architecture will succeed in providing all-round solutions, i.e. capable of meeting different individual, social and technical requirements.

Looking ahead, what is already clear is that a challenge for steel in the context of construction simply has to be viewed in overall terms, i.e. as a challenge for architecture. With its inherent selectivity and creativity the latter will have to chart rather than pursue its difficult course through the increasingly well-defined demands of industrial production and man's inevitable individual demands which, partly by reaction, will drift increasingly towards the realm of the fanciful and the utopian. While, on the one hand, the continuing population explosion in urban areas and the resulting acute housing shortage will entail a non-selective use of all available construction techniques, on the other the growing dearth of exploitable land, of sources of energy and raw materials in general will inevitably shift the emphasis on to the most appropriate techniques from this point of view. There is therefore no doubt that steel will become increasingly the solution which will optimize space-efficiency and minimize the use of structural elements. Hereby permitting rational use of insulating materials. It will be the solution which will offer the greatest energy savings in terms of its production cost-to-performance ratio and when compared, for example, with the extremely high cost of aluminium. In addition, it will always permit total recovery of the structural material in the event of demolition.

If we leave aside for a moment the pessimistic outlook for the future mentioned earlier and take a longer-range look at standard of living targets rather than economic constraints - which I hope will be relatively short-lived - it seems increasingly likely that steel will be the basic construction material of the future. Its comparative lightness (in relation to its performance) and the resulting ease of prefabrication, transport and assembly mean that it will always be more capable than any other construction material of catering for the constant need to adapt to the changing human requirements involved, in other words for the undercurrent of inspirational construction which recurs in modern macrostructural designs as a constant ambition, albeit completely utopian for the time being.

It would be rash to make more specific and more detailed forecasts, but a word on the two major paths towards the future already being taken by steel-based construction is in order. The first of these paths involves open-web latticed structures which will increasingly give rise to designs which are continuous and infinitely variable, and will end once for all the distinction between pillars and beams, as predicted by Konrad Wachsmann.

The second involves tension-based structures, which have already opened up new and expanding horizons to design as regards forms and structural analysis. And in this context I feel duty-bound to mention the name of Frei Otto.

The true major revolutionary function of steel in the future, however, will perhaps be less grandiose and less linked with gigantic infrastructures, and more tailored to man and his natural habitat. At least this is, I am sure, what we all hope.

Lest I should be accused of being over-optimistic, let me now mention the inherent disadvantages of using steel, for they do exist, or rather they continue to dog us and sometimes impose serious constraints upon architectural inspiration. Briefly, these problems concern maintenance, fire hazards and the transmission of heat and noise. Admittedly, these are very grave problems which have not yet been solved despite the considerable technological advances made in recent years.. These advances are nevertheless grounds for an optimistic outlook as regards the solution of these problems.

I can therefore close by saying that if technological progress solves these problems in the near future, steel will become one of the most potent weapons in humanity's arsenal in the fight against the daunting large-scale problems ahead, such as overcrowding in the cities and scarcity of raw materials, problems with which science alone cannote cope and which will call upon all the resolve and creativity of Man and Providence."

The chairman thanked Professor GANDOLFI for his most interesting contribution and then asked Dr. W. EASTWOOD to speak on behalf of consulting engineers.

Dr. W. EASTWOOD (Great Britain) stated that he thought one of the major growth areas in the use of steel in building would be in cladding. Until quite recently, particularly in Britain, many structures used asbestos-cement sheeting and this despite the fact that, even when coloured, they were prone to staining and always tended to look dingy anyway. Now the health hazard was very much in the public mind and this had given an impetus to the use of steel. In addition, steel sheeting could now be bent to quite sharp curves, using a system known as Flowclad in Britain, which had provided opportunities for all kinds of architectural profiles and buildings with hidden drainage gutters. These were used in conjunction with the bright colours now availabe for plastic coated sheets and the sheets themselves could be arranged in horizontal as well as vertical lines, or even in diagonal patterns, producing a kaleidoscopic pattern. Such products were giving architects opportunities which they had not had befor and which could only increase the sales of sheeting.

In considering the overall position of the construction industry and the part the fabricator played in it, he wondered if there was not an encouraging analogy with that of the aircraft industry. The forward work load of the British aircraft industry was three times what it was a year ago, much of the demand being from Third World countries. These countries were also demanding steel industries, however costly, as a status symbol. Mr EASTWOOD felt that there was a steady growth market there for all the established steel producing countries.

The other growth area would be at the expense of the reinforced concrete industry. During the past twenty years concrete had done better than steel simply because it was now almost universal practice to use high yield stress steel for reinforcement, while mild steel was still widely used in the structural steelwork industry.

A number of factors were responsible for this. First of all, the question of deflection was treated unfairly as far as high yield stress steel was concerned. In refinforced conrete the stresses were slightly higher than in a Grade 50 structural steel and, with Young's Modulus being the same for the two materials, the stretching in the concrete could not be less than in the steel. In addition, the effective depth of a concrete beam was usually less than that of the analogous steel section, while there could be considerable creep and shrinkage deflections in concrete.

The posistion needed to be reviewed. Steel chimneys had already been considered in Britain and a new British Standard had been issued. The old standard had limited deflection to 1/200 of the chimney height. Such a limitation generally increased the chance of aerodynamic instability. The new standard merely required, in addition to the calculation of overturning moments, that account be taken of the fact that, as the chimney was leaning, its own weight would produce bending stresses.

As far as electric overhead travelling cranes were concerned, British and other national standards limited deflections. Again, this was nonsense. If a load were to slip on a crane hook, an impact load would be applied, and a flexible crane could more readily absorb the strain energy with a higher deflection.

The fire resistance requirements were also disadvantageous to steel. If fire resistance were really critical, cold formed purlins would no longer be used, because they were heated in a matter of seconds, not minutes. Also, because they were cold formed, their higher yield point would rapidly disappear on heating.

There had been an interesting paper the previous day on partial fire protection, but Mr EASTWOOD felt that there was a great field for research on the cost benefit of fire protection of steel structures. In Britain, the top storey of most buildings was exempt from the fire regulations, a strange piece of logic, which had resulted in many multi-storey concrete buildings being completed with bare structural steelwork and decking.

Mr EASTWOOD said there were still quite unjustifiable suspicions about the weldability of high yield stress steel and cited a recent case in which a British client was prepared to pay 20 % more for a steelworks building constructed in mild steel, rather than use a higher grade steel.

Mr EASTWOOD said that, in a similar way, corrosion problems were exaggerated. Recently, he had the task of surveying the steel roof of the Lyceum Theatre, the oldest framed building in Sheffield. He discovered that the steel girders spanning the main auditorium had originally had a priming coat of red lead paint, on which had been painted the beam marks, the fabricator's name and the date - 1892. The rust was negligible, but this was typical of what one might expect in a dry environment, even if the theatre were only heated for a few hours per day for a few months in the year.

The chairman thanked Mr EASTWOOD for his contribution and then called upon Mr J. RORET to speak on behalf of the structural steelwork industry.

Mr RORET (France) said that the members of the Round Table had been asked to comment on one of two questions. The first was "What do we expect from steel construction in the future?" He said that structural steelwork had been a source of pleasure for him for thirty-one years and all he could hope was that it could just go on and on. The second question was "What should be the objectives for steel construction in the future?" His brief reply was that he looked for growth and development.

There was, however, a third question that was not asked but which he wished to put forward and then try to provide an answer. It was :
How can steel construction grid its loins and where must it aim in order to forge ahead?

He believed there were three avenues available. First, the improvement of technology. Secondly, the reduction of production costs to become more competitive. Thirdly, commercial aggressiveness leading to a great trade drive.

Considering the first, steelmakers were now producing steels of better quality and improved performance with greater resilience, weldability, resistance to corrosion, and so on. The structural steelwork industry would have to rack its brains to find economic examples to meet market requirements. It would have to invent new composite construction with other materials without excluding industrialisation and prefabrication. Structures should not be studied in isolation. There was still progress to be made in dealing with fire and corrosion resistance and sound insulation and there were still welding and connection problems. There were also possibilities in the use of prestressing. Greater thought could also be given to the transport and erection of steelwork. Very often the erection problem was the most critical.

The second avenue was to reduce production costs to become more competitive. Here, the increased use of computers at the service of technology and management should help considerably. A much greater effort was needed at the design stage. Standard connection details should be introduced and the workshop drawings prepared automatically. There was room for improvement in the organization of the flow of work through the workshops, in transport and erection. There were many new processes for corrosion protection available, there was also the possibility of using prepainted steel. The earlier the protection was applied, the better.

Finally, there was a need for marketing drives. These could be individual or collective efforts. The national associations, as well as the European Convention for Constructional Steelwork and the specialist section of the Brussels Commission were achieving a great deal, but they could do still better by co-ordinating their measures. Training had been mentioned earlier in the conference. Training should extend beyond their own management and personnel to architects and consulting engineers as well. The public image of steel had to be improved. Preconceived ideas on rust and noise were difficult to dispel. Architects and engineers tended to belong to the concrete clan and were therefore adversaries of steel. A good general contractor should be capable of appreciating both media. Indeed, some steel fabricators were also general contractors. In addition, national and international standards should display impartiality, which was often not the case. Similar impartiality should apply to the education of architects and engineers.

Commercial aggression was also needed, especially in external markets. He had some personal hope, particularly in the developing countries. His own firm had built a Sheraton Hotel in Saudi Arabia which was opened to customers nine months after ordering. European architects and general contractors were beginning to discover the virtues of steel as a spin-off from these exports.

Marketing and aggressiveness had never been a strong point in the steelwork industry. The industry had to be convincing in order to regain lost ground. There had to be steel crusade, to develop industries, to raise the general economy and to help the steelmakers, who were in great difficulties, in order to forge ahead.

The chairman thanked Mr RORET for his analysis and especially for emphasizing the links among the various bodies within the European Community. He then invited Mr GARDIN to speak on behalf of the construction industry :

"What view do general contractos hold of the likely role of steel in building construction during the coming years?

So as to provide some basis for an answer to this difficult question, which has been put to me in order to start the discussion off, I think it would first of all be useful to remind you of how public-sector and private-sector demand in the building trade has developed.

My remarks are based on the latest economic analysis carried out by our International Federation of European Construction* in July 1980.

In all Member States, except in the Federal Republic of Germany, where a slight improvement took place between 1978 and 1979, the proportion of the gross domestic product invested in the building trade is diminishing. This is so for reasons which are common to all the various Member States :

- housing construction costs are rising faster than household incomes;
- the cost of borrowing money is rising;
- the cost of building land is rocketing up;
- governments are reducing public expenditure, beginning with investment;
- certain sectors of industry which have been traditionally big investors are in difficulties.

On the other hand, three factors ought to help to improve the situation :

- demand for commercial premises and office buildings continues to be firm;
- renovation and refitting work on existing buildings is expanding;
- campaigns to promote the use of alternative sources of energy to oil (mainly nuclear energy, but also coal, hydroelectric power and geothermal energy) and, in the shorter term, energy saving campaigns are also likely to expand.

It is likely that these three sub-sectors will consume a relatively large amount of steel, whether in the form of the metallic frameworks which are often used in the construction of office buildings, or in the restoration and refitting of existing buildings, where, as Messrs LUCAS and GIANGRECO have pointed out, steel often plays an important part, and especially in energy supply programmes, which are very large consumers of steel.

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* Report by the group of economic experts of the Standing Committee for the European Common Market.

In this way growth in steel consumption in particular sectors of the building trade ought to make up, at least partially, for the overall downturn in investment in the building sector.

I should now like to deal with a second aspect of the question that has been put to me. What are the advantages for the builder of steel compared with other materials? These advantages may be assessed in terms of the builder's objectives :
- to build at the lowest cost for the customer;
- to achieve a high standard of workmanship;
- to keep the building time to the minimum.

As far as the standard of workmanship is concerned, the use of steel is usually subject to extremely thorough quality controls, so that very small tolerances can be achieved. As a consequence of this, the proportion of skilled labour is relatively high on building sites that use a lot of steel.

Nevertheless, experience in building nuclear installations has shown that absolutely comparable results can be obtained with concrete; quality control can be just as thorough and the tolerances may be of the order of 1 mm (in the cooling ponds, for example).

Regarding building time, there is again no evidence to suggest that metal structures have a decisive advantage over concrete ones. The extensive use of concrete chuting masts on the various floors of a building, along with more and more powerful concrete-pumps, has made it possible to carry out the work extremely quickly, as has been shown in the case of nuclear power-station sites. In addition, steel boxes may be used as sacrifice shuttering in the floors in order to reduce building time even more. It is worth pointing out, according to the analysis given to us by Prof. A.A. DOUWEN, that this particular technical solution to the problem may well spread even faster if the price of steel continues to rise more slowly than wages and salaries, notwithstanding the rise in the cost of energy and raw materials.

Finally, we should not forget that concrete structures may also benefit from the advantages of prefabrication and that a 50 000-seat stadium, for example, can be built in this way in less than 14 months.

The quality of a structure and the time needed to build it are closely linked to costs. From this latter point of view, the most economic solution consists very often in a middle course between building everything of steel and building everything of concrete. As is often the case, the best solution is a compromise.

This may be arrived at in two different ways :

a) by determining which material is best suited for each part of the structure. For instance, more and more cable-stayed bridges are being constructed with concrete decks, in order to take as much advantage as possible of both the strength of the steel and the high level of inertia of the concrete box girders, which can be manufactured at a relatively low cost.

b) by putting more and more steel into the concrete. Nowadays, in the construction of nuclear power stations, for example, up to 260 kg of steel may be used per cubic metre of concrete in the reactor buildings, and up to 160 kg of steel per cubic metre of concrete in the machine rooms. Another example is the huge off-shore oil-drilling platforms, which are supposedly made of concrete, but which use very considerable quantities of steel, namely between 120 and 160 kg/m^3*.

In this way the intrinsic qualities of each material are put to the best possible use :

steel : great mechanical strength, high coefficient of elasticity

concrete : high level of resistance to heat and chemical attack, great stability (relative to the weight of the structure), less fragile.

In conclusion, although there is an overall stagnation in the building sector, it looks as if it will remain a very important customer for the steel industry, for two reasons :

- first, because the trend in demand in the building sector involves factors which are favourable to steelmakers, e.g. new types of structure that use a relatively large amount of steel;

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* FRIGG TPI : 50 000 m^3 of structural concrete
6 000 t of passive steel
500 t of prestressing steel

BRENT C : 105 000 m^3 of structural concrete
15 000 t of passive steel
1 100 t of prestressing steel

- second, because technical progress makes it possible to combine different materials more and more effectively, this being particularly true of steel and concrete.

The process of continual adaptation to new trends is a difficult, but also fascinating, task that building contractors have to master."

The chairman thanked Mr GARDIN for his contribution and then asked Mr P. LEFEVRE to speak on behalf of specifiers in the public sector.

Mr LEFEVRE (Belgium) said that the composition of the Round Table had been wisely chosen. Unity was strength. Even if they did not start from the same point of view, they could envisage the future with calm confidence. Among those present there were steel producers, steel fabricators, general contractors, consulting engineers, architects and the academic staff from universities, altogether a distinguished gathering. The theme of the conference was the challenge for steel. He had to make decisions about all kinds of civil engineering projects in the Ministry of Public Works in Belgium. He had to keep his ear to the ground and keep himself well-informed. Now the French word "pari" meant not only a challenge, but also a wager, where there was some doubt about future events. But there was no doubt about steel. There might be some short term difficulties, but it had enjoyed over one hundred years of success. There had been many spectacular achievements, such as very long suspension bridges, skyscrapers, enormous industrial buildings, locks and masts, all essentially one off jobs. Anything difficult had been done in steel.

He thought, however, that there was often a serious lack of communication. Information should be more widely and more quickly disseminated. Concrete was often considered as a rival material but, like brickwork, timber, aluminium and glass, each had an important role to play. But in Belgium, during the last twenty years, consulting engineers and architects had neglected steel because they were neither properly informed nor properly trained. At a given moment, a choice had to be made between materials. It was not just a case of saving energy, which was important, but in making savings in the medium or long term. One had to think of operating costs and maintenance. The overall balance should be favourable to steel.

Finally, the most important aspect was construction time and, there, steel was undoubtedly still advantageous.

The chairman thanked Mr LEFEVRE for expressing his views. He hoped there were responsible people in every European country who would think about these subjects and express their own views. Mr LEFEVRE had stressed the need for the wide distribution of information. He hoped that in the discussion period after the coffee break delegates would state how they thought information could be assembled and then redistributed.

After the coffee break, the chairman invited the delegates to take part in an open discussion, not only on the remarks already made by the members of the panel, but on any aspect of the conference.

Mr R.A.C. LATTER (Great Britain) said that he wished to deal with the theme of stronger marketing already referred to by Mr RORET and Mr LEFEVRE.

Mr CHEHI, in his address, had drawn attention to the sales engineering activities of Bethlehem Steel in which his team set out to persuade architects and engineers to choose steel solutions for particular buildings. A similar operation had been mounted for conventional steelwork by the British Steel Corporation about eighteen months ago and it was now beginning to make an impact. As Mr CHEHI had said, it really did work. The sales engineering team were also being supported by an information service on fire protection, the area which constituted the largest single business problem. Help was being given to fire protection material manufacturers to develop new higher performance and cheaper products. The B.S.C. research laboratories ware being placed at the disposal of these firms, which were often too small to develop new products themselves.

The sales engineering team were propagating the knowledge so gained among specifiers either individually or at presentations, some three of which were held every two weeks. A similar approach was also being made with regard to corrosion protection, which was the second problem area, but one within which there was again considerable expertise in the steel industry.

The chairman thanked Mr LATTER for his remarks and wondered if there was anyone else who would like to speak on the theme of fire protection.

Miss Margaret LAW (Great Britain) stated that she was a fire engineer responsible for all types of safety measures in buildings comprising structural steelwork, masonry, concrete, timber, aluminium and even air! She felt that fire resistance design should be a normal part of the work of the structural engineer. Unfortunately, at the moment, the safety levels were not quantified in an engineering fashion, neither was the effectiveness of the various measures which one could use.

When one examined what happened in a fire, one found that deaths were rarely attributable to the degree of fire resistance of the structure. Normally, people just died one at a time, asphixiated by the smoke. Yet fire experts in the authorities asserted that there were good reasons for structural fire protection because of public concern about large fires. The only way to persuade the authorities to adopt a civil engineering approach was for structural engineers to present a well stated case, not an emotional one, demonstrating that the fire ratings were too stringent and unreasonable. She put in a plea that there should be some initiative for such an approach, either nationally or in Brussels.

The chairman welcomed Miss LAW's proposals and suggested that the existing research information should be pooled to this end.

Herr Dipl.-Ing. ELLER (Germany) said he wanted to augment the remarks of the previous speaker. He felt that their clients should not be burdened with safety problems and therefore within the Deutscher Stahlbau Verband, of which he was technical director, there was a fire engineer whose task it was to ensure that the authorities were able to discriminate between situations where fire protection was necessary or not required. Already, in eighty cases, they had had successful negotiations. He, personally, believed that every engineer dealing with steelwork should make himself familiar with the essential features of fire resistance and corrosion protection, so that straight-forward problems could be solved for the client without bringing in experts on every occasion.

The chairman thanked Mr ELLER and called upon Mr FRUITET to speak.

Mr FRUITET believed that the problem of safety against fire was primarily the task of the architect. If a building were well designed, taking safety into account, the protection of structures should not be the rule, but the exception. The elements which should receive protection were only those playing an important part and the number of these could be considerable reduced. From this point of view, common sense should play its part as much as science, technology and the regulations, which did not cover every individual case. In the ordinary way, (and this also applied to the problem of deflections) two attitudes could be adopted in the face of regulations considered to be unfavourable :

1. Try to comply with the regulations, often at great expense, or
2. Consider the regulations and apply them with discrimination, in accordance with the spirit, rather than the letter, if necessary making other arrangements which render them invalid.

The chairman thanked Mr FRUITET and then summarized the remarks which had been made about fire protection.

Professor SCHNEIDER (Germany), speaking briefly, said that he came from the Fachhochschule in Biberach where he had to lecture to architects on steelwork. Not only was there a historical dislike of steelwork in South Germany, but the architects thought quite differently from engineers and there was, therefore, a psychological problem to overcome.

Mr THOMAS (Belgium) and Mr RORET then had a short dialogue on the speed of erection of steel and concrete structures, when it was agreed that if the building were small, there was little difference in erection time.

Mr DE MARTINO (Italy) stated that information on the fire protection of steelwork had not always been correctly presented. It was necessary to examine all the possible structural solutions with objectivity, including prestressed concrete, and evaluate the behaviour in terms of fire resistance.

Structural steelwork could be combined with the rest of the construction (floors, external walls, partitions and internal spaces) in fire resistant materials (concrete, brickwork, plaster etc.) and therefore it was possible to include or to avoid the fire protection of the structure itself. It should be possible to produce recommendations at a European level on the basis of the evaluation of actual fires and the results of experimental research.

Mr J. MESKENS (Belgium) said he was a reader in architecture at the St. Lucas Institute in Brussels. He felt that the discussions that had taken place that far had been largely of an engineering character, which had not dealt with aesthetics or environmental conditions. He thought that most architects tried to use the old materials because they felt that steel and concrete were not compatible with environmental conditions. Yet, one of the most amazing examples of industrialized building was the Crystal Palace, designed by Joseph Paxton, who was a gardener. Could not Paxton's philosophy be employed at the present time? The Bionica was a new science combining technical systems with organic systems met in nature. A multidisciplinary team under Frei Otto in Stuttgart had been able to produce the roofs of the German Pavilion at the Montreal Expo and the stadia for the Olympic Games in Munich. He was pleased that students in his Institute were interested in these concepts and, as steel had certain intrinsic qualities, he felt it had an important role to play.

Mr N. LAUN (Germany) agreed with Mr MESKENS that really only the technical aspects of steelwork had been treated until then at the conference, while the artistic possibilities had been almost entirely neglected. Nothing had been said about the mighty and almost aggressively beautiful stressed skin structures of Frei Otto, nor about the filigree appearance of the Centre Pompidou, which was only made possible by steel. He believed that steelwork should be seen not just as a competitor with other current constructional media, but as a specific noble material both in the technical sense and from the formal point of view. If steelwork were considered in this way, as Mies van der Rohe had done, then it would have a rosy future.

Mr TISSIER (France) said that it was undesirable that the good intentions expressed during the conference should remain just pious hopes. At a time when the relevant trade organizations in France were experiencing a reduction in their means of action, it was necessary to find new remedies for the problem and to call in consultants for information and educational purposes. It was not proposed to pass over the authority of the local organizations, but to give them effective help. Such action would sell their expertise and also steel in an effective way.

Mr J. DE LA HAMETTE (Luxembourg) said that Mr EASTWOOD had expressed the opinion that high yield stress steels were penalized by an inadequate requirement in the standards relating to the deflection of rolled sections. Within the framework of research of the Community, would it not be possible to prepare a research programme having the object of replacing the current requirements in the standards in question by a more realistic concept, taking advantage of the greatly improved mechanical properties of high yield stress steels?

Mr EASTWOOD, in reply, said he could not speak for other countries, but certainly the rules in Great Britain should be rewritten. He elaborated on his previous remarks that deflections in concrete structures were greater and far more critical than in steelwork. He believed that codes of practice should have a rule for general guidance stating that the designer must take account of deflections, both visual and physical, and there should be no limits quoted.

Dr. A. CARPENA (representing the ECCS) stated that in order to eliminate technical obstacles to discussion within the European Community, the Commission were preparing Eurocodes for the design and construction of structures in different materials : steel, concrete and composite steel-concrete structures, as well as timber and brickwork. Each material would be treated in its own particular Eurocode, while the general principles for security which would be valid for all construction would be dealt with in the first of the codes : Eurocode 1, the preparation of which was well advanced.

In order to co-ordinate the regulations, the European trade associations representing the different materials were being called upon to play an important role, especially in drafting the Eurocodes which affected them directly; among these being the ECCS for Eurocode 3 : "Steel Structures" and Eurocode 4 "Composite Construction". These Eurocodes would be based on the "European Recommendations for Steel Construction", published in 1978 by the ECCS, and on the "Model Code for Composite Structures" prepared by a joint committee representing C.E.B., I.A.B.S.E. and E.C.C.S. and published also by the ECCS.

The construction bodies expected that the programme proposed by the Commission would lead rapidly to the adoption of modern regulations on a European scale. The steel fabricators, in particular, hoped that the many unnecessary and unjustified difficulties which they encountered in their work, within and outside the Community and which had been mentioned at the Conference, could be minimized, if not eliminated.

The ECCS hoped that the technical activities which they had pursued for a quarter of a century and the results of the enormous research programmes undertaken by CEC, as well as all the recent investigations in the field of structures, could contribute to the improvements of existing codes and provide fundamental help in the preparation of the Eurocodes and, in consequence, to the use of steel, which was very often unnecessarily penalized by codes and by rules based on outmoded concepts.

Mr CARPENA said he would like to refer to another subject by following up a remark made by Mr LEFEVRE in his talk that morning. He had referred to the necessity of providing a correct global evaluation of the different projects presented with a tender in order neither to penalize nor favour a solution in one material by reference to other solutions in different materials and, finally, that the owner could choose the best solution.

In this connection, he wished to point out - for those who had not had the opportunity to read it - that in August 1979 a report on Efficiency Analysis undertaken at the Planning Stage in the Assessment of Multi-Storey Buildings, written by Mr M. MEYER, had appeared in the IABSE Journal J-8/79.

The 24-page article recommended a cost function-time analysis for every project. This analysis would produce the significant information needed in order to arrive at the best possible solutions. Te method proposed was equally applicable to architectural competitions, tenders and the appreciation of all types of avant-projets.

The article gave the bases, the method and an example of the application of the analysis in the course of decision taking for the construction of buildings. The original report was in German - Nutzwert-Analyse zur Beurteilung von Geschossbauten in Projektsstadium - but a French edition was also available.

The chairman thanked Mr CARPENA for giving this most important information and then called upon Mr J. CRAN (Canada) to speak.

Mr J. CRAN said that he came from the Steel Company of Canada and appreciated the opportunity to attend what was basically a European conference. He wanted to make the observation that the title of the conference was "Construction - A challenge for Steel", but really the comments had been addressed to a very narrow part of construction and he thought that in North America they were similarly guilty but, of the steel used in construction, only one-third went into structural frames in buildings and bridges. The remaining two-thirds of the steel went into hydrocarbon plants, pipelines, heating and ventilating systems etc. in buildings. He thought the challenge was to address themselves more to that bigger part of the market. He felt that everything was so refined for structural steelwork nowadays that it had been basically killed. There were probably no mechanical engineers present, but it was to them that they should be talking.

The chairman agreed that this comments were very relevant.

Mr A. DOBRUSZKES (Belgium) stated that the use of high yield stress steels was often restricted by excessive deflections, due to the fact that the modulus of elasticity was constant for all steels and simple concrete encasement was ineffective as concrete cracked.

Preflection was a solution to this problem. Experience had shown that, with equal spans and loads, the deflection a Prefix beam, in steel AE 36, completely encased, was equal to :

$\frac{1}{2}$ of the deflection of otherwise identical beams, but not preflexed;

$\frac{1}{3}$ of the deflection of a composite beam having the same height and the same capacity.

In addition, preflexed beams did not change curvature in their length and did not induce any alteriation in the main or secondary elements.

The chairman thanked Mr DOBRUSZKES for his contribution and asked Mr RORET to speak.

Mr RORET (France) said he wished to comment on the remarks of Mr GARDIN who had spoken about the widespread use of steel in concrete oil rigs. He had been interested to hear Mr GARDIN mention that 160 kg of steel were used per cubic metre of concrete in oil rigs and that the weight of the frame was about the same as that of the competitive all-steel rig.

Until about a decade ago, all rigs were designed in steel but then various forms of concrete rigs were introduced. The wheel of fortune was turning and he predicted that in the next five years or so some twenty steel platforms would be built in the North Sea but no more than one or two in concrete.

Nr NAUDO (France), speaking very briefly, confirmed what Mr RORET had said.

Mr J. BEDEL (France) said that he worked for a small steel fabricator. He wanted to ask two questions :

1. Were the relative overall energy costs of concrete and steel available? Were they favourable to steel?

2. Fabricating firms had had hardly been mentioned, but when they were, they were large firms. Was it thought that small firms had the resources to meet the present challenge or would they dissappear?

In reply to the first question, Mr RORET said that attempts had been made to compare the energy costs of concrete and steel, but there were so many factors to consider that generally the results had been inconclusive. However, if the possibility of re-cycling the steel was considered, then steel was always advantageous from this point of view.

The chairman thought that probably this question would be pursued more vigorously in the future. As far as the second question was concerned, he could provide an answer as he represented a small firm as well. He believed that in France and many other European countries there were trade associations which did not differentiate between small and large firms. Larger companies had greater scope but smaller firms were often more flexible and more mobile. The same applied to most sectors of industry.

Mr A. SPINELLI (Italy) said that he not only designed but he also made steel structures, mostly industrial buildings. With regard to aids to designers, he found that they normally needed assistance only in special areas. He was a member of an Italian working group which had concentrated on the mass-production of housing units, because this was where the real challenge lay. They concluded that the best solution would be to use square a d rectangular hollow sections for the frameworks. They had received considerable aid from CIDECT in the design of joints and with fire protection questions as well. They had used laser beams for the preparation of the hollow sections although they were normally used for much larger elements. They had also discovered that hollow sections had facilitated the installation of all the technical services.

Mr LEFEVRE (Belgium) thought he could only conclude from the discussion held that morning and from the papers previously presented that steel was the victim of considerable prejudice, particularly with regard to its cost, but on a long term basis steel was not expensive. Similarly, there was prejudice in relation to its behaviour in fires. As far as maintenance was concerned, steel had a remarkably good record. One had only to think of the Eiffel tower. From the aesthetic and environmental point of view iron, which was the basis of steel, was one of the noble materials and one of the strongest, yet there was prejudice against exposed steelwork. Unfortunately, all these prejudices were reflected in official regulations and steps had to be taken to make them more amenable to steel construction.

The chairman closed the discussion by thanking all those who had organized the conference, those who had participated in various ways that morning and last, but not least, the very able translators. He then called upon Mr P.R.V. EVANS to give his closing address.

Closing Address

Mr. Chairman, Ladies and Gentlemen,

In bringing this international Conference to a close, may I thank, on behalf of the Commission of the European Communities, all who have contributed to the success of this occasion.

In particular, we are greatly indebted to M. Barthel, Minister for Transport and Energy of the Grand Duchy of Luxembourg who was able to find time to be with us and give the address of welcome. I would like to express also our appreciation of M. Vouel's opening address and remind you of the need he expressed for optimism over the future of the steel industry at this difficult time.

We are most greatful to the speakers, the members of the discussion panel and the session chairmen who have borne the real burden of the proceedings with a special thanks to Mr. Chehi and Mr. Hori who accepted our invitation to travel large distances to present us with excellent reviews of the role and prospects for steel construction within their own respective countries.

Next, our thanks go to the steel information centres of the Community who have collaborated in the organisation of the conference and to the members of the Programme Committee who, under the able chairmanship of M. Paul Borchgraeve, undertook the careful preparatory work that laid the foundations for the success of the event. Furthermore, the assistance of the Luxembourg authorities on the organisation of the conference and the warm and generous hospitality that has been extended to us all are greatly appreciated.

The conference was conceived with two major objectives in view; firstly, to review and to reflect upon the current state-of-the-art on steel utilisation in construction covering the progress that has been made over recent years and, secondly, to promote a dialogue between steel producers and users, constructors, architects and representatives of public authorities to identify the opportunities and the obstacles to the further exploitation of steel in this important consumer sector. I believe we can be well satisfied that they have both been achieved.

But such a conference is not an end in itself; it must prompt further action if steel utilisation in construction is to grow and if it is to meet the challenges that lie ahead from competitive materials and from new and more demanding customer requirements.

I will not try and sum up all that has been said over the past 2 1/2 days but let me remind you of one fact that has emerged which is particularly significant for everyone connected with steel production and utilisation in Europe; that is that the construction sectors in North America and Japan are, on a percentage basis, far higher consumers of steel than is the case in Europe. This has resulted, to a large extent, from carefully formulated strategies for the promotion of steel extending from steelmaking and processing to product development and marketing. Surely, this must serve as a stimulus for us to re-examine our production and fabrication methods, our technology and its exploitation, our producer-customer relationships, our approach to education at university and beyond, our methods of information diffusion and so on in order to extend the use of European steel.

In view of the considerable potential markets in, for example, the developing world, there must exist impressive rewards for our steelmakers who are eagerly searching for new markets and for an increase in demand for their products.

The Commission will continue to play its part by contributing to technological progress through the ECSC steel research programme, of which, some 20 % of total annual effort i.e. approximately 5 million EUA, is currently devoted to problems of steel utilisation in construction. Also, continued support will be given to work on the harmonisation of codes of practice and on standardisation at the Community level; as you know progress in this particular area is already being made in collaboration with the European Convention for Constructional Steelwork in establishing Eurocodes.

In addition to what is already being undertaken, it is now necessary to reflect upon the main conclusions of the conference and on their implications for the future of steel in the large and diverse market of construction. Should this examination reveal that additional collaborative effort would be appropriate, then the opportunities must be explored and the priorities selected in conjunction with producers and constructors, research establishments and steel information centres as well as with the other organisations connected with the building sector.

I trust that when we next meet to review progress in this field, some of the developments we will then discuss will have stemmed from the work we have undertaken over the past two and a half days.

On this point, Mr. Chairman, I would like to conclude by finally paying tribute to the most valuable assistance given by the Commission's services in Luxembourg in the organisation of the Conference and I refer particularly to Mr. Rotondo and Mr. Linster as well as to the interpreters for their indispensible contribution to the proceedings.

P.R.V. EVANS

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