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Reflections on the Development of Structural Engineering

Réflexions sur le développement de l'ingénierie des structures

Ueberlegungen über die Entwicklungen im Konstruktiven Ingenicurbau

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SUMMARY

"New horizons in structural engineering" — may first evoke the thought of innovative new structures to be built in the future. For this reason recent realizations of outstanding structures are briefly presented as an indication of potential new developments in this field. However, the challenge we face today, which is to create a viable environment for everybody, is much more of economical, social and political than of purely technical nature. Thus, it seems imperative that the IABSE and other international engineering organisations enhance their influence in decisíon-making bodies.

RESUME

Le sujet "Nouvelles frontières dans les constructions de génie civil" pourrait au premier abord nous faire penser à des perspectives nouvelles et innovatives dans les constructions. Les récentes évolutions de certaines constructions exceptionnnelles, évoquées brièvement, permettront de tirer profit pour de potentielles, nouvelles applications. Toutefois, le défi posé, soit de créer et de conserver un environnement viable pour l'humanité, est surtout une tâche de nature économique, sociale et politique, et ne pouvant pas uniquement être résolue au niveau technique. Pour cette raison, il est primordial que l'AIPC et d'autres organisations internationales d'ingénieurs gagnent de l'influence dans la phase de décision pour de nouveaux projets.

ZUSAMMENFASSUNG

Beim Thema "Herausforderungen an den konstruktiven Ingenieurbau" mag man zunächst unwillkürlich an neue, bahnbrechende Bauten denken, die in Zukunft realisiert werden könnten. Daher wird zunächst die jüngste Entwicklung hervorragender Bauwerke kurz aufgezeigt, in der Absicht, Schlüsse für potentielle, neue Anwendungen zu ziehen. Allerdings ist die Herausforderung unserer Zeit, das heisst der Menschheit eine lebenswerte Umwelt zu schaffen oder zu erhalten, vielmehr eine wirtschaftliche, soziale und politische Aufgabe, die mit technischen Mitteln alleine nicht gelöst werden kann. Daher sollte sich die IVBH und andere internationale Ingenieur-Organisationen darum bemühen, bei Entscheidungs-Prozessen für neue Entwicklungen vermehrt Einfluss zu gewinnen.

1. PRELIMINARY REMARKS

It is indeed laudable that an important international organisation such as IABSE devotes a whole congress to pressing problems of the future of mankind, rather than to treat technical topics only. There can be little doubt that civil engineers could and should play a more important rôle in the quest to create a viable environment for everybody. It seems however somewhat doubtful if this can be achieved by fabulous innovations or - as the title of this session suggests - by striving for new horizons in structural engineering, at least if this is interpreted as referring to technical progress only.

The challenge we face today is much more of economical, social and political, rather than of purely technical nature. If we only compare the beauty and cultural harmony of ancient towns with modern cities which look very much the same throughout the world, one realizes that even for a technically relatively simple problem, such as the one of providing adequate housing for the evergrowing world population, no convincing solution has yet been found, in spite of the many earnest, albeit sometimes questionable attempts made in this respect.

Even though the high spirited endeavour to improve "civilization through civil engineering" will be extremely difficult to achieve, it seems certainly worthwhile to make attempts in this direction.

2. OUTSTANDING STRUCTURES

When referring to "new horizons in structural engineering", one is indeed inclined to think first of ever larger, higher and more gigantic structures. As suggested in the introduction, this is hardly one of the most pressing issues of the future of mankind. As a matter of fact, the precarious world situation would not greatly change if the Strait of Gibraltar - to cite just one example - could be crossed by an enormous bridge or a tunnel rather than, as so far, by ferry boats. However, since the theme of this session implies such notions and since the topic is indeed very interesting from an engineering standpoint, we shall have a brief look at the recent development of outstanding structures, and in particular of bridges.

Among the most gigantic ones count certainly modern off-shore structures which go to ever greater depth of several hundred meters below sea level. Immense technical progress have been made in this field, if one thinks only of the sliding formworks employed, comprising a developed and accumulated circumference of up to 2 km to be continuously lifted in uniform manner (Fig. 1). The experience gained from such pioneer work will certainly sooner or later be adopted for bridge foundations in deep seas.

As for very high towers, sometimes deemed necessary, to broadcast Media Programs to the last corner of the world, they do not cause unsurmountable technical problems. However, one may rightly question if the flood of sensational and often useless information contributes to the improvement of our civilisation and thus justifies such investments.

Another matter is the one km high chimneys envisaged for the thermo-solar energy plants. Technologically this can certainly be realized if only the political and financial problems can be overcome.

There can be little doubt that, especially in the field of bridge construction, enormous progress has been achieved in the more recent past. This pertains somewhat less to spectacular new systems or concepts of bridges, but much more to advanced construction and erection procedures. Compared with the general costs of living, bridges have indeed become relatively cheap and can be built in extremely short time.

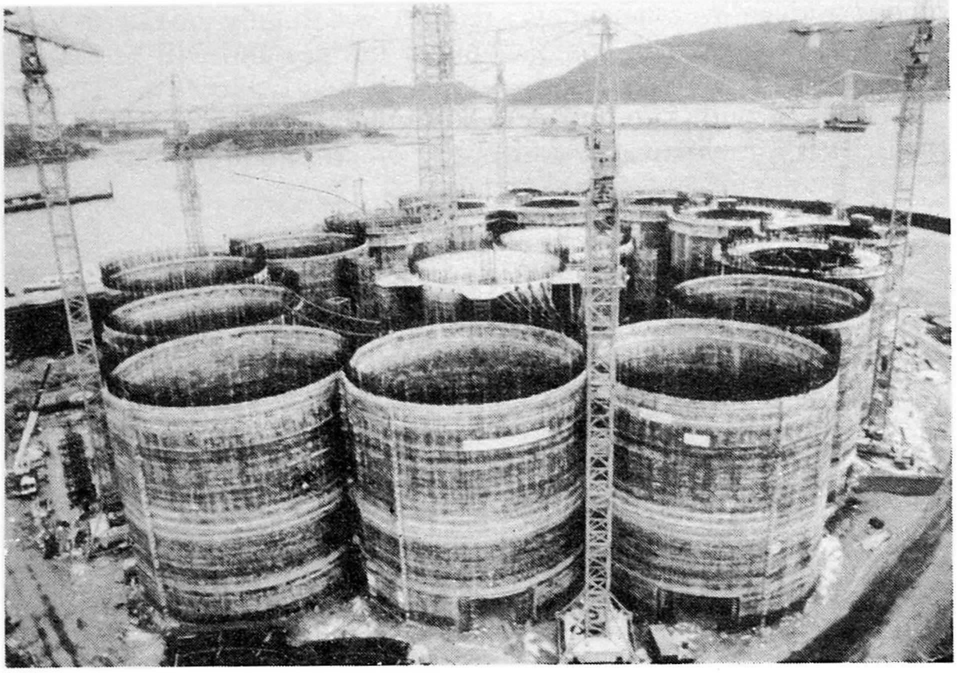

Fig. 1

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As an example, the remarkable Pont de Ré in France, which links the off-shore island with the continent, may be cited. The whole 2930 m long bridge was constructed by the cantilever style method in a record time of only 20 months for a unit price of less than 1000 US$ per meter square (Fig. 2).

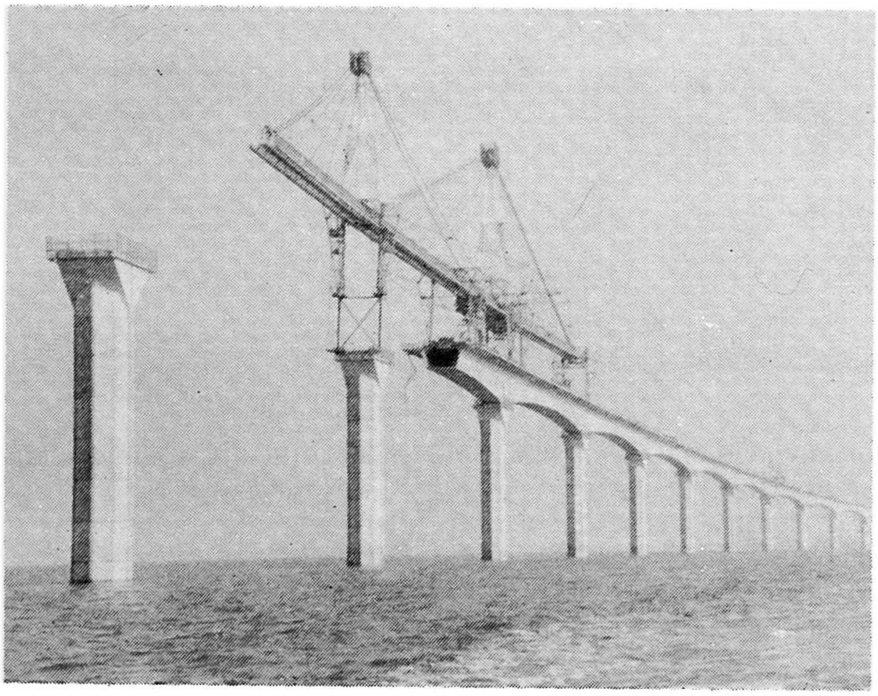


Fig. 2

The most ambitious bridge development ever realized is certainly the one of the Honsu-Shikoku crossing, which comprises some 20 major bridges and will be completed in 1998 by the Akashi-Kaikyo Bridge with a span of nearly 2000 m. This gigantic endeavour carried out in only two decades, unthinkable in former times, was only possible due to the very sophisticated and heavy erection equipments the Japanese engineers had developed to this end (Fig. 3 and 4).

Fig. 3

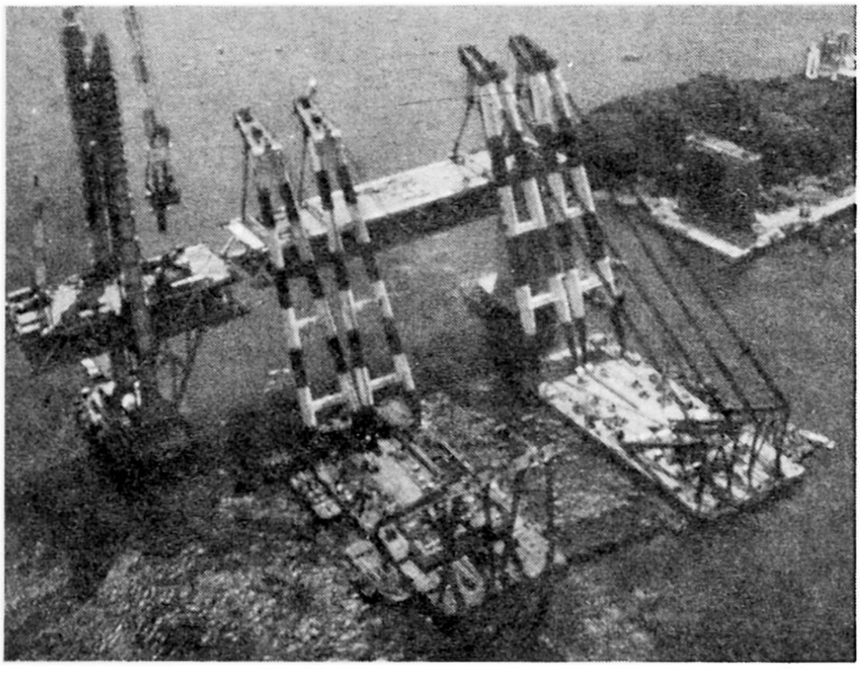


Fig. 4

Since in this paper it is intended to analyse the actual trends critically, it may be allowed to state that our admiration for this enormous undertaking would even be greater if the aspects of aesthetical harmony would have been given as much attention as to the unquestionable epochal technical achievements.

The pre-eminence of construction methods becomes also clearly evident in the case of arch bridges. Big labour-intensive falseworks as used in the past are not anymore envisageable economically. Thus arch bridges are nowadays built by skillful combinations of cantilever methods, incremental launching or even sliding formworks (Fig. 5 and 6).

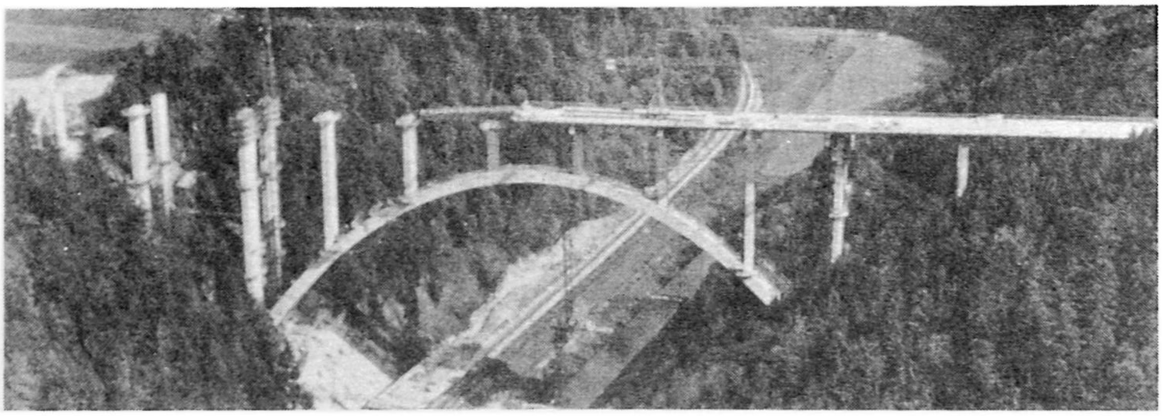


Fig. 5

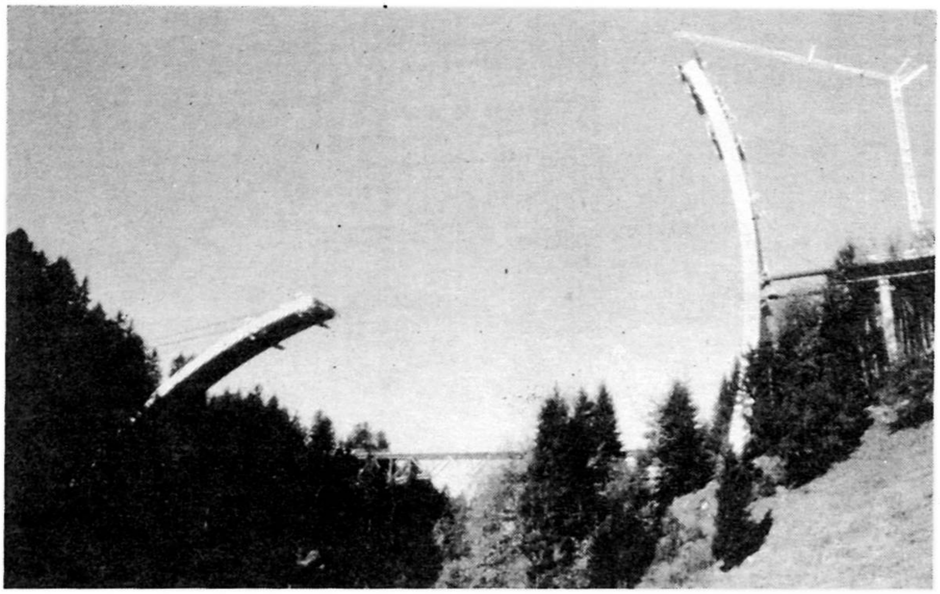


Fig. 6

Erection speed and economy can greatly be enhanced by prefabrication combined with external prestressing. In the case of the Sylan-Bridge in France prefabricated match-cast truss segments were assembled on a huge launching beam and tied together by external prestressing calbes (Fig. 7).

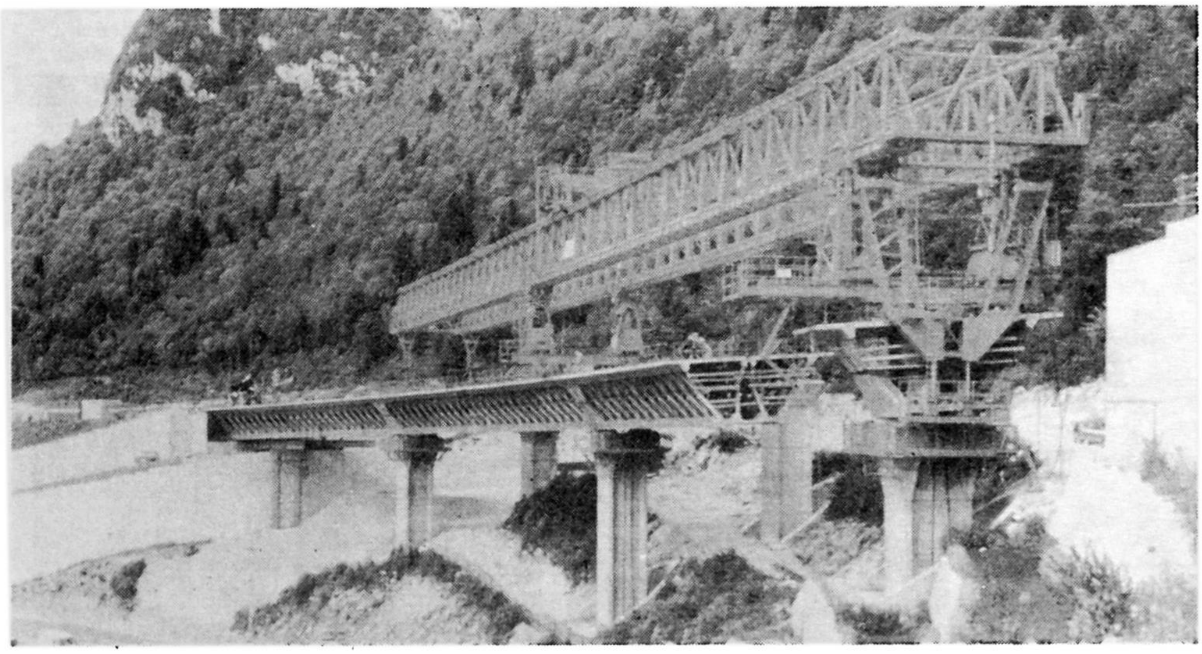


Fig. 7

The spectacular, worldwide success of cable stayed bridges is to a large extent due to the comparatively simple and economical erection procedure normally by the cantilever-method. It would lead too far to retrace this remarkable devlopment here in detail. Just two recent oustanding projects shall be mentioned: the recently inaugurated Skarnesund-Bridge in Norway (Fig. 8) has a record span of 530 m, which is all the more remarkable considering its width of only 13 m corresponding to a daring transverse slenderness ratio 1/40. Its fully satisfactory aerodynamical stability was achieved by an adequately shaped, rigid concrete box section.

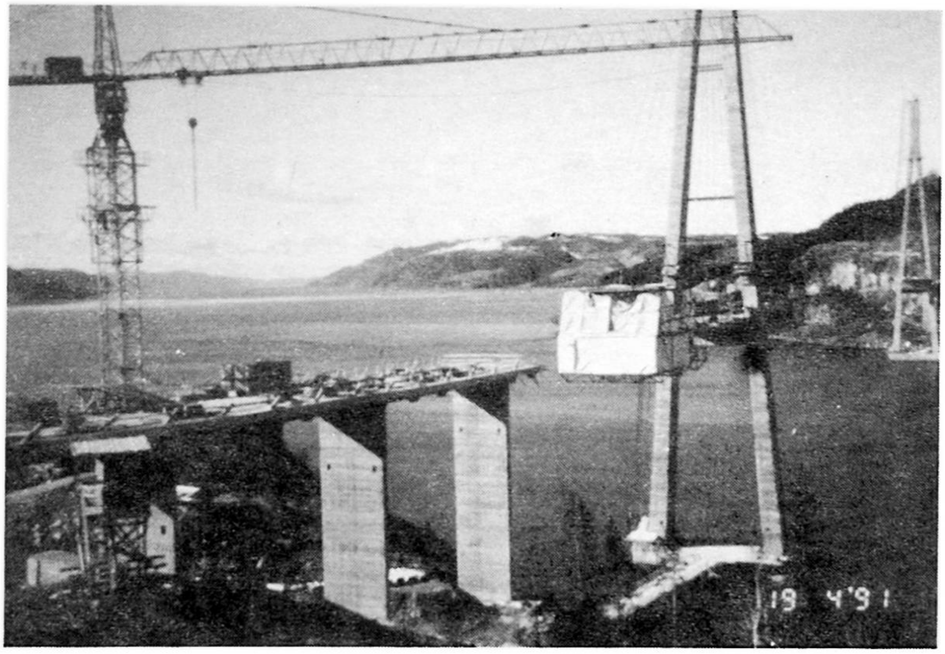


Fig. 8

The Normandy Bridge actually under construction will have an even greater span of 865 m (Fig. 9). There had been some quite heated arguments on whether or not it is prudent and feasible to extend the range of application of cable stayed bridges to such large spans. On the account of the experience gained from the Starnesund Bridge, the answer is clearly positive. As might be known, Prof. Leonhardt and his Italian partners have proposed to cross the Strait of Messina by a 1800 m span cable-stayed bridge (Fig. 10), which could undoubtedly be built, but which was not deemed acceptable, mainly for navigational and geotechnical reasons.

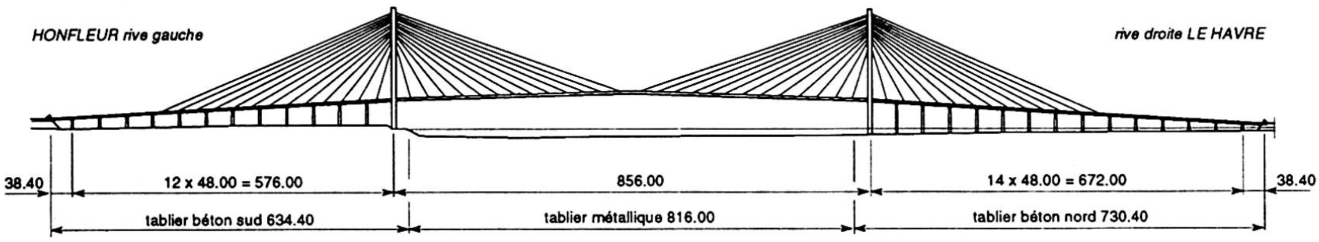


Fig. 9

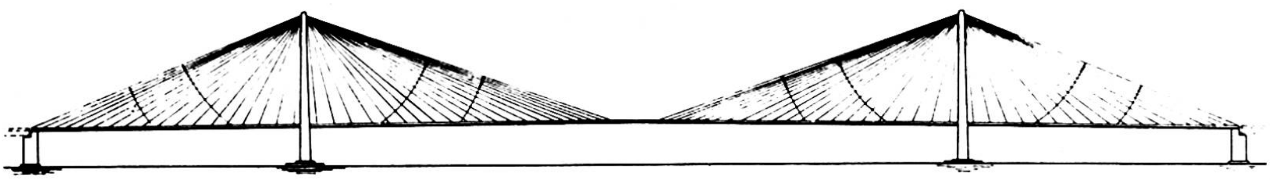


Fig. 10

On the other hand, the very thought that new types of cables made out of carbon fibers will enable us to build a bridge over the Strait of Gibraltar with a central span of over 8 km belongs for the foreseeable future to the world of pure fantasy. It would be all but impossible to erect and stabilise 4 km long free cantilevers. However, the advantage that such cables are about four times lighter than steel cables could be potentially of interest for future but somewhat more modest applications.

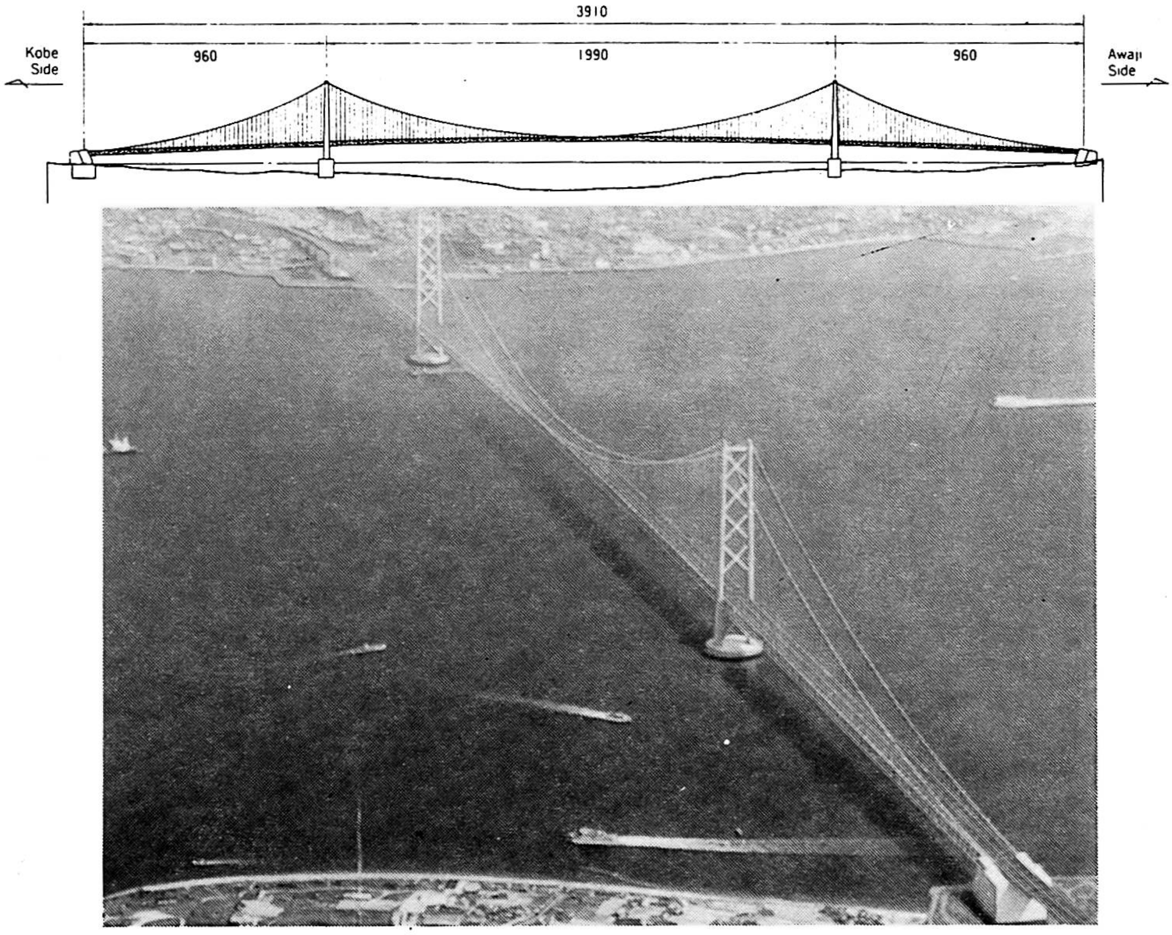


Fig. 11

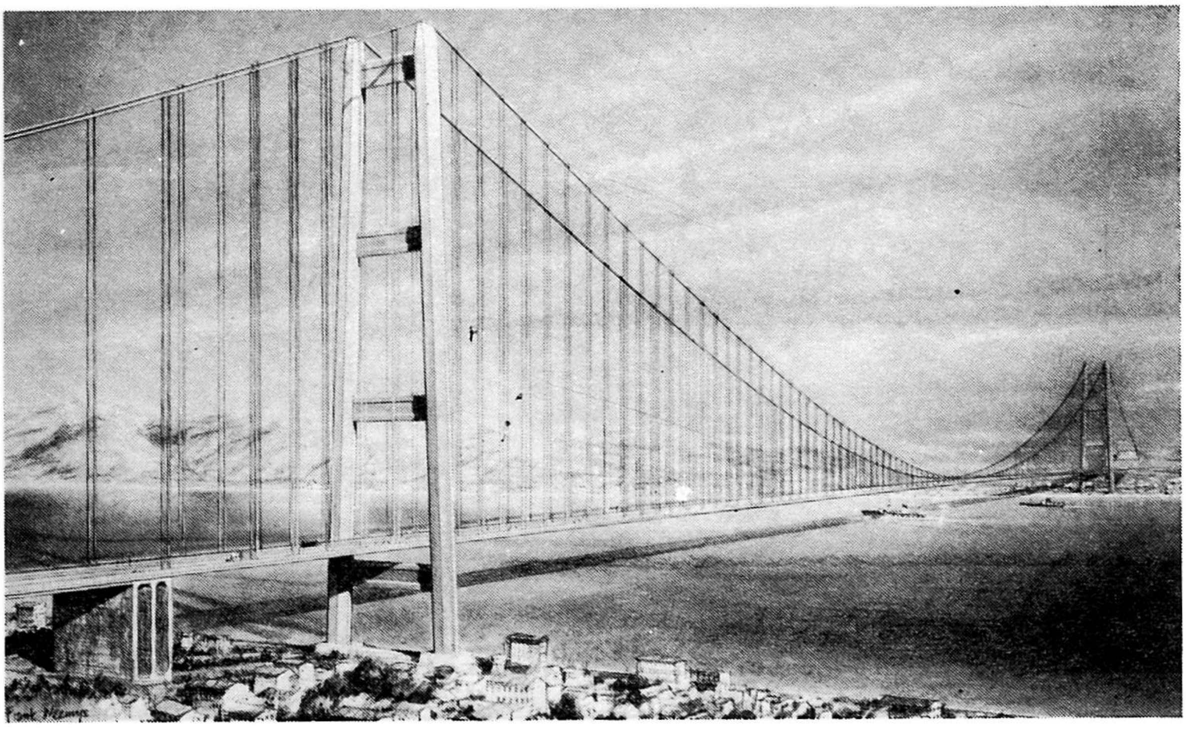


Fig. 12

For the time being very large spans will probably remain the domain of suspension bridges with steel cables. At any rate the two largest projects in view pertain to this category, namely the Akashi-Bridge in Japan acutally under construction with a span of 1990 m (Fig. 11) and the Messina Strait-Crossing with an even more daring central span of 3300 m (Fig. 12).

3. ON INNOVATION AND ORIGINALITY

The theme "new horizons in structural engineering" might also evoke notions of revolutionary innovations, which - if they ever come true - can hardly be foreseen. If we indulge in some objective modesty, we have to admit that in spite of all the spectacular technical progress we witnessed in the recent past, there were rather few fundamental innovations. The last major break-through, the invention of prestressing by Jackson, dates already one century back and it took another 50 years to develop it to its present standard.

It is indeed true that a great many interesting new developments have taken place, such as for example very high strength (or high performance) concrete, composite materials, carbon - and glass-fibers etc., however none of these taken as such seems at least at present to open radically new horizons in structural engineering.

One may deplore this fact but the gun powder cannot be reinvented every so often and we have also to bear in mind that the most glorious periods of human civilisation were usually brought about by utmost perfection of the cultural inheritance rather than by sudden technical innovation.

In our opinion, innovation at all price should not be an end in itself, all the more since the search of ostentatious originality bears sometimes rather dubious fruit, as for example the palace shown in figure 13 which is in reality a low-rent apartment building.

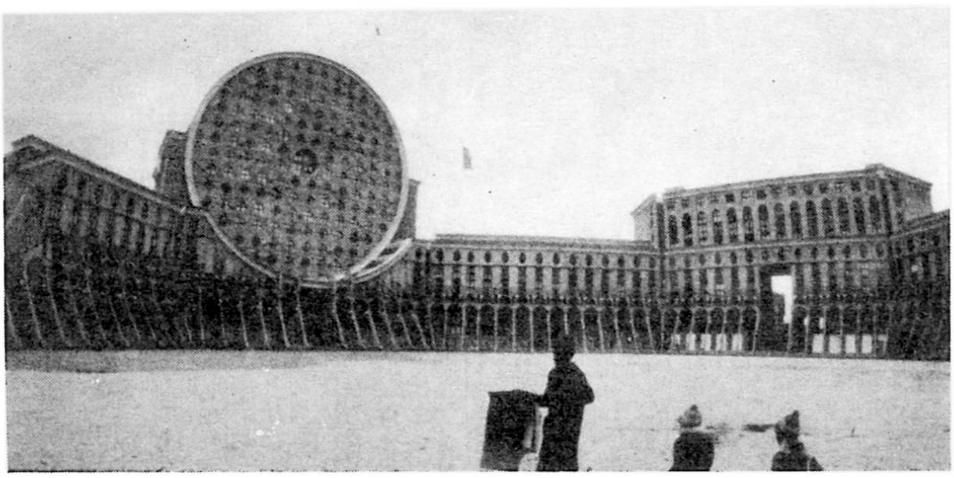


Fig. 13

4. ON THE ROLE OF STRUCTURAL ENGINEERS

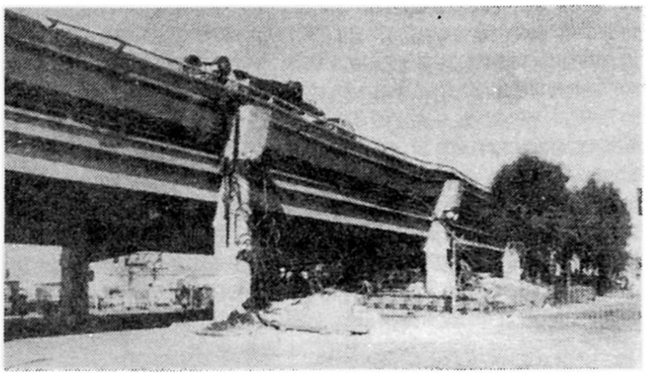
In many parts of the world, especially in industrialized countries, the reputation and status of engineers is not anymore as high as it used to be in the past and certainly not what it should rightly be in accordance with the great responsability they have to shoulder, in particular if anything goes wrong in the building process.

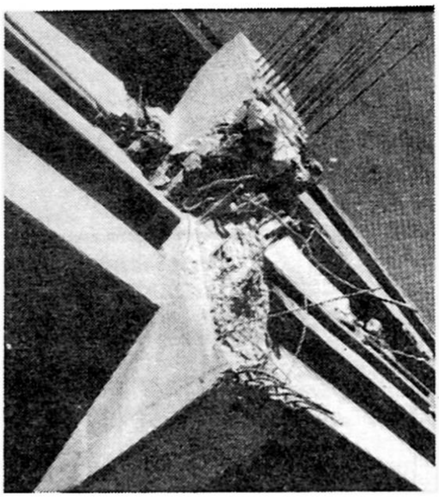
Among others this decline in the public recognition of the decisive rôle of the engineers is for example demonstrated by the fact that even for bridge competitions, it has become fashionable to assign the task of the conceptual design to architects rather than to engineers.

Indeed many reasons exist for this deplorable situation which are beyond our control. However, the engineers have also to shoulder some blame in this respect.

The excessive preoccupation of many scientists with setting up ever more detailed codes and specifications hardly contributes to the image of engineers as creative designers. It is a small wonder that architects consider the latter as mere interpreters of these intricate documents and more often than not call upon engineers only to dimension structures already conceptually designed by them.

On the whole the ever growing narrow specialization and in particular the unfortunate drifting apart of theory and practice have very detrimental effects on our profession. The most basic law in engineering that is the one of equilibrium, should also be observed in education; however it is nowadays grossly violated at many universities in favour of a onesided emphasis on theoretical science with no or only marginal reference to practical application. One striking example is the collapse of the double-deck highway bridge (fig. 14) during the 1989 Loma Priesta Earthquake in San Francisco, which was mainly due to bad detailing. This seems all the more incredible since in the very same region there are several first rate universities with the world's foremost specialists in seismic engineering, computer science and management. Unfortunately all the profound knowledge accumulated there evidently did not in this case find its way to practical design and construction.





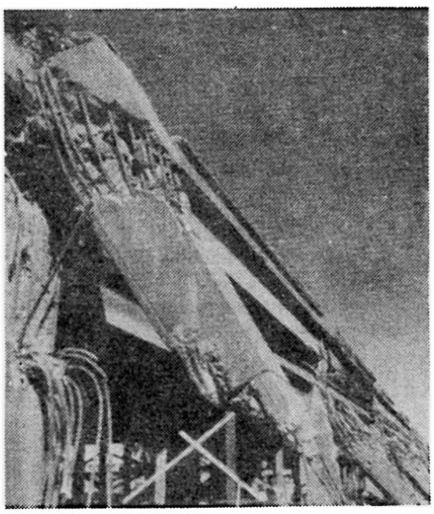


Fig. 14

Civilization through civil engineering cannot, however, be brought about by learned discussions but only by practical achievements, which necessitates also a more active participation of our profession in the decision making political process.

In our opinion the IABSE should spare no effort in helping to improve the image and rôle of civil engineering in our society. There must somewhere be a forum which actively defends the interests of our profession.

This is admittedly more easily said than done, but the importance of this urgent task warrants such an endeavour by the IABSE, preferably in close collaboration with other international organizations.