Plenary Session 1

New Horizons in Structural Engineering

Nouvelles frontières dans les constructions de génie civil

Herausforderungen an den konstruktiven Ingenieurbau

Organizer:	Michel Virlogeux, France
Chairman:	D.W. Quinion UK

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Civil Engineering and Water Conservation

Génie civil et protection des eaux

Bauingenieurwesen und Wasserschutz

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Thierry Chambolle, born 1939, graduated from the Ecole Polytechnique, the Ecole Nationale des Ponts et Chaussées and the Institut des Sciences Politiques in Paris. Initially Manager of several French ports, subsequently Manager of Water Pollution Prevention and Major Risks Representative at the Ministry of the Environment. In 1988 Thierry Chambolle became a director of the company Lyonnaise des Eaux, and since September 1991, he is Vice-President responsible for Technology, the Environment and General Communication for the group Lyonnaise des Eaux-Dumez.

SUMMARY

The author tackles the problem of the impact of civil engineering structures on rivers and groundwater. Having mentioned the principal characteristics of aquatic areas and of water resources on the earth, he goes on to discuss firstly the case of those structures serving no particular hydraulic purpose, such as transport infrastructures, and then that of hydraulic structures. The effects of these structures as a whole are very diverse and sometimes difficult to foresee. It is important to take these effects into account right from the start at the time when the structures are conceived, in order to avoid ecological obstacles and elevated costs at the time of realisation and subsequently of operation.

RÉSUMÉ

L'auteur aborde le problème de l'impact des ouvrages de génie civil sur les eaux. Après avoir rappelé les principales caractéristiques des milieux aquatiques et des ressources en eau sur cette planète il évoque successivement le cas des ouvrages sans finalité hydraulique particulière, comme les infrastructures de transport et le cas des ouvrages hydrauliques. Les effets de l'ensemble de ces ouvrages sont très divers et parfois difficiles à prévoir. Il importe d'en tenir compte dès la conception des ouvrages pour éviter les blocages d'origine écologique et les surcoûts au moment de la réalisation, puis de l'exploitation.

ZUSAMMENFASSUNG

Der Verfasser behandelt Auswirkungen von Baumassnahmen auf Gewässer. Mit Blick auf die Wesensmerkmale der Wasserumwelt und -vorkommen der Erde stellt sich der Verfasser die Frage von hydraulischen Bauwerken und von jenen ohne bestimmte hydraulische Nutzung, wie zum Beispiel die Transportinfrastruktur. Die Auswirkungen der Gesamtheit dieser Bauwerke sind sehr verschieden und manchmal kaum vorherzusagen. Von der Konzeption an müssen solche Folgen in Betracht gezogen werden, damit Hindernisse aus ökologischen Beweggründen und Zusatzkosten zum Zeitpunkt der Realisierung und des späteren Betriebes vermieden werden können.

THE ROLE OF CIVIL ENGINEERING IN PROTECTING WATER RESOURCES

Mr. President, Ladies and Gentlemen,

Allow me to begin by telling you how honored I am to be speaking for the first time to the AIPC (IABSE, IVBH). Although originally trained as a highway engineer, I have spent a large part of my career working for the environment, and more particularly in the field of water resources. In my company, Lyonnaise des Eaux-Dumez, which includes such well known civil engineering companies as GTM and Dumez, there are several people -- like F. Lemperière and J. P. Teyssandier of GTM and B. Raspaud of Dumez -- that are much more competent than I in the field of civil engineering structures.

But since we're talking about protecting water resources, they preferred that I take the podium. They helped me prepare this presentation, so in fact I'm speaking in their name, and I'd like to thank them publicly for their help.

I hope you don't mind if I take a personal tone with you. I'll be talking more about my experience, rather than my rather limited knowledge of this field.

My first job was building roads and bridges, and I had learned in school that their most important enemy was water. I built my first road, a pretty small affair, in Martinique, over terrain that was very sensitive to water. My first concern was to prevent water -- and there's a lot of it on the island -- from ruining a road that I was very proud of.

A little later, as an engineer in Bayonne on the Atlantic coast of France, I was in charge of monitoring an old bridge, whose pilings had been undermined by the river on both sides, so that they were sort of perched on top of huge piles of sand and gravel.

So you can see that what I had learned in school was true: **water is the civil engineer's greatest enemy.**

After ten years as a highway engineer, I served as Director of Water Resources and Pollution Prevention at the French Ministry of the Environment. This was a complete change of view for me, and I had to admit that **the civil engineer could be water's greatest enemy.**

My position was unique and full of contradictions. As the person in charge of protecting France's water, I had to make sure that the large infrastructure builders, like Electricité de France or Compagnie Nationale du Rhône, did not harm the environment and the quality of water resources. As the person in charge of flood and drought control, I was encouraging the construction of barrages to combat these disasters.

I think all civil engineers are feeling this contradiction today. They are working to improve water management, but they are often accused of helping to spoil water and destroy nature.

This introduction has already been too long, but I think it was necessary to us to understand each other.

I'd now like to talk to you about water and its role in human society, but also -- and perhaps most of all -- its role in our ecosystems. I'll also mention the many dangers that threaten our water resources.

I'd then like to discuss the problems specific to infrastructure projects, both those that are not involved with water resources, such as bridges and roads, and those that are designed to improve water management, such as dams and dikes.

1. WATER AND WATER PROBLEMS WORLDWIDE

We'd need a whole book -- or maybe several -- to do this subject justice, so for now, I'd like to mention briefly some of the key ideas concerning water and water-related issues.

The Blue Planet

It's not for nothing that Earth is called the Blue Planet. One of our most distinguishing features is an abundance of water -- some 1.4 quintillion cubic meters of it worldwide. Fresh water only amounts to 2.5 percent of this total. The water cycle uses around 500 trillion cubic meters, of which 110 to 120 trillion actually concern the land masses. These figures may not mean much to you, but on a per capita basis, we're talking about an average of 20,000 cubic meters of water a year -- which is a lot.

A wide diversity

The extreme diversity of terrain, weather, seasons and population densities means that water is unequally available worldwide. Per capita resources range from over 100,000 cubic meters a year in very wet, lightly populated countries, like Iceland, Canada and the Congo, to less than 1,000 cubic meters a year in such dry countries as Saudi Arabia, Israel and Libya, or even less than 100 cubic meters a year in a few extreme cases like Malta or the Bahamas.

All water is not available as a resource

Around sixty percent of water evaporates into the atmosphere, while the rest can rarely be found where we need it when we need it. Around 28 trillion cubic meters flow uncontrolled down the world's rivers every year -- although this can decline to as low as 12 trillion. Of this amount, six trillion cubic meters are held behind dams or in reservoirs, and only seven percent, or two trillion, is controlled.

Future imbalances

In the future, the unfair distribution of water resources is going to be further skewed by demographics. By the year 2020, water will inevitably grow increasingly scarce in Africa and Southern Asia.

A major role in the economy

Water is an important economic force in all civilizations. It plays a major role in farming, of course -- you need nearly 1,000 square meters of water a year per irrigated crop to feed one person -- but also in energy, industry and city life. You need 60 to 400 cubic meters to make a ton of cardboard, up to 1,000 cubic meters for a ton of paper, 12 to 50 cubic meters per person per year in the country, 150 in Paris, 500 in New York.

An even greater role in the environment

Water has physically or chemically sculpted the very face of our planet, through erosion, transport and sedimentation; water also washes the planet clean every day. Water makes our landscapes; the level and amount of groundwater determines the type and abundance of vegetation. And naturally water is responsible for biocenosis -- the community of biologically integrated and interdependent plant and animals.

Rivers cannot be separated from the land environment. The ecology of river systems is primarily an ecology of imbalance. On a planetary scale, river-scapes are highly varied, and to understand their dynamics, you need a planetary vision.

Endangered water

In every country, in every region, water can be threatened just as much by excessive use as by pollutants, both concentrated (from industry and cities) and dispersed (from farms and rural communities).

Some countries, where demand has reached or outstripped supply, are in a critical situation. But in many others, where demand doesn't exceed 25 percent of total resources, there are already many local or temporary shortages. Water tables are shrinking, rivers are drying up and wetlands are disappearing.

In all of the industrialized nations, rivers and underground water are suffering serious damage from oxydizable wastes (from cities and industries), nutrients (from cities and farms) and toxic wastes (from industries and farms). Throughout Europe, a good percentage of underground water has been polluted by nitrate and pesticide runoff, making their use as drinking water questionable.

The vast world movement that has formed to protect the ozone layer, prevent changes in the climate, preserve the Antarctic, and limit destruction of the forests cannot ignore fundamental role of water in all its forms, and must make a commitment to protecting this valuable resource -- even as we use it wisely -- for the very future of our planet.

2. THE IMPACT OF CIVIL ENGINEERING STRUCTURES

In this sensitive environment, civil engineering works have an impact that can remain fairly limited or be very powerful and decisive, depending on their type, use and size.

We'll be talking about three types of works :

- Structures without any particular rèlationship to water
- Small water-related structures
- Large water-related projects

2.1 Structures without any particular relationship to water

This is mainly transportation infrastructure, such as bridges, roads and railroads.

They can affect water in many ways. Because they cross natural drainage areas, they can have an impact on water flows, especially during peak periods, and on water table levels. Their waterproof surfaces increase the accumulation rate. Washing runoff can spread traffic pollutants to the environment.

In the case of a traffic or railway accident, toxic substances may be spilled into the surrounding environment. Roadway products, such as deicing salts, or maintenance products, such as weed-killers, can contaminate groundwater. Side effects can be observed in quarries, extraction and dump areas.

Let's look at the example of a bridge runoff. Traditionally, floor plate runoff used to be caught in side drainage channels and directly discharged into the environment via gully holes or drainpipes.

Today, large bridges are equipped with special facilities to catch and treat runoff before it is returned to the environment. These facilities include :

- Side drainage channels.
- Screened gully holes across the cantilevering.
- A drainage network composed of a main drainage basin located along the bridge's center axis, generally inside the precast segments, and of side drainpipes crossing the web and connecting the gully hole to the main basin.
- Downspouts located along or inside the river bank abutments, equipped with water tanks that follow plate/abutment shifts.
- A sand-catcher/oil trap located upstream from disposal.

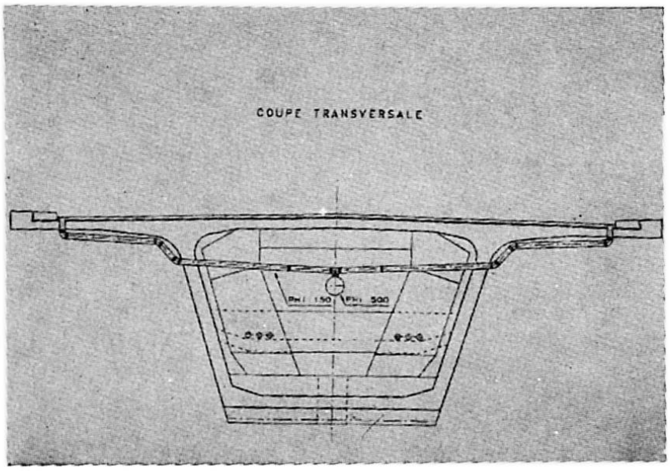

Fig. 1 Cross section

These facilities are being used on both road and rail bridges.
A second example concerns the restoration of groundwater flows. Here I'll be talking about the St-Cyr-Boulevard Périphérique Nord covered drainage channel in Lyon, which cuts across the thalweg of the Rivières brook.

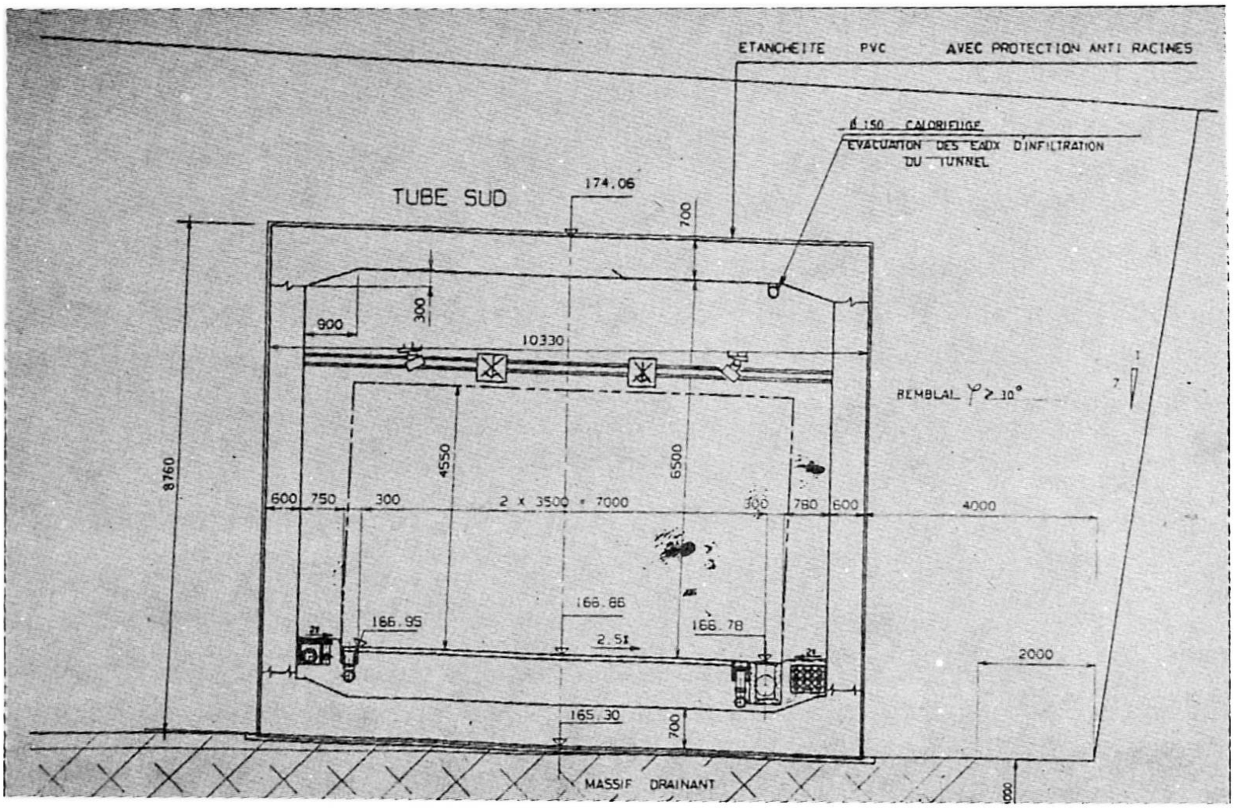

Fig. 2 Special Equipment (for large bridges) to catch and treat run-off before it is returned to the environment

To maintain groundwater flow at all times and prevent blockage by the frames, which descend almost to bedrock and are placed perpendicular to the main groundwater flow, it was decided to build a thick draining layer under the frames. The layer is highly permeable, allowing around 10^2 meters/second flowthrough.

Now let's look at a linear structure like a road. Pollution can come from a number of sources:

- The erosion of unplanted soil and embankments, which can have many negative effects, such as embankment washout or destruction, filling of drainage systems or pollution of receiving watercourses.
- Construction equipment (motor oil or washing runoff).
- Pollution spills.
- Deicing salts.
- Chronic pollutants (dust, lead, zinc, hydrocarbons).

I'd like to use the example of the A-36 Motorway as it crosses Mulhouse. This highway crosses the secure protection zone around the city's catchment fields. This is why it is so highly protected, as shown in the attached drawing. It is built on an embankment, but to prevent any vehicles from exiting accidently, it is protected by high berms on either side. Rainwater is collected by a sewage network and deposited in settling tanks and reservoirs that can store toxic substances as needed. Naturally, rainwater is disposed of upstream and far from the catchment fields. Lastly, a waterproof coating has been applied under the road and the berm embankments to prevent any seepage into the motorway embankment.

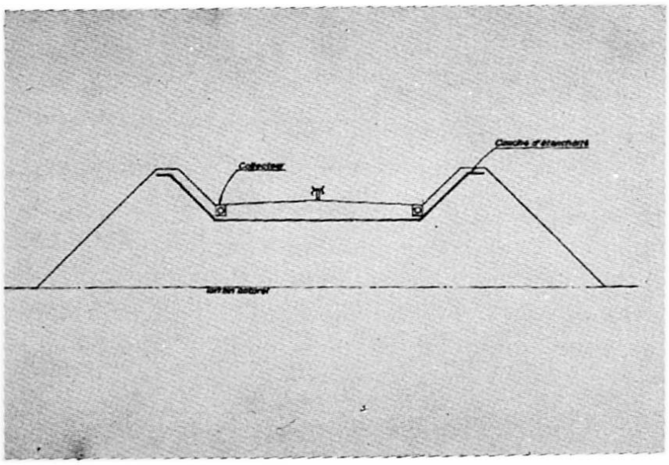

Fig. 3 Protections of the Mulhouse "Catchment fields" (A 36 Mortorway)

J. M. Bernard, who works for SETRA, the French Roads and Highways Technical Engineering Agency, has briefly described the measures to be taken:

"Highway authorities have a number of ways to limit the impact of roads on water resources when they design infrastructure. During the environmental impact study, it is important to prepare a full and accurate initial description. The different types of water resources (groundwater, watercourses, etc.) should be located, their current and future use identified and their exposure to road pollution determined.

The most important step is determining the route, since routing the road away from recharge areas is the only real way to guarantee water quality. This is because, while some of the pollution will be caught by the sewage system, the rest will be discharged into the surrounding environment and cannot be controlled by the protective or regulatory devices installed in the sewage system.

Lastly, the installation of protective or regulatory devices limits the contamination of the environment by runoff. Some forms of pollution are hard to manage, however. This is the case of salts which dissolve in water and are thus impossible to screen out. These devices should designed to reflect the type of pollution they are expected to treat (suspended solids, hydrocarbons, etc.) and their maintenance and management requirements.

In addition to the problems of water quality mentioned above, roads also have an impact on surface runoff and on groundwater. A road's impact on water resources and water environments should be studied in a comprehensive way. Solutions exist and each case deserves special attention to avoid upsetting the delicate balance of nature."

Let me add that it is possible, in cities and suburbs, to adjust construction methods to allow the use of roads made of thick open-grain asphalt as storm reservoirs. In this case, the road can actually be a solution to a rainwater management problem.

2.2 Small water-related structures

These are the small or medium-sized barrages or diversion cuts that only have limited influence over the entire water basin. Their impact on water is well known. The first examples of this type of structure were built around 5,000 years ago. These were often simple dikes built to create artificial ponds recharged by seasonal rains. Then dams appeared. It seems that the oldest dam still in existence was built by the Mongols in the thirteenth century in Kbar, near Qum, Iran. It is 26 meters high, 55 meters long and five meters thick, and already looks like a road. Since that time, many dams have been built over the centuries, especially in India. In 1990, there were 36,138 dams over fifteen meters high in the seventy-one countries that are members of the International Commission on Large Dams. But the total number of barrages, dikes and dams is much higher, probably over 500,000. These structures are fairly commonplace, and their impact on water is not new. In the earliest times, this impact was the reason why they were built -- to store water for drinking or irrigation, to control floods or to generate electric power. It is only recently that we have begun to study their side or unintended effects.

In the late seventies, the International Commission on Large Dams, fully aware of the importance of environmental issues and public sensitivity to them, created a technical committee to deal specifically with this subject. The commission published a report in 1980, but they realized later that it was too technical for the general public to understand easily. In 1981, therefore, they published a brochure entitled *Dams and the Environment: A Success Story*. The title makes you wonder and even sounds funny when you consider all of the problems encountered by many dam projects in different parts of the world.

The report and the general public brochure deal with the many environmental problems raised by dams:

- Crossing the dam (migrating fish)
- Sediments (accumulation and disposal)
- Discharges (heat, turbidity, water oxygenation)
- Weather effects
- Eutrophication
- Plants and animals
- Changes in groundwater for lowland dams
- Flooding risks due to landslides or earthquakes.

All of these problems and their solutions are well known. The International Committee's bulletins have discussed them many times (notably in 1985). It would be pretentious and time-consuming to talk about them here, before an audience that is well aware of these difficulties and their solutions.

Nevertheless, a dam can profoundly modify the environment, at least locally, and it is becoming harder and harder to get people to accept one "in their backyard", no matter what technical solutions are implemented. In many countries, you need to plan for a compensation program, with not only economic and social measures, but also a whole series of ecological measures, such as reconstituting biotopes, creating reservoirs, and implementing systems to collect and treat wastewater upstream to avoid problems with eutrophication or water quality.

In some densely populated countries, these measures are still not enough to prevent environmentalist opposition, and other solutions have to be found. Examples include creating groundwater reservoirs by artificially recharging the water table, building waterproof underground walls or raising existing dams.

The first solution, already used in France to build drinking water reservoirs, requires very good understanding of groundwater regimes and the use of waterproof underground wall construction techniques, that have been mastered by companies like Bachy and Solétanche.

An innovative technique recently developed to increase the capacity of existing dams is the Hydroplus process, designed and implemented by GTM.

With most high dams and hydroelectric complexes, retained water levels are regulated by sluice gates that let flood waters through. But with the vast majority of lower dams, flood waters flow over a spillway that is a few dozen meters wide and unequipped with any sluicegate control. At flood crest, the spill can rise to around a meter deep, but sometimes exceeds five meters.

The dams are designed for peak flood water levels, but are used only to retain water below the spillway level. This means that there is a great deal of reservoir capacity going to waste. Lost capacity can amount to over twenty percent of the total volume on an average non-sluicegate equipped dam.

One safe, cost-effective way of raising the spillway is to build overspill fusegates that remain submerged for moderate overspill, trigger part of their fuses to rise slightly for the higher waters that come every fifty years or so, and trigger all of the fuse and rise to full height for exceptional flood levels. This solution is very economical.

Every year around the world, the lack of such systems causes us to lose around fifty billion cubic meters of water, much of which could be saved at low cost and relatively quickly through a system of overspill fusegates.

This system can be adapted to most existing free spillways, but can also present major advantages for future dams.

2.3 Large water related projects

The impact of large multi-purpose water-related projects on water regimes and quality is even harder to forecast. And the ways of reducing that impact are even more difficult and unpredictable.

As I said above, the ecology of river systems is an ecology of imbalance. The engineer intervenes in a complex, constantly changing system to substitute a new system that is also in imbalance and will undergo its own process of change.

It is not enough to compare the post-construction state to the initial state. Comparisons have to be made between the different stages of the initial system (without the proposed development) and between these same successive stages in the event the development is carried out. Since it is highly uncertain how each of these stages will evolve, you can imagine how difficult it is to compare them, especially when you have to convince sceptical inhabitants who will not necessarily benefit directly from the project.

All of the major development projects like the Aswan Dam or the reclamation of the Zuider Zee have had unexpected consequences.

The Aswan Dam had many positive effects, but the reduction in silt flows also had a serious negative impact. The river's banks and bed eroded, the delta 1,000 km downstream eroded, fish reproduction declined and salt concentrations rose.

In the Zuider Zee, the improvement in flood control and the development of new polderland also caused the disappearance of biotopes and related species, as well as water eutrophization.

Thus, engineers who prepare large development projects and who analyze their predictable impact on water and the environment have a very difficult task. So do the political authorities who have to take the decision to develop and convince the surrounding population that it is a good idea. If you doubt this, just think about the Bangladesh flood control system. This project offers a number of alternative solutions, such as nearby dikes and distant dikes, but in all cases it means a radical transformation of the local economy and lifestyles, notably in their relationship to water. There is already a great deal of controversy about the future consequences and disadvantages of the different solutions.

I was personally involved in the development of a large French river, the Loire, which is full of history and famous for its beautiful scenery and dramatic floods. The first attempts at flood control date from the twelfth century, when levees were built along its banks.

An initial project prepared in the seventies to develop the water resources needed to cool nuclear power plants and irrigate farmlands proposed the construction of not less than twelve dams. A critical analysis by a blue-ribbon commission of experts reduced the project to five dams -- three for flood control, of which one was already built, and two for low water support, of which one was already partially built.

Environmentalist opposition has caused the number of new dams to be cut to two, with, in addition, the raising of an existing dam and the construction of close set protection dikes.

All of these changes were the subject of major controversy both in France and internationally.

In conclusion, nobody would think of denying the importance of civil engineering works designed to meet new demand for transportation, to enhance the value of our water resources and to protect lives from natural disasters. But these structures cannot be built to the detriment of the environment and of water quality.

We must be aware of the fact that, once a project has aroused environmentalist opposion, it then becomes very difficult to prevent the construction process from grinding to a complete halt : either the project has to be abandoned altogether or those involved must reckon with considerably elevated costs to finance the necessary modifications to the original project. This being the case, it is imperative that we ensure that environmental issues are taken into consideration from the very beginning of each project.

In the past, civil engineers have sometimes underestimated the psychological or factual impact of what they built. As a result, they have sometimes incited feelings of hostility on the part of inhabitants and sometimes of elected officials. They need to act to regain the people's trust.

In closing, I'd like to quote Michel Virlogeux, of the Association Française Pour la Construction:

"Engineers (i.e. all of us) need to learn modesty and should analyze the long-term impact of their actions, particularly on water resources."

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Preservation of Newly Built and Historical Buildings

Conservation des bâtiments historiques et récents

Bewahrung historischer und neuzeitlicher Bauwerke

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Giorgio Croci, born 1936, has carried out important research, studies and projects for the strengthening and restoration of historical buildings. The Colosseum and Senatorio Palace in Rome, the Ducale Palaces in Modena and Genova, the Castle of Spoleto, the Basilicas of S. Francis of Assisi and S. Ignatio de Loyola in Spain, represent some examples of his activity.

SUMMARY

This paper deals with the preservation of existing buildings. The main problem is the evaluation of the safety level, taking into account the crack patterns, the deterioration of materials, etc. As a result of this analysis, decisions can be taken about the opportunity and the criteria for intervention. The paper illustrates some cases, referring especially to historical buildings in Italy and Spain.

RÈSUME

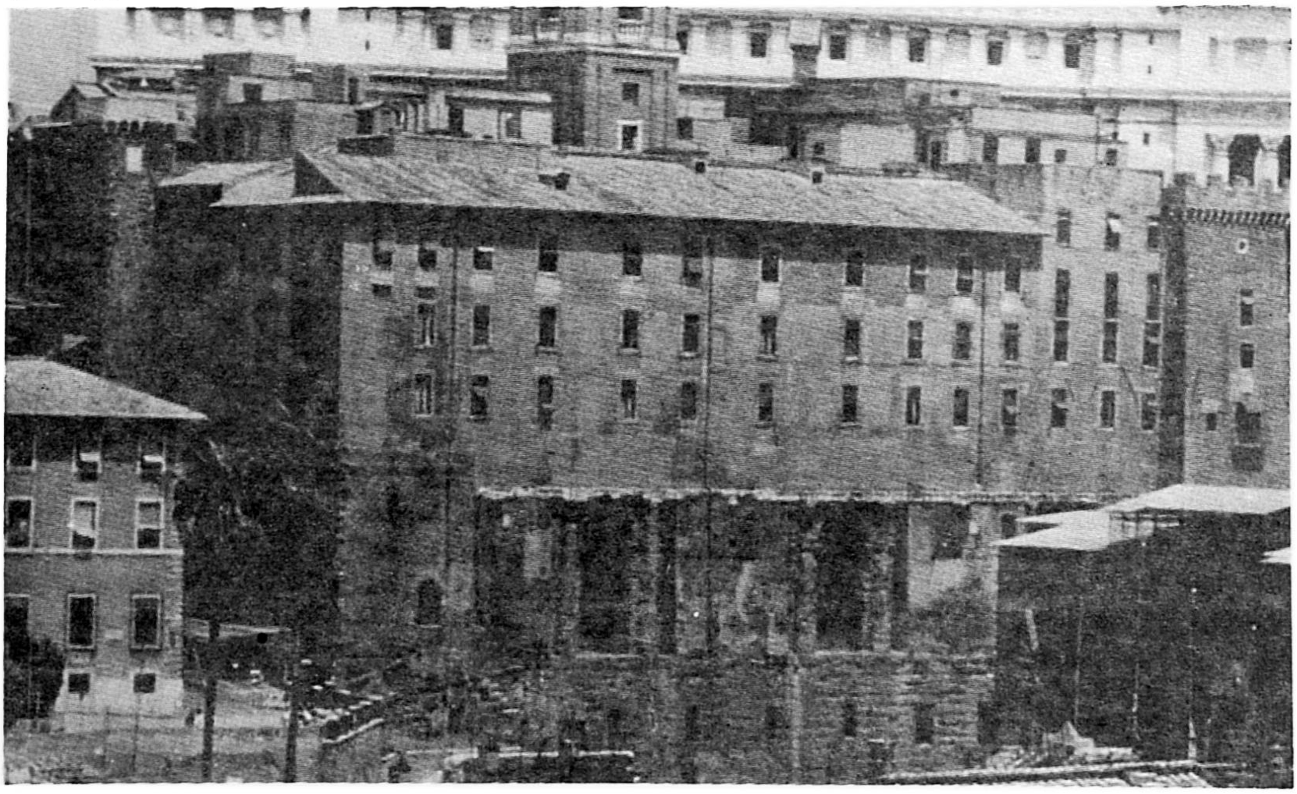
L'article traite de la conservation de bâtiments existants. Le problème principal concerne l'évaluation du niveau de sécurité, prenant en compte l'évolution des fissures, la détérioration des matériaux, etc. Cette analyse permet de prendre des décisions sur l'opportunité d'une intervention, et sur les caractéristiques de celle-ci. Des exemples de bâtiments historiques en Italie et en Espagne illustrent l'article.

ZUSAMMENFASSUNG

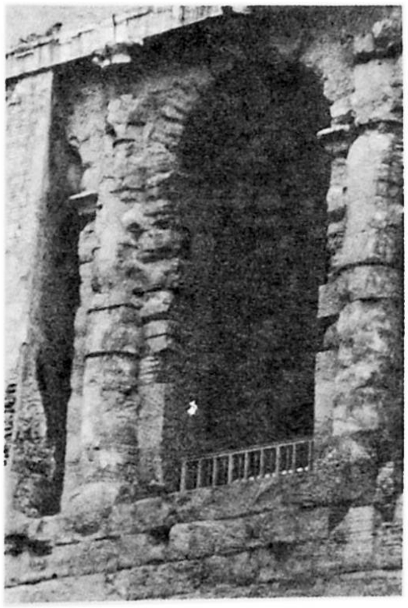
Der Artikel handelt von der Bewahrung vorhandener Bauwerke. Der Schwerpunkt liegt dabei auf der Berechnung der Standsicherheit unter Berücksichtigung des Rissbildes, der Baustoffverwitterung usw. Diese Analyse erlaubt Entscheidungen bezüglich Eingriffsmöglichkeiten und Alarmgrenzwerten. Beispiele für historische Bauwerke in Italien und Spanien erläutern den Artikel.

1. INTRODUCTION

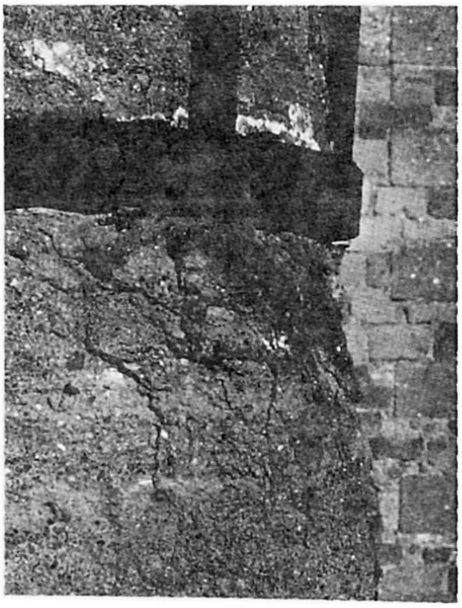
The first point to examine in the preservation of a structure is the analysis of the deterioration of the materials. This deterioration in the oldest buildings is linked not only to the chemical and physical phenomena, but also to the countless alterations, that, as in the case of Palazzo Senatorio in Capidoglio, Rome, (fig. 1) have occurred during the centuries (fig. 2), sometime stressed by incorret reinforcements (fig. 3).



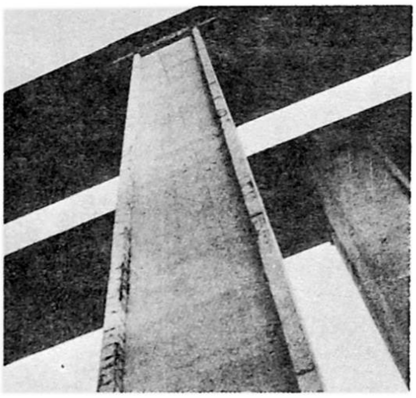
Pic.1: General view of Palazzo Senatorio and Tabularium in Campidoglio from the side of the Roman Forum



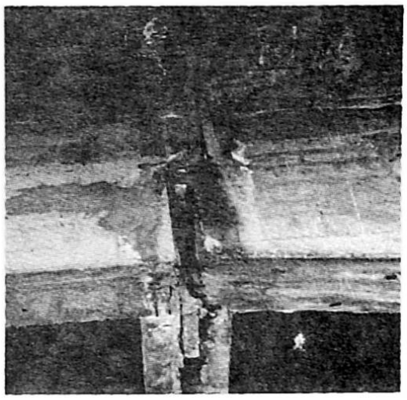
Pic.2: Alterations and deteriorations of Palazzo Senatorio



Pic.3:Effect on the columns of Tabularium

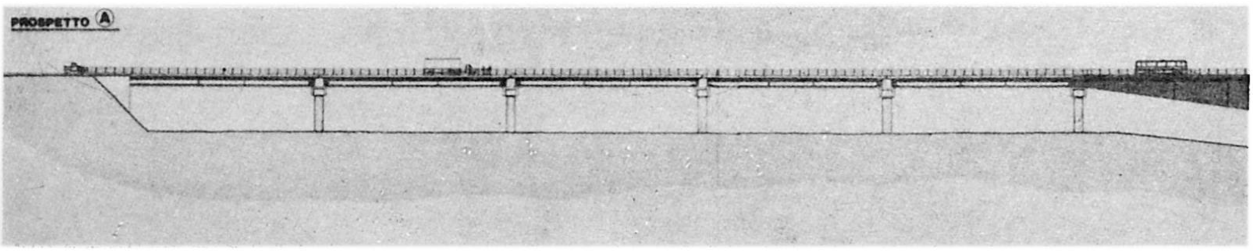


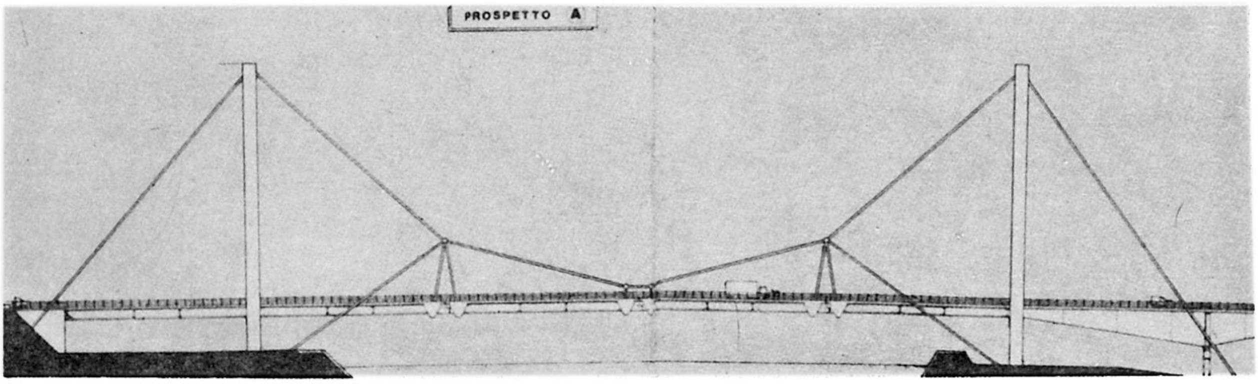
Pic.4: Concrete motorway bridge



Pic.5: Deterioration in a bridge deck

For newly built constructions, unluckily, the situation is often worse, despite the support offered by science and modern technology. It is not uncommon to find in some bridges (fig. 4) high levels of deterioration due to lack of maintenance, insufficient protection of the steel, bad quality concrete, imperfect design of details. (fig. 5) Repairing and strengthening will be an important activity for the future.
The second point to consider is the assessment of the structural capacity. This evaluation, which will be examined in the following paragraphs, related to historical buildings, is often very difficult and always delicate, because it involves the decisions and criteria of interventions. Structural interventions, however, are not only related to insufficient bearing capacity. In some cases, new requirements can suggest a substantial change in the original behaviour; this is the case, for example, of a bridge (fig. 6) where it was decided to remove the pillars, substituting the support of the beams with cable, transforming in this way the old structure, to a new suspended bridge (fig. 7), satisfying the need for a free area below.

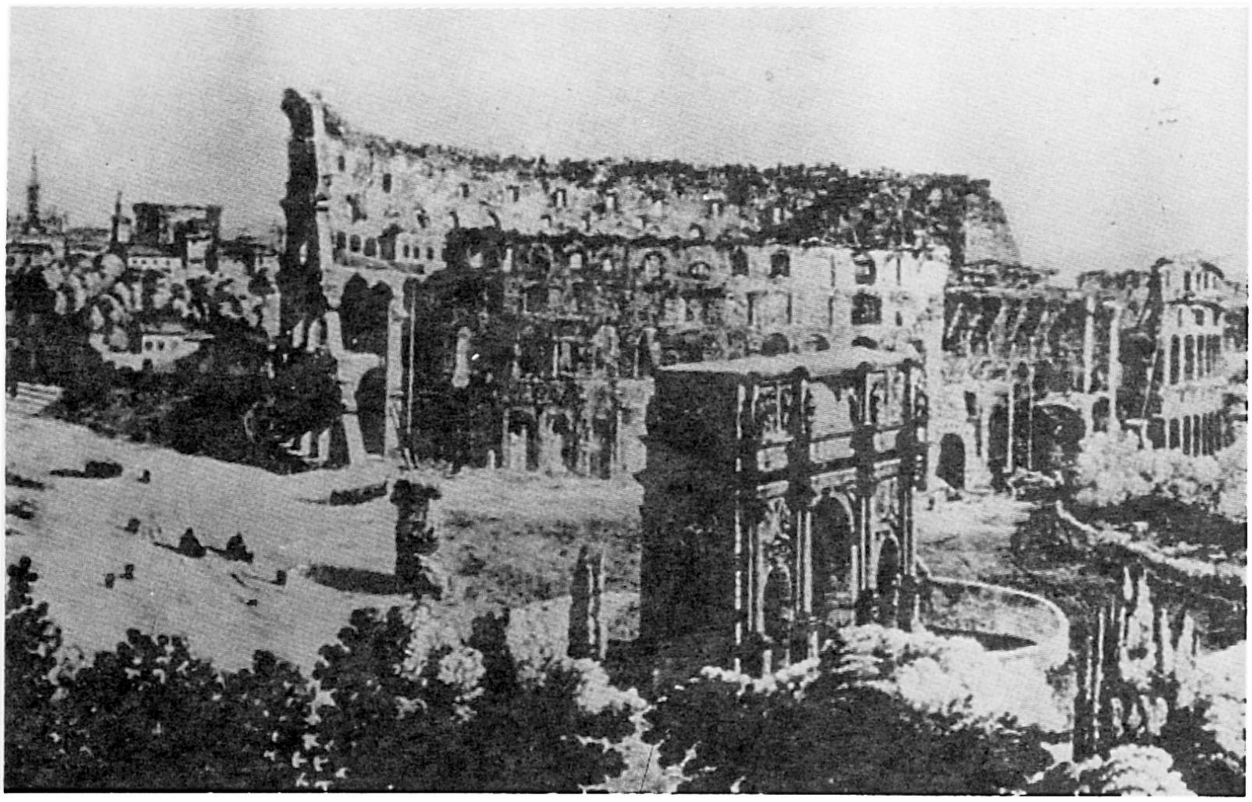




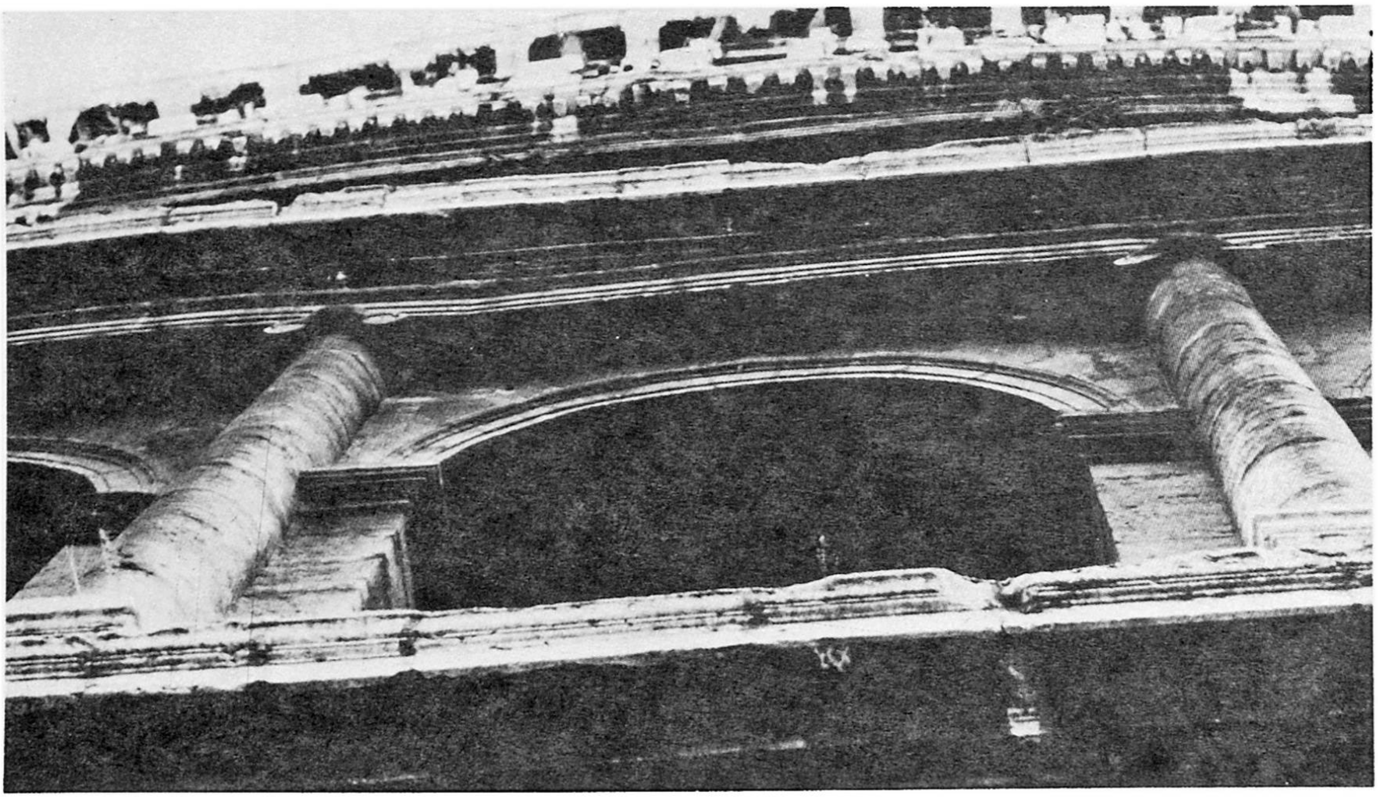
Pic.6,7: The same bridge before and after the substitution of the pillars with cables

2. THE ASSESSMENT OF THE RESIDUAL CAPACITY

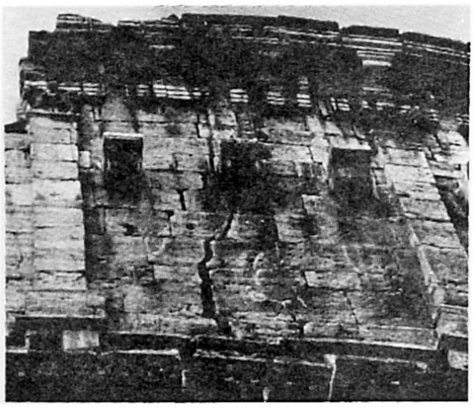
The evaluation of the safety level, expecially for historical buildings is not an easy task and, as a general rule, it is necessary to follow simultaneously three different routes or criteria.
The safety assessment, should thus result from the synthesis of the best information obtainble from the following different approaches:
I - historical survey (historic-critic method) which consists of the systematic reading and interpreting of historic documents;
II - in situ observations (or empirical-qualitative method), often with the support of investigations and monitoring systems, which consists of the survev of the crack patern, the quality of materials, and so on;
III - structural analysis (theorical quantitative method), that is an abstraction of the reality, reducing the complexity of the Monument's behaviour to simplified mathematical schemes.
The study of COLOSSEUM can be seen as a significant example of this methodology, following a continuous feed-back process.
The historical survey has pointed out the role of the earthquake in the failure and collapses that have been occurred in 443, 801, 1347, 1703 (fig. 8).
As a initial result of the historical survey there appears to be a discrepancy between the quantity of crumbled portions, as seen today, and the description of historical collapses related to the earthquakes that have been recorded
We will see later the mechanical behaviour which has caused spontaneus collapses a long time after the earthquakes have occurred. The second congitive process, the in situ survey, shows sinusoidal deformations of the external wall, (fig. 9) clearly due to the seismic effect, and considerable out of plumb.



Pic.8: the Collosseum in the XVIIIth Century

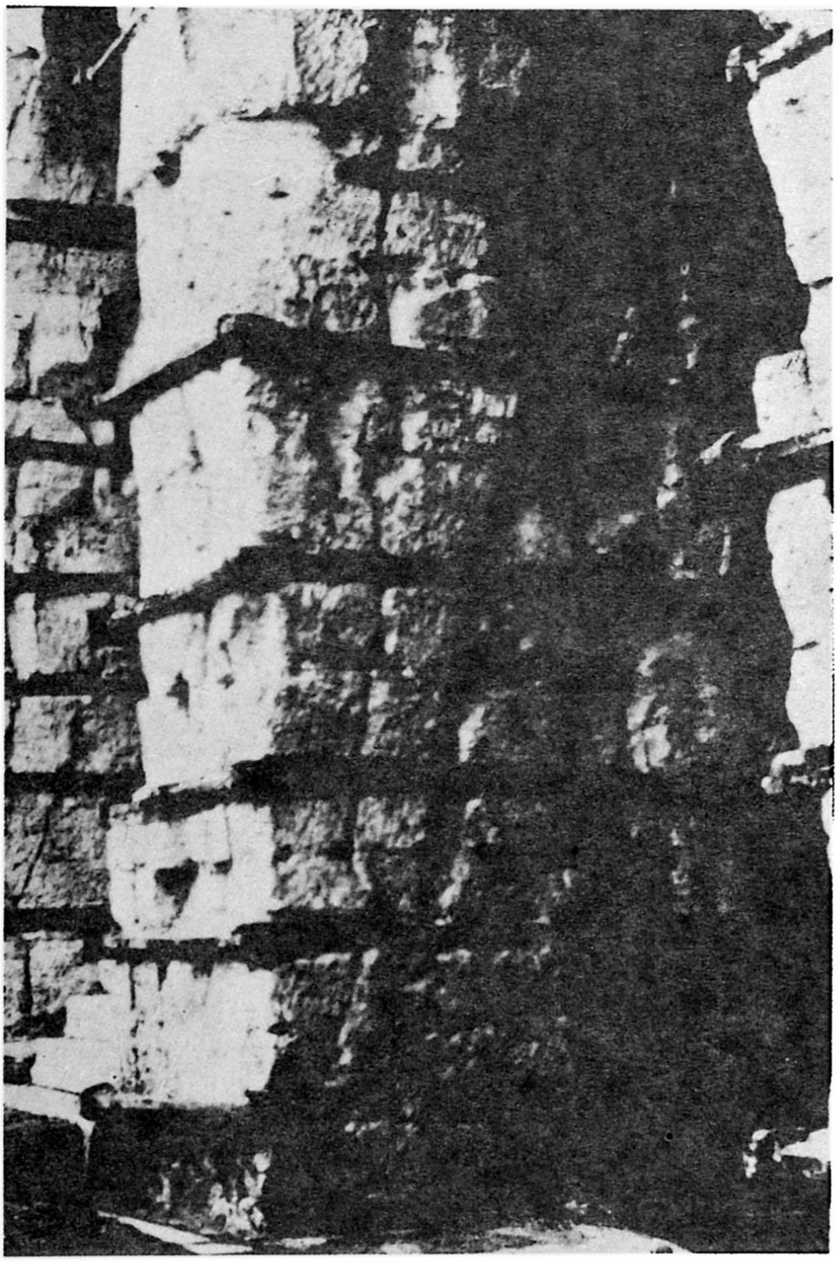


Pic.9: Sinusoidal deformations of the external wall showing the signs of the earthquake



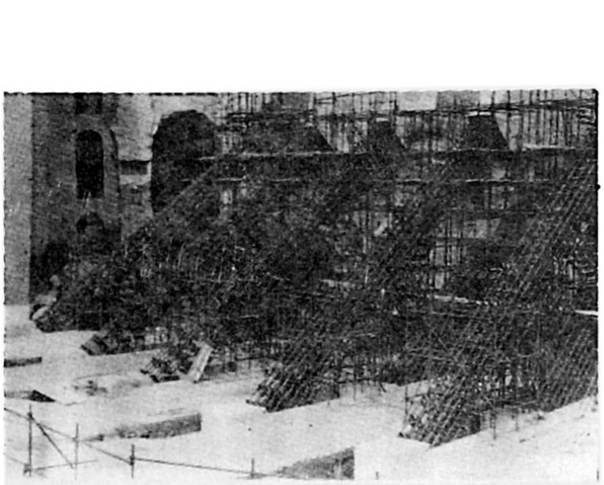
Pic.10,11: Displacements and discontinuities in the structure of Collosseum

Consequences of this outward movement are relative displacement of the blocks (fig. 10) and discontinuity between the outer elliptical structure and the radial masonry (fig. 11).
The corresponding increase of the stress level has been the cause of the worrying signs of collapse present in some pillars ten years ago (fig. 12). This occurred in such fast evolution that the pillars had to be shored urgently (fig. 13).
We will see later why the Colosseum arrived at a situation of collapse two centuries after the last important earthquake, without apparent motivation.
The third criterion, the mathematic analysis (fig. 14), has shown that the foundation dishomogeneties caused a different amplification of the seismic action and have been the cause of the wellknown assymmetric collapse of Colosseum.
The mathematical analysis has also shown the importance of the dissipative behaviour under dynamic actions linked to the dry friction coefficent between the blocks.

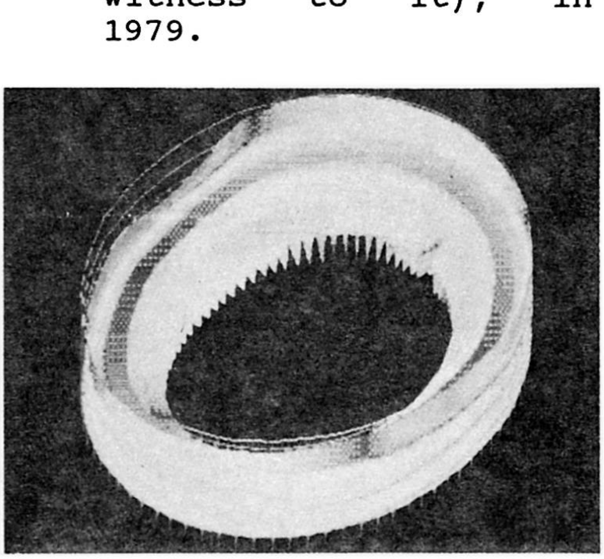


Pic.12: Warrying signs of collapse in some pillars of Collosseum 1979

On the basis of all the information obtained (historical survey, in situ observation and mathematic analysis), we can try to explain what has happened: due to the seismic actions the cylindrical outer surface suffered a loss in shape, with an increase of the elliptical length that caused out of plumb. The increase in the stress level caused the first collapse; at the same time the adjacent structural elements were left weaker because of the lack of circumferential continuity.
Once the stability had been in such a way compromised then, even weaker earthquakes, slow decay and deterioration of materials, the pushing of iced water in the small fractures caused by the high stress levels, ... generated, years, or even centuries after, the "spontaneous failures". A situation of this kind occurred, (I was witness to it), in 1979.



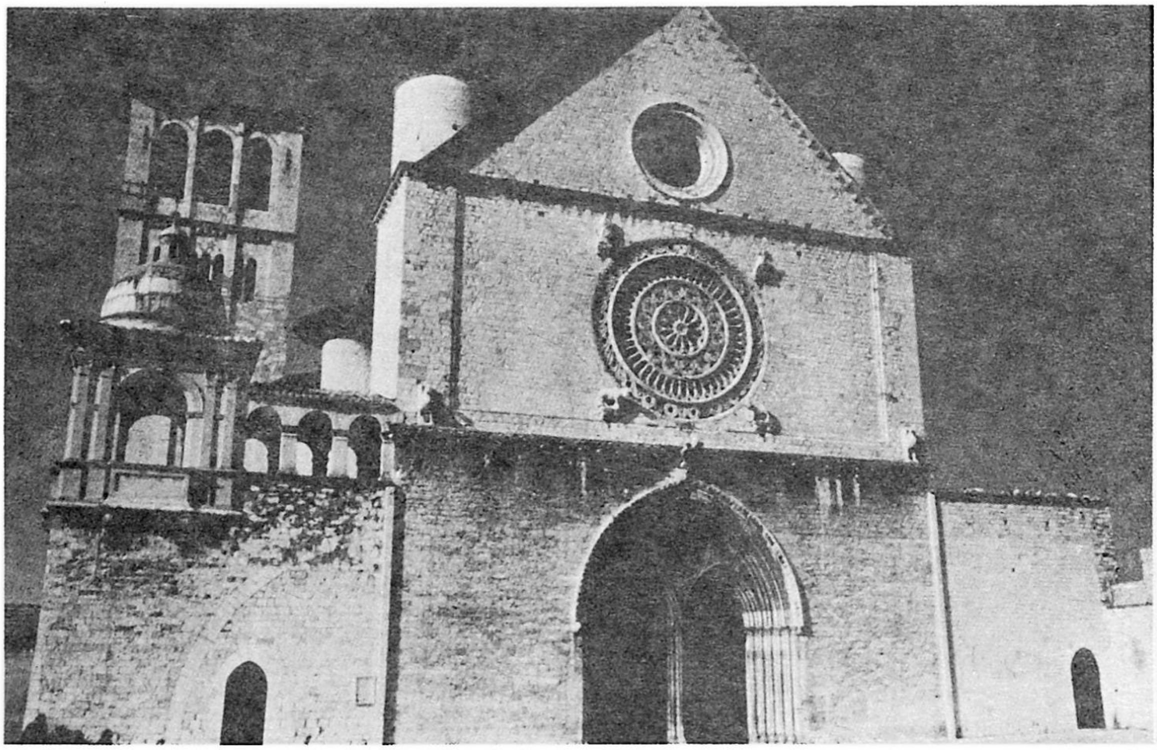
Pic.13: Shoring put in place in 1979



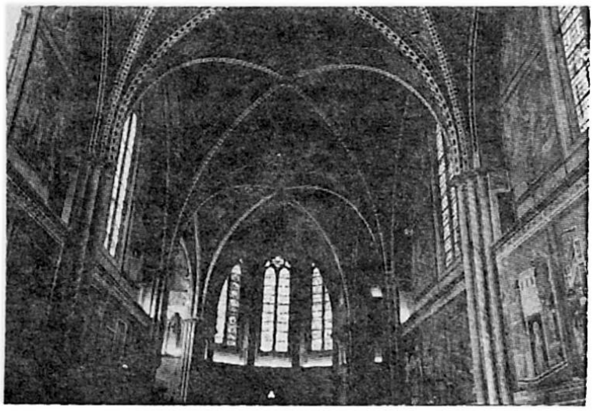
Pic.14: Mathematical model

3. INTERVENTIONS IN MONUMENTS RELATED TO EARTHQUAKE EFFECTS

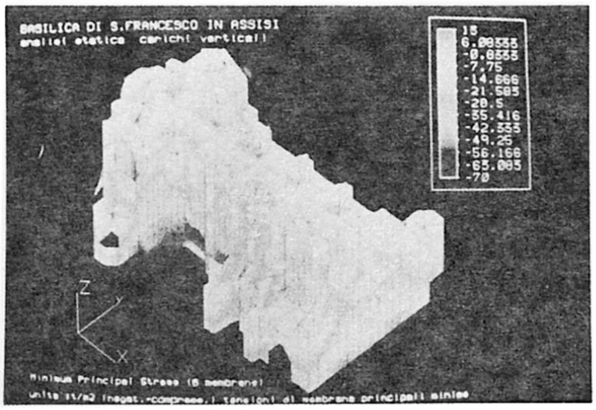
The earthquake has been also the main cause of damages in the Basilica of S. Francis of Assisi (fig. 15). Many signs are visible, the cracks in the central columns of the large windows and the damages that in the centuries have effected Giotto frescos (fig. 16).
The mathematical model shows the general stress distribution (fig. 17). In the wall that supports the Giotto frescos we can see in further detail the tensile stresses in the inner surface, and the compression stress in the outer surface, corresponding to bending moments; these stresses change sign many times during the sinusoidal seismic action, causing the cracks that we have observed. In order to reduce these effects, a steel trussed beam will be placed over the internal cornice (fig. 18, 19). This beam is connected to the masonry by oleodynamic dampers in a position to allow thermal deformations, but to react rigidly under the effect of dynamic impulse due to the seismic action.



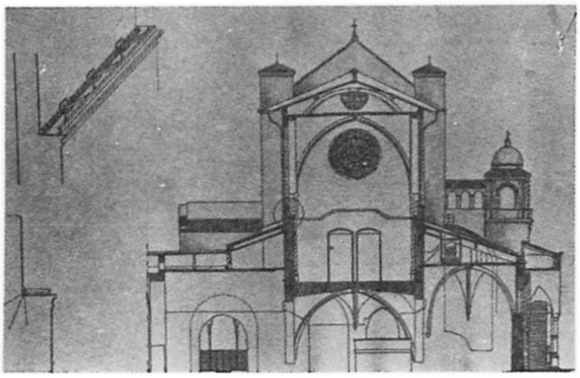
Pic.15: The Basilica of St. Francis in Assisi

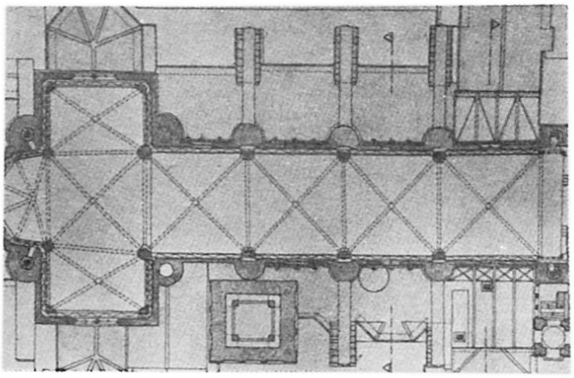


Pic.16: Damages in the Giotto frescos



Pic.17: Mathematical models of Basilica of St. Francis in Assisi

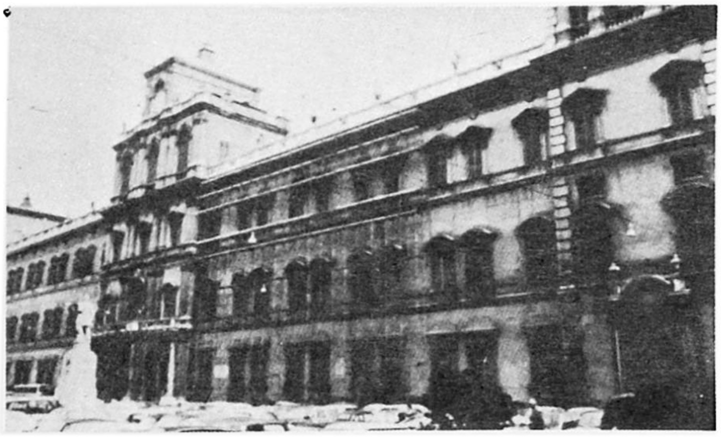




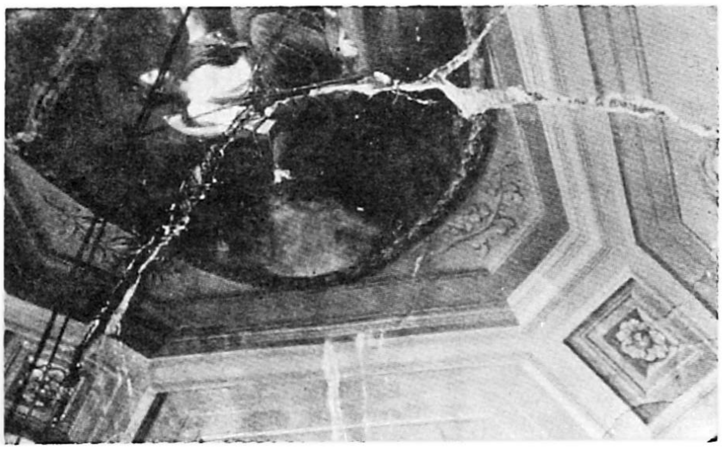
Pic.18,19: Steel trussed beam placed the internal cornice of Basilica of St. Francis in Assisi

4. INTERVENTIONS IN MONUMENTS RELATED TO SOIL PROBLEMS

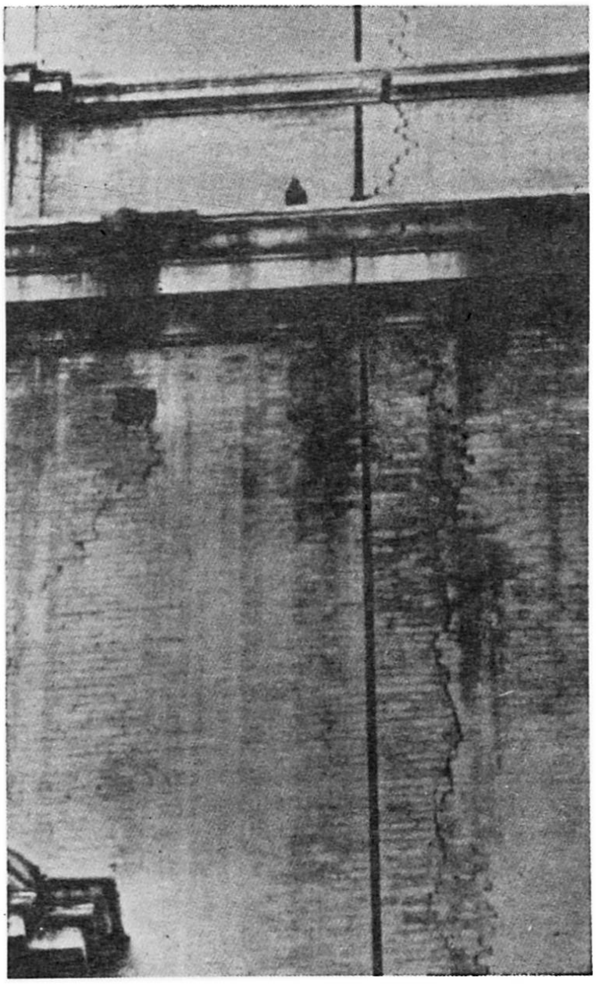
Soil deformations represent a further group of phenomena that often effect old buildings. The solution is not only in improving the bearing capacity of the foundations (underpinning, ...) or in strengthening the building as a whole. It is often better to use different solutions: in the Ducal Palace of Modena (fig. 20), where important cracks due to soil rettlements effect the walls, floors and vaults (fig. 21), we have proposed to make joints (fig. 22), to allow differential settlements to occur without inducing significant stresses in parts of the Palace.



Pic.20:Ducal Palace of Modena

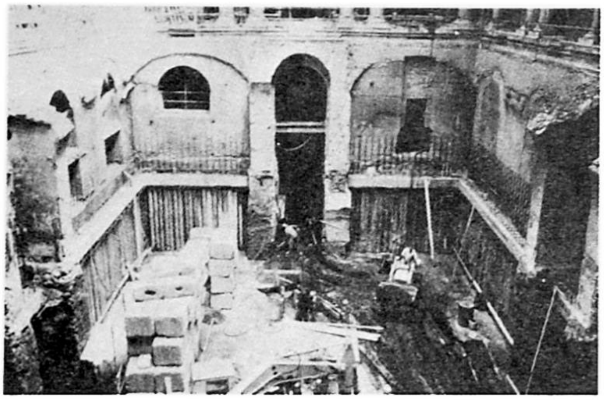


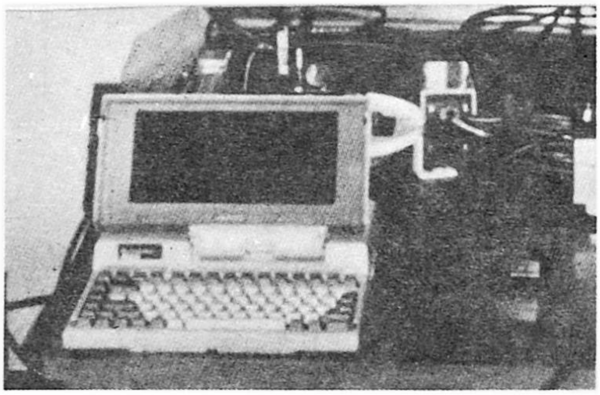
Pic.21: Cracks in the voults of Ducal Palace of Modena



Pic.22: Joints realized by cutting the walls, following the main crack pattern

In other situations the repairs to foundations are related to the buildings current needs.
This is the case of Palazzo di Istituto Massimo in Rome, where it was necessary to make important excavation works to obtain new space for a permanent museum, containing old coins of the Roman Empire (fig. 23); a monitoring system has been set up in order to control the settlements of the foundations and, if necessary, to take corrective measures (fig. 24).

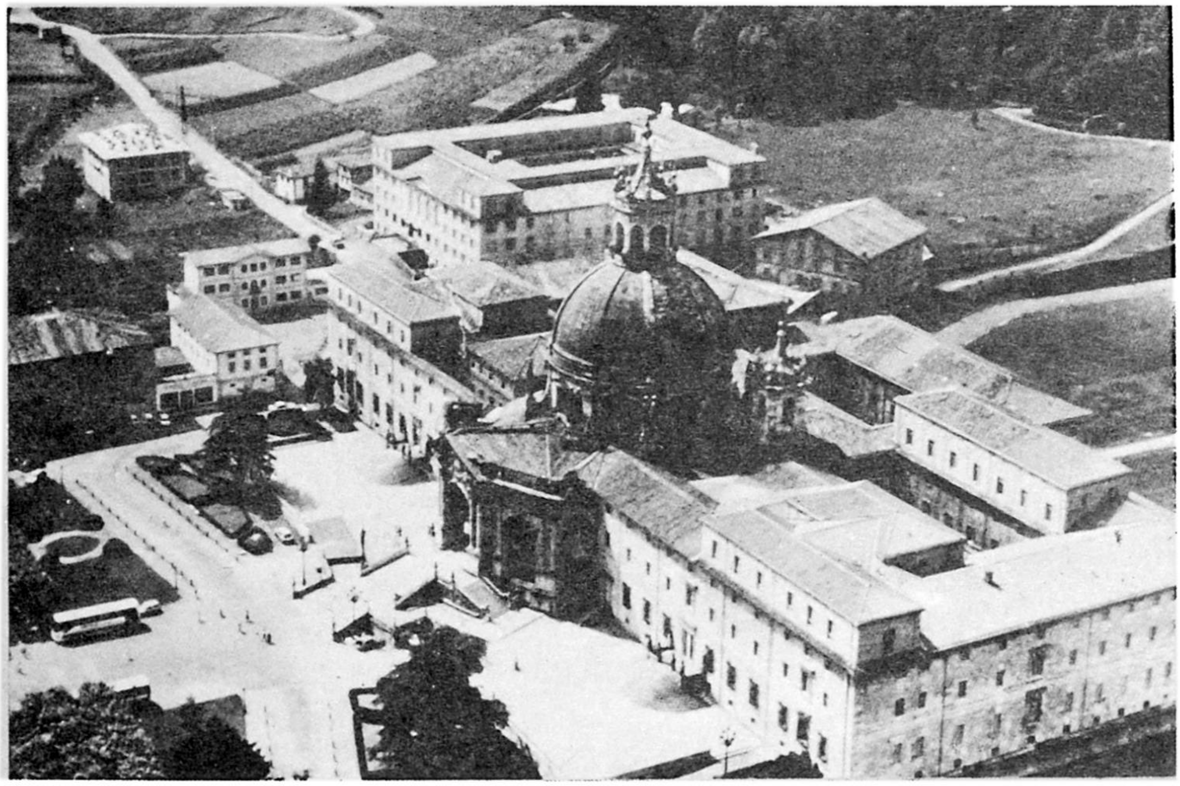




Pic.23,24: Excavation works under the foundation and monitoring system

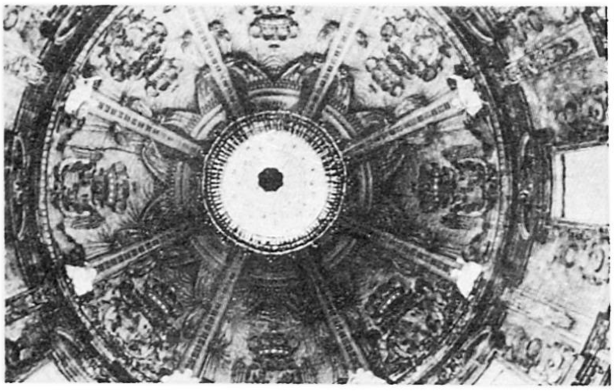
5. INTERVENTIONS IN MONUMENTS RELATED TO IMPERFECTIONS IN THE ORIGINAL CONCEPTION

A third category of problems are due to the direct forces, namely the dead load. In the Basilica of S. Ignatio de Loyola in Spain (fig. 25), this has been the cause of important cracks that effect the dome (fig. 26).

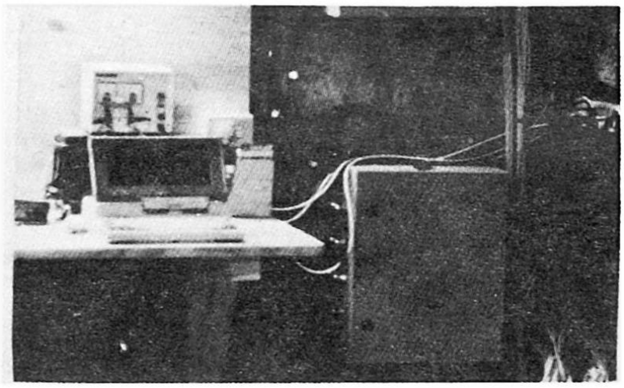


Pic.25: Basilica of St. Ignatio de Loyola in Spain

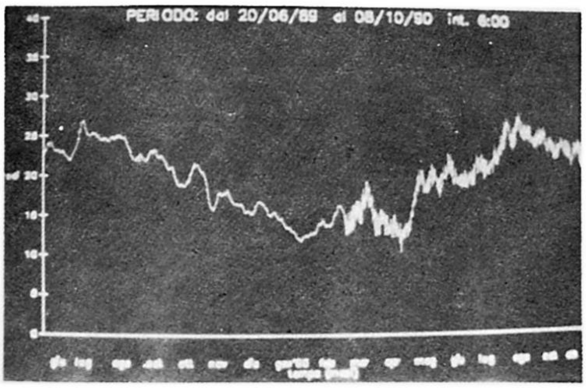
A monitoring system has been installed (fig. 27) to assess the evolutionary character of the phenomena; the results show the dependence on temperature and a low trend of the width of cracks to increase (fig. 28, 29).



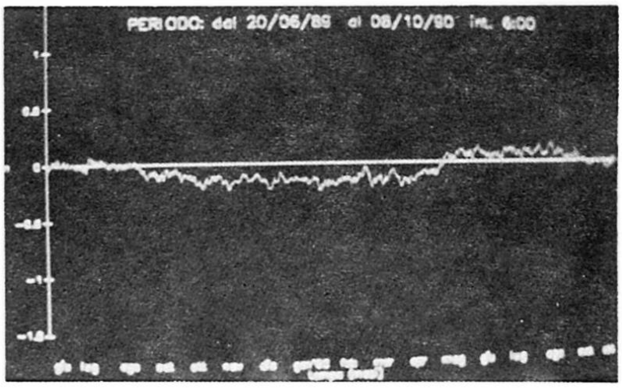
Pic.26: Cracks on the dome



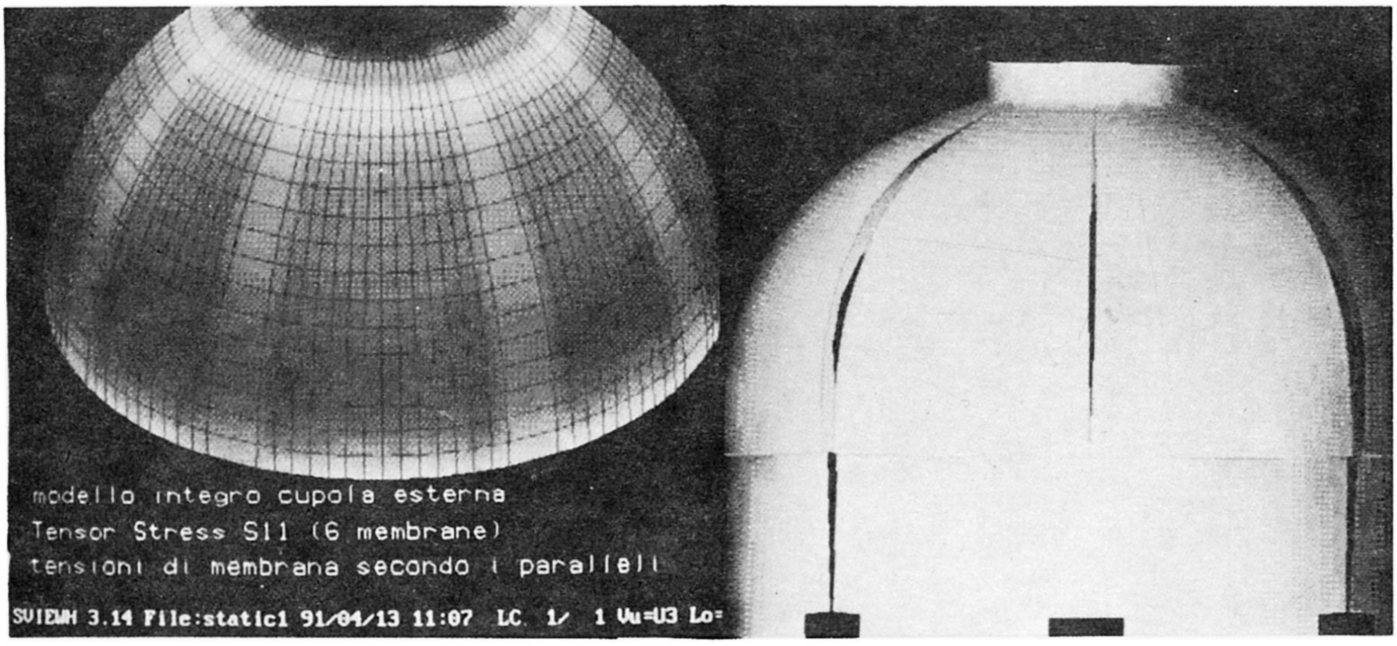
Pic.27: Monitoring system



Pic.28: Diagram of temperature evolution

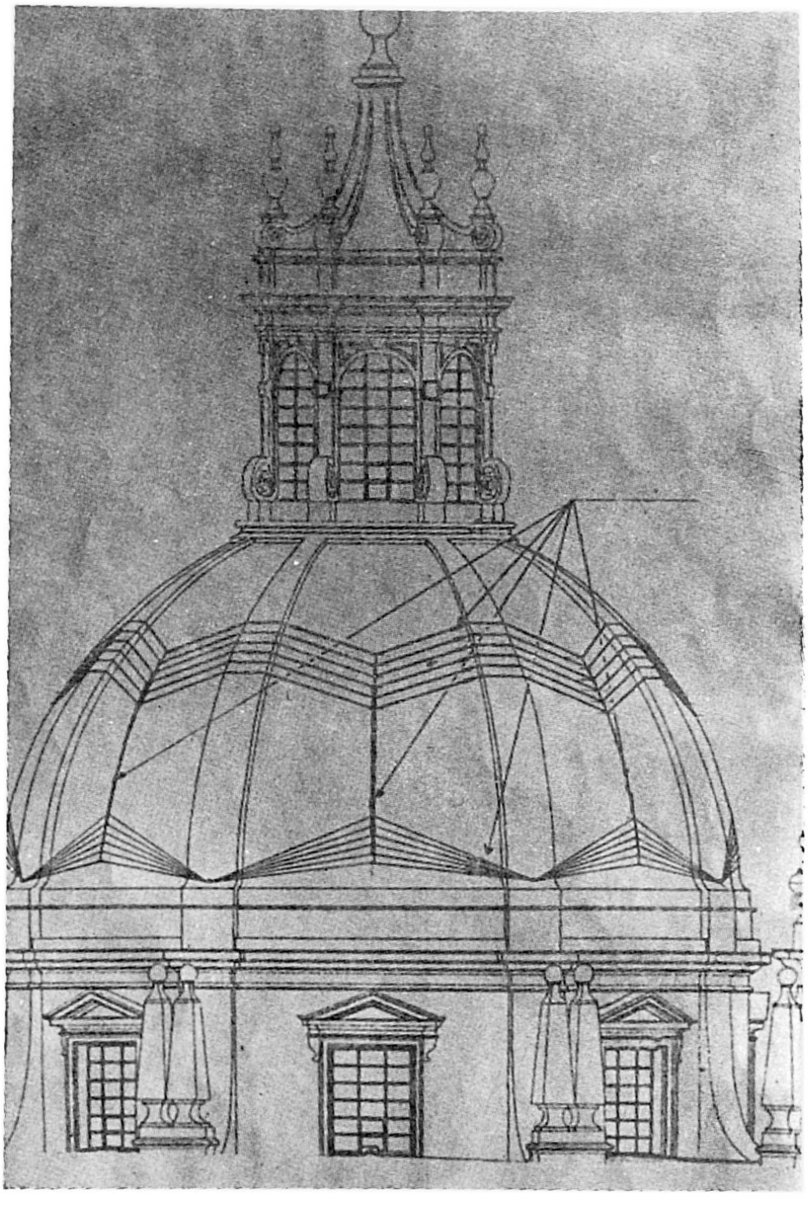


Pic.29: Diagram of crack evolution

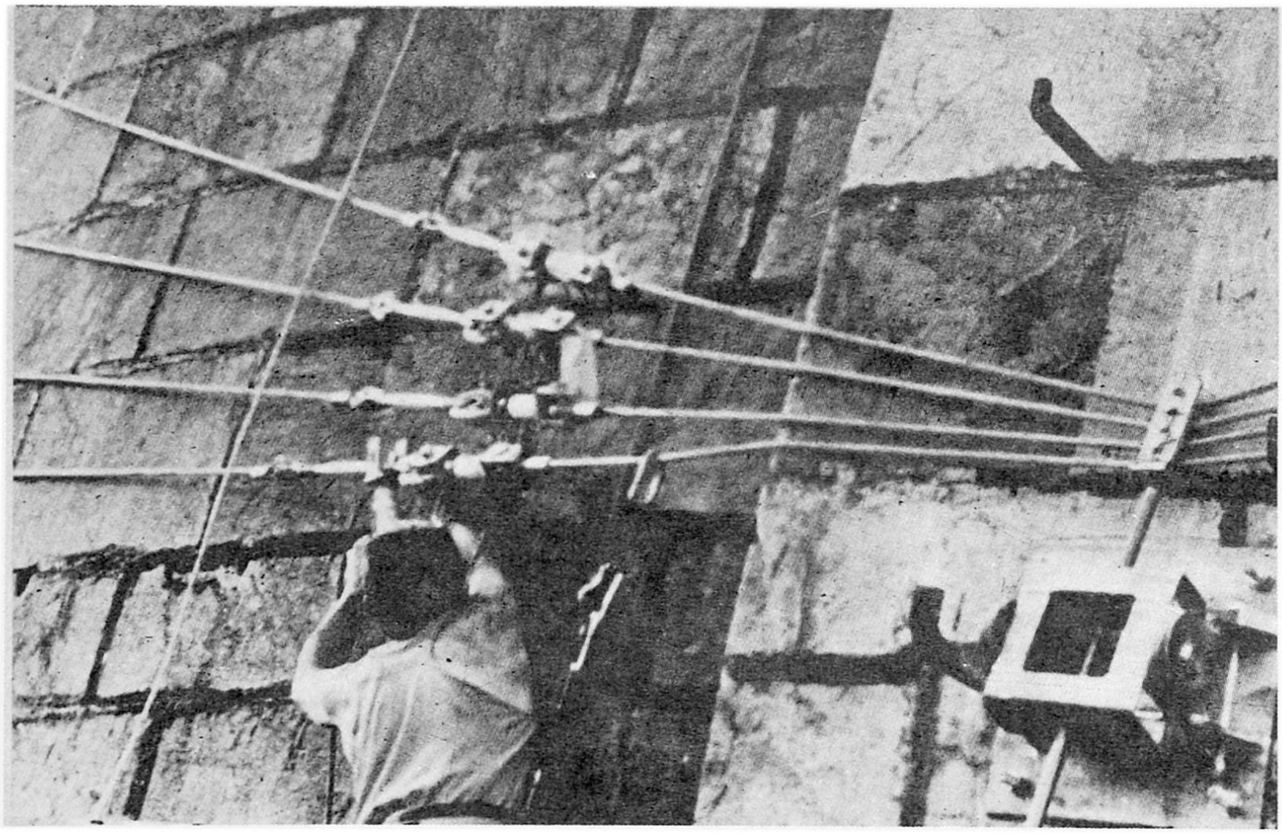


Pic.30 : Mathematical model of the dome

A preliminary mathematical model (fig. 30) shows that the shape of the dome, bein quite hemispherical, is the cause of important tensile stresses in the parallels and, consequently it has led to the crack pattern that we have observed.
A second mathematical model, taking in account the discontinuites represented by the cracks, has shown that now the equilibrium is assured only by important bending momentes in the meridians, represented by tensile stress and compression stress, on the inner and outer surface of the dome.
In this situation the margin of safety is very low.
The reinforcement that we proposed consisted of prestressed cables of the same kind usually employed to sustain the masts of sailing boats (figg. 31, 32). The advantages of this solution are economy and durability.
The stainless steel cables have been put in place by "escaladores" (fig. 33) and the phase of pretensioning has been monitored (fig. 34).

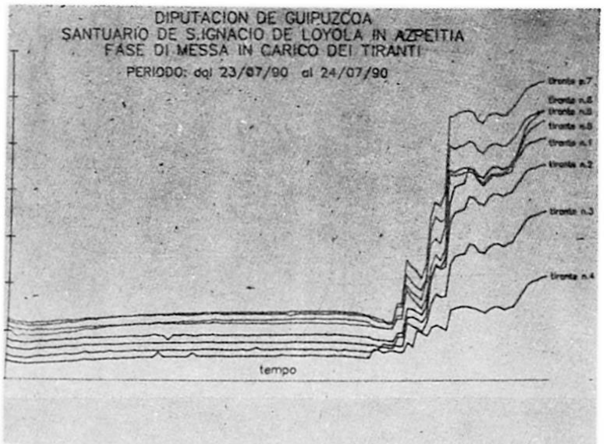


Pic.31: Prestressed cables for the reinforcement of the dome



Pic.32: The cables for the reinforcement of the dome

Pic.33: The operations to place the cables



Pic.34: Monitoring of the phases of prestressing

Engineer's Role in Shaping Civilization

Rôle de l'ingénieur dans l'évolution de la civilisation

Die Rolle des Ingenieurs bei der Gestaltung der Zivilisation

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Peter Sluszka received his degree from Hofstra University, Uniondale, NY. He has supervised bridge rehabilitation and new bridge design projects including major structures throughout the United States. He is currently in charge of Steinman's firmwide operations.

SUMMARY

Engineers have played a vital and driving role in the evolution of civilization as we know it today. Tracing the thread from prehistoric times to the visions of the future, one becomes aware of the awesome responsibility the engineer has to his fellow man.

RESUME

Les ingénieurs ont joué un rôle essentiel et prédominant dans l'évolution de la civilisation actuelle. En parcourant l'histoire, des temps préhistoriques aux visions futures, l'on peut voir facilement la responsabilité impressionnante de l'ingénieur vis-à-vis de la société.

ZUSAMMENFASSUNG

In der Entwicklung der Zivilisation, wie wir sie heute kennen, haben Ingenieure eine lebenswichtige und treibende Rolle gespielt. Folgt man dem Faden von prähistorischen Zeiten zu den Visionen von morgen, so sieht man mit Ehrfurcht die Verantwortung des Ingenieurs gegenüber seinem Mitmenschen.

"... the bridge is more than an embodiment of the scientific knowledge of physical laws. It is equally a monument to the moral qualities of the human soul. It could never have been built by mere knowledge and scientific skill alone. It required, in addition, the infinite patience and unwearied courage by which results are achieved."

With these words, the Honorable Abram S. Hewitt, on May 24, 1883 expressed humanity's indebtedness to the builders of the Brooklyn Bridge.

If today Hewitt's words sound overly poetic and soaring, it may indeed be due to the changes in oratorical style that have occurred over the past century, but it is also due in part to our own loss of perspective and appreciation for the driving force that engineering works have been in shaping the physical world, society, and the basic human condition that we take for granted.

We have come to accept the fantastic as commonplace, the incredible feats of engineering achievement as the expected. But it was not long ago that the engineer was seen as a heroic leader of humanity, whose mission was to "subdue" the earth, as the Bible says God ordered man to do. Walt Whitman, the great American poet, expressed this thought in his lines;

> Lo, soul, seest thou not God's purpose from the first?
>
> The earth to be spann'd, connected by network,
>
> The races, neighbors, to marry and be given in marriage,
>
> The oceans to be cross'd, the distance brought near,
>
> The lands to be welded together.

What defines engineering and when did it begin? Some engineers, tongue-in-cheek, claim that it is the second oldest profession. This view may be valid if we allow latitude in the use of the term "profession." For when did we become civilized and in turn begin classifying individuals as doers of specific tasks? It was not when humans first gathered together to live in groups for the common good, because lower forms of life such as wolves, lions, even insects, preceded humans with this "societal lifestyle" (bees and ants seem to be more adept at it than we humans are, even today). It was not when humans developed the ability to communicate with each other, because again, many lower life forms do that. It can be argued very convincingly that civilization began when mankind broke free of the bounds set by its natural environment and began to shape its own world. It appears that this was an inevitable result of the physical evolution of man, as it is the human spirit, that exists for the sake of bettering itself, that has ultimately defined the species.

So we began to build. It doubtless began with primitive dwellings to deal with the weather, and primitive bridges of logs and stones connecting primitive highways cleared of brush to provide transportation to sources of food and water. It may have been very early in this evolutionary process that some individuals emerged as builders, while others were more suited for hunting, farming, etc.

As population centers grew, shortages of space and food undoubtedly led to rivalries between groups (an inherent but unfortunate characteristic of the human spirit) and defense and aggression became a more important concern of the builders. The most ancient ruins of civilized settlements generally bear one prominent feature in common, that of a system of fortifications in the form of protective walls or embankments. When man learned to protect his territory by building structures to thwart rival groups from taking what they wanted it became mutually advantageous for different societal groups to learn the concept of trade and commerce. This required transporting people and goods from one place to another and organized building of roads and bridges was born. Archaeological discoveries reveal that primitive man was remarkably industrious and creative in such civil works, even thousands of years before recorded history.

Until relatively recent times the word "engineer" had a military connotation. The empire of the Romans was based on military strength, but this strength was primarily a product of their highly developed skills in engineering. "All roads lead to Rome," the saying goes, and throughout its reign, this was literally true of the roads of the Roman Empire. In order to maintain its rule over the many settlements that were so remote from its capital, the Empire built roads and bridges, barrelling straight through from city to city to create an unhindered way for its legions of soldiers. The subjects of the Empire knew very well where the end of the road was.

But this formidable system of great roads also caused the intermingling of knowledge and cultures from the diverse peoples throughout much of the old world, and accelerated the evolution of civilization. Individual societies were no longer left to develop in isolation and mankind grew closer to becoming a singular, collective, whole. Eventually, through this exchange of knowledge more and more societies found the means and will to create important civil works for the betterment of their lives. Human intellect steadily moved toward higher ideals and philosophies and the recognition that society's reason for being is to work toward the common benefit of all.

While today we do not usually think of the engineer in terms of the governing segment of society, in ancient times the leaders were those who could direct the building of public and military works. The word "Pontiff", which today refers to the Pope of the Roman Catholic Church, originally meant "Bridge Builder," an interesting clue to the leadership role the engineer has played in history. It was recognized that society could only be sustained and improved when people did not have to struggle merely to survive. The construction of dwellings, systems to provide adequate water and sanitation, and reliable transportation routes were absolute necessities if civilization was to continue its course. The engineer was thus very powerful and influential in ancient times.

As this process of evolution continued, the human mind delved deeper into an understanding of the physical world. Science and mathematics progressed in the relentless pursuit of the technology that humanity demands, eventually leading to the industrial revolution of the 19th century. Engineering was freed from its military limitation and became a profession dedicated to building machines, structures, and highways for civilian purposes as well.

It was during this time that industrial machinery increased our ability to manufacture all nature of goods in mass quantities, making them available to a much broader segment of the population. The invention of electrical power generation and incandescent lights changed forever the way humans lived. As the industrial and commerce centers of the world grew steadily larger, so did the concentration of people needed to keep the machinery running.

These developments are what shaped the modern cities of the world. New York, as a glowing example, became overcrowded and began to overflow its geographical boundaries. The development of taller buildings was seen as a partial answer to packing more people and more industrial space within its confines. In 1849, James Bogardus built a factory framed entirely of cast iron, the first such use of the material, although it had been known to man for thousands of years. The practical height of conventional brick, stone, and concrete buildings was five or six stories due to the massive walls and foundations that were required to bear the weight. But with the innovative use of iron, and later steel, previously unimagined heights were now possible. The invention in 1854 of Elisha Otis's "safety hoister," or safe elevator made the skyscraper not only possible, but practical as well. An increasing boldness and a spirit of rivalry drove American engineers to build even taller buildings, and by 1890 the Pulitzer Building, on Manhattan's Park Row, held the world's record at 106 meters.

These furious advances in the construction of buildings were accompanied by still other advances in engineering that illustrate the old saw that "necessity is the mother of invention." The need to supply water to the teaming population led to the construction of the Croton Reservoir and Aqueduct, itself a major engineering achievement completed in 1842. Where 70 years earlier the city's sewage was being removed by lines of slaves carrying tubs to the river, over 150 km of underground sewer pipes were doing the job by the late 1850's (today, the system totals almost 10,000 km). The need to transport the city's workers to and from their homes in nearby rural Brooklyn set the stage for John Roebling to design his masterpiece Brooklyn Bridge which, using steel wire in its cables for the first time, was the prototype for modern long-span suspension bridges.

One cannot over emphasize the importance of transportation in the proliferation of civilized society worldwide. The construction of canals, railroads, and highways, with their requisite bridges and tunnels, was a key factor in shaping today's world. It is self-evident that the exploration, settlement and industrialization of larger geographical areas depend on transporting people and things. As we observe the new order of a more unified world taking shape there are monumental transportation projects underway as the first and necessary step to make the future possible.

Great Britain and France will soon be joined by a tunnel beneath the English Channel, one of the greatest civil engineering achievements in history and a milestone of cooperation between an international alliance of engineers and builders. There are numerous bridge building projects underway in Asia and Europe that will change civilization forever. The Great Belt Link, which is now under construction will permanently unify the three major land masses of Denmark, and will be accomplished through the combined efforts of Engineers and Contractors from several European countries as well as the United States. While this project also contains one of the world's greatest tunnels, the East Bridge, with the world's longest span to date, will be yet another "monument to the moral qualities of the human soul," created by the engineer. A bridge from Denmark to Sweden is the planned next step. Japan's Honshu-Shikoku project will similarly unify its major islands. In Italy, plans are being developed to bridge the Straits of Messina, the deep and treacherous waterway that separates Sicily from the mainland. Its proposed main span of over 3,000 meters will double that of even the Great Belt Bridge.

With our steady advances in technology and physical achievements has come a heightened awareness of a not so obvious responsibility of the engineer of today and the future. We realized only recently that our machinery and construction projects have been insidiously damaging the world we inhabit, and had we chosen to ignore the evidence, we would have engineered our own destruction. We have thankfully become markedly more environmentally aware, and have begun to install checks and balances to control the impact that our creations will have on the Earth's fragile ecosystem. We have seen in some quarters a complete turnaround in our attitude toward harnessing nature. In the United States, a telling example is the changing charter of the U.S. Army Corps of Engineers. The Corps dates back to the early 1800's and is charged primarily with protecting and developing the country's inland waterways to provide for transportation and adequate water supply. To this end, it fervently proceeded with massive dredging, damming and wetlands reclamation projects. Within the past thirty or forty years we have begun to learn how important wetlands are in the ecological balance of the environment, by moderating the climate, providing natural pollution control, and supporting the life cycles of a multitude of living organisms. For what was seen as disregard of these vital natural systems, the work of the Corps came under severe criticism in the 1960's, and in 1972 the U.S. Congress, with ironic brilliance, gave the Corps responsibility for protecting all of the nation's wetlands. Taking its new responsibility in earnest, the Corps now wreaks havoc on those developers who would potentially damage estuaries and swamps.

Hopefully, we have realized in time that our technology must be used carefully lest we destroy our own Mother Earth. The depletion of the ozone layer, the spectre of global warming, disastrous nuclear power plant accidents, and the visible destruction of plant and animal life throughout the world's lands and oceans are feedbacks from the engineer's work that are now redefining the engineer's role for the future. We obviously should not stop building dams to supply water to needy humanity, or rail and highway systems that bring better living conditions to undeveloped parts of the world. We have no choice but to continue building, but we must do it with an eye toward the larger scheme of things and balance the immediate human needs with the long term needs of our partner in survival; Nature.

We will continue to envision and execute great works to improve our lives and to gradually unify the peoples of the world. The shaping of the world by major engineering works is not over by any means, as some might believe.

Developing nations are moving rapidly toward industrialization and construction of infrastructure by importing and developing technology to meet their particular needs. India, for example, already has a well developed rail system that is the envy of its neighbors, and there is a national move toward increased industrialization and export of goods that will bring in the capital needed for further development. Major public works in water supply and power generation have already begun to move the country toward improved living conditions.

It is expected that major civil engineering works will eventually take place in the independent states of the former Soviet Union, where an abundance of recognized engineering skill and advanced technology will no doubt flourish with an infusion of investment from the outside world. The vast resources of these states can be tapped once a viable transportation system has been built. Russia is already revamping its civilian communication systems to do business with the rest of the world.

There is talk of bridging the Straits of Gibraltar and connecting the Aleutian Islands with Siberia. These bold visions are typical of the human spirit's natural drive to create that has brought us this far. We are witnessing blinding advances in computer aided design technology and the development of new engineering materials. The use of plastics, fibers and ceramics that developed through the space program may yield profound advances in future structures. E-Glass and Kevlar fibers, for example, have been manufactured with a tensile strength nearly two times that of modern bridge wire, opening the possibility that we may someday build superspan suspension bridges that will dwarf even the proposed Messina crossing. Advances in concrete making have yielded compressive strengths three to four times that of conventional concrete, allowing us to design more daring and more economical structures.

We will be forever occupied in repairing, maintaining, and upgrading our existing infrastructure. Well over one billion U.S. dollars will ultimately be spent on rehabilitating New York's four East River Bridges alone. We are developing ways to extend the life of these aging structures by refurbishing suspension cables and replacing roadways with more durable materials. We are strengthening the creations of our predecessors to make them capable of meeting modern demands of traffic and economical maintenance.

Major upgradings of our transportations systems will require innovative ways to increase the capacity of existing structures. The Tagus River Bridge in Lisbon, for example, is about to be retrofitted to carry rail traffic on a new second deck, as is San Francisco's famous Golden Gate Bridge.

As engineers, we can surely take pride in our profession, and we must surely never lose sight of the awesome responsibility that civilization has assigned us. It is a responsibility to the past and to the present, but even more so to the future generations. It is a responsibility to leave them with a world that is better than the one we entered.

In The Sons of Martha, a poem of tribute to the engineering profession, Rudyard Kipling eloquently portrays the engineer's place in society. This stanza from the poem is my favorite:

They do not preach that their God will rouse them a little before the nuts work loose.

They do not teach that his pity allows them to leave their work when they damn-well choose.

As in the thronged and the lighted ways, so in the dark and the desert they stand.

Wary and watchful all their days, that their brethren's days may be long in the land.

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.

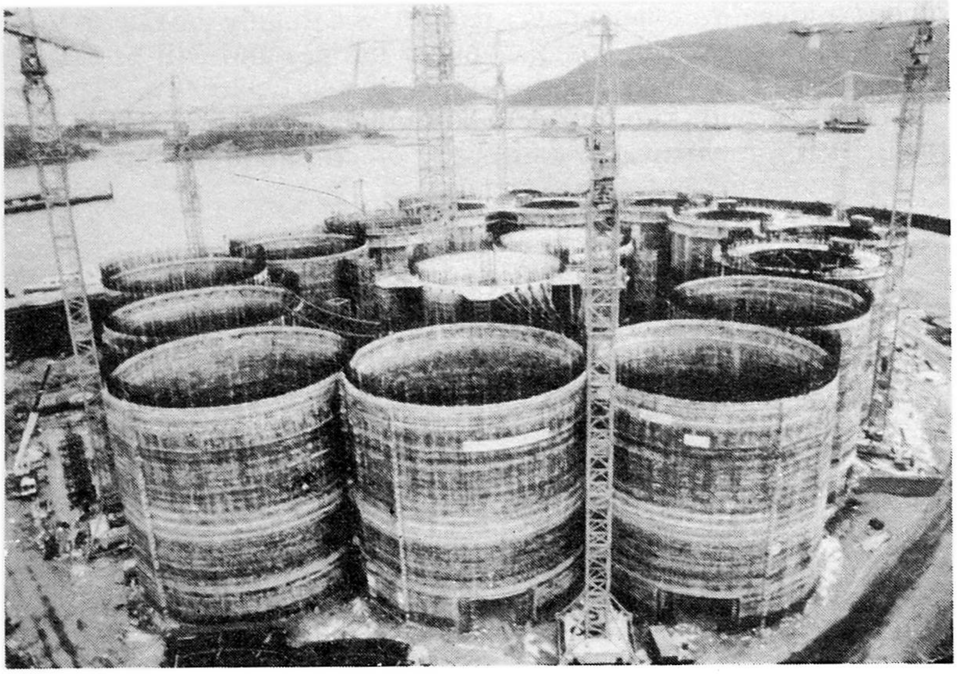

Fig. 1

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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).

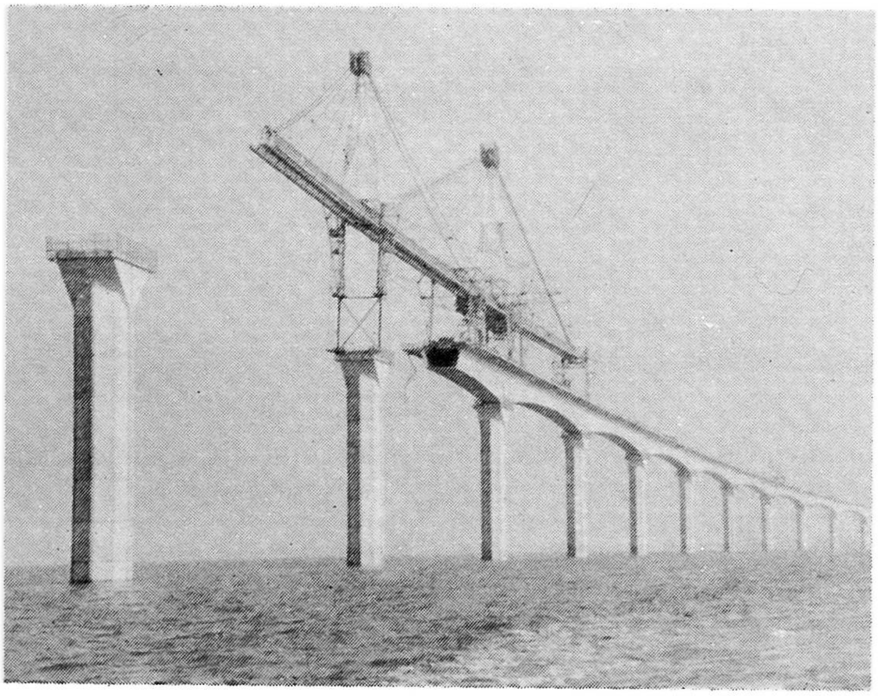

Fig. 2

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

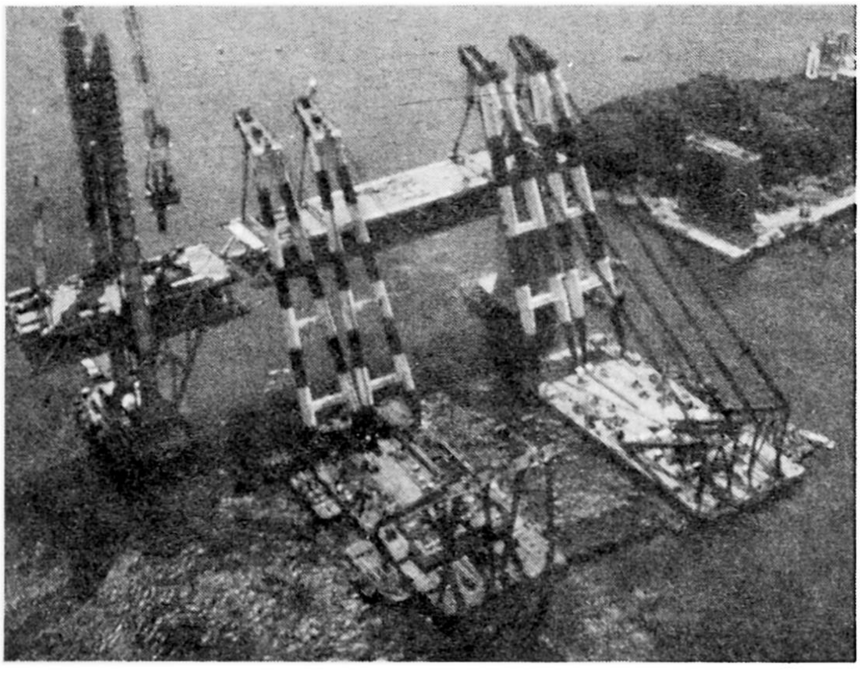

Fig. 4

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).

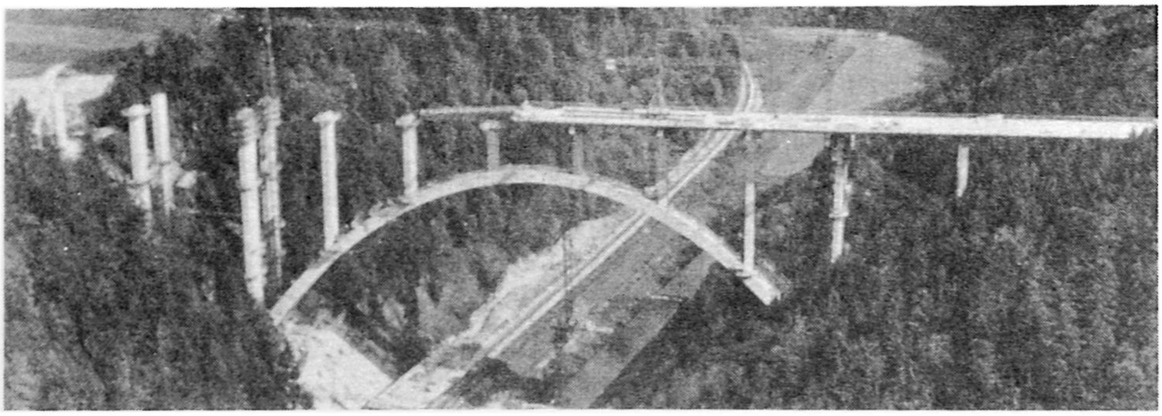

Fig. 5

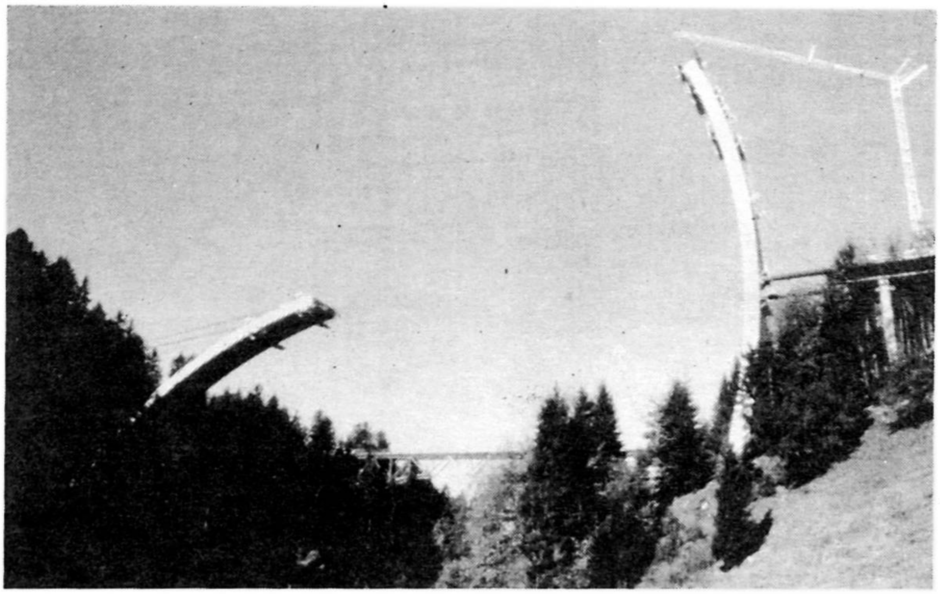

Fig. 6

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).

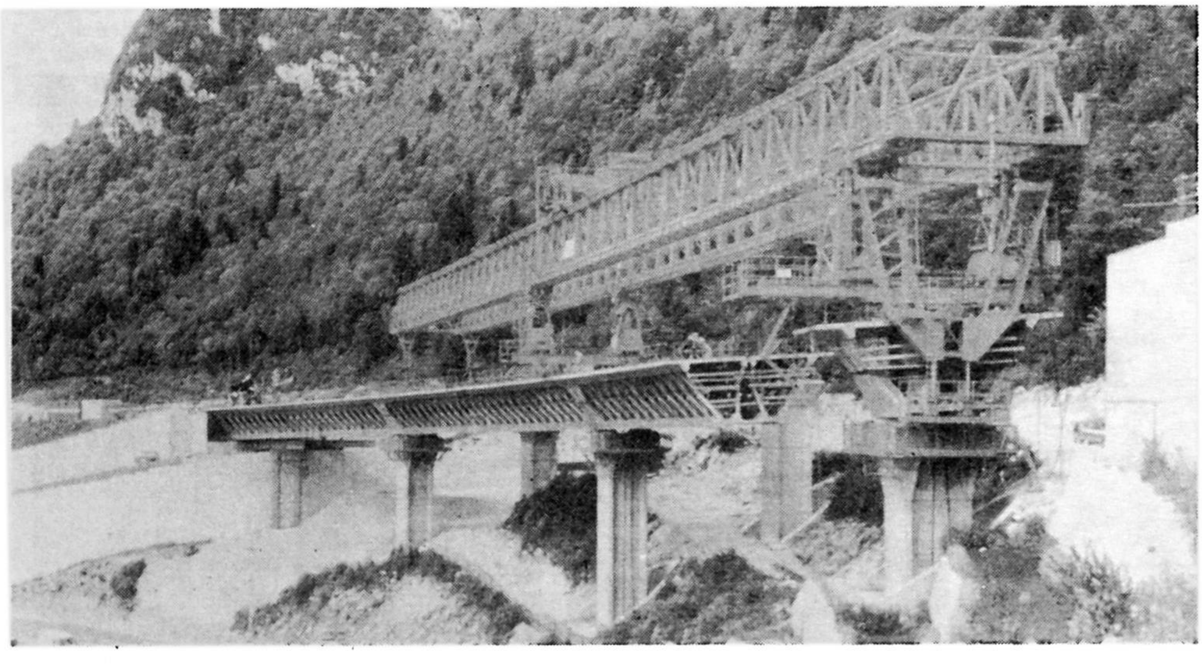

Fig. 7

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.

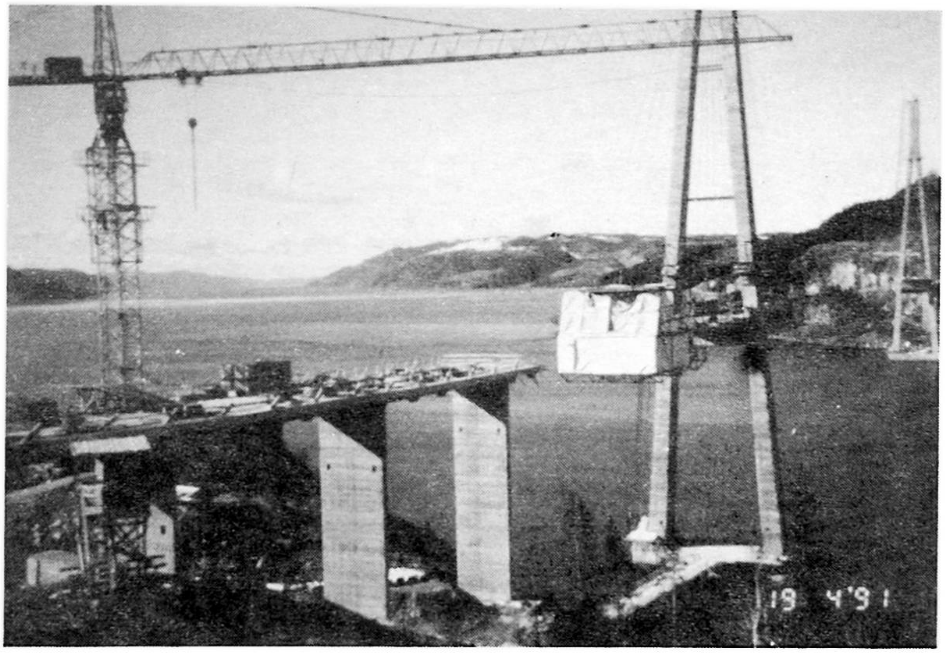

Fig. 8

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.

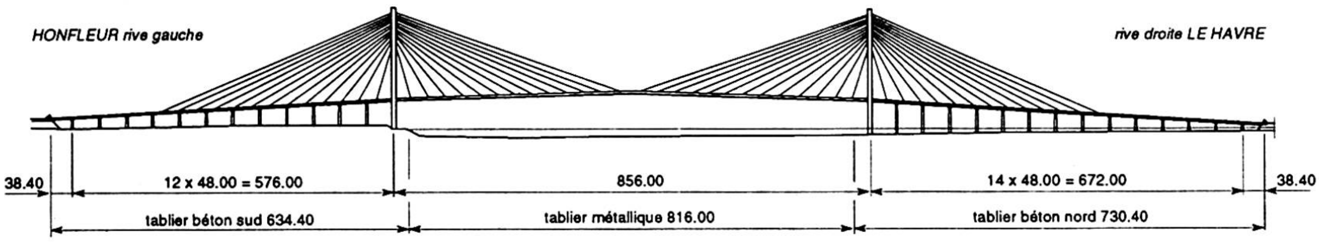

Fig. 9

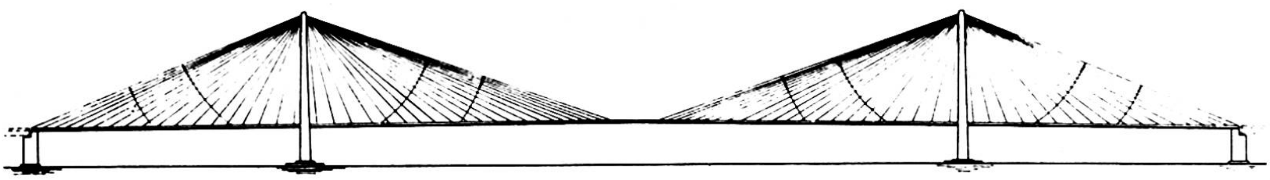

Fig. 10

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.

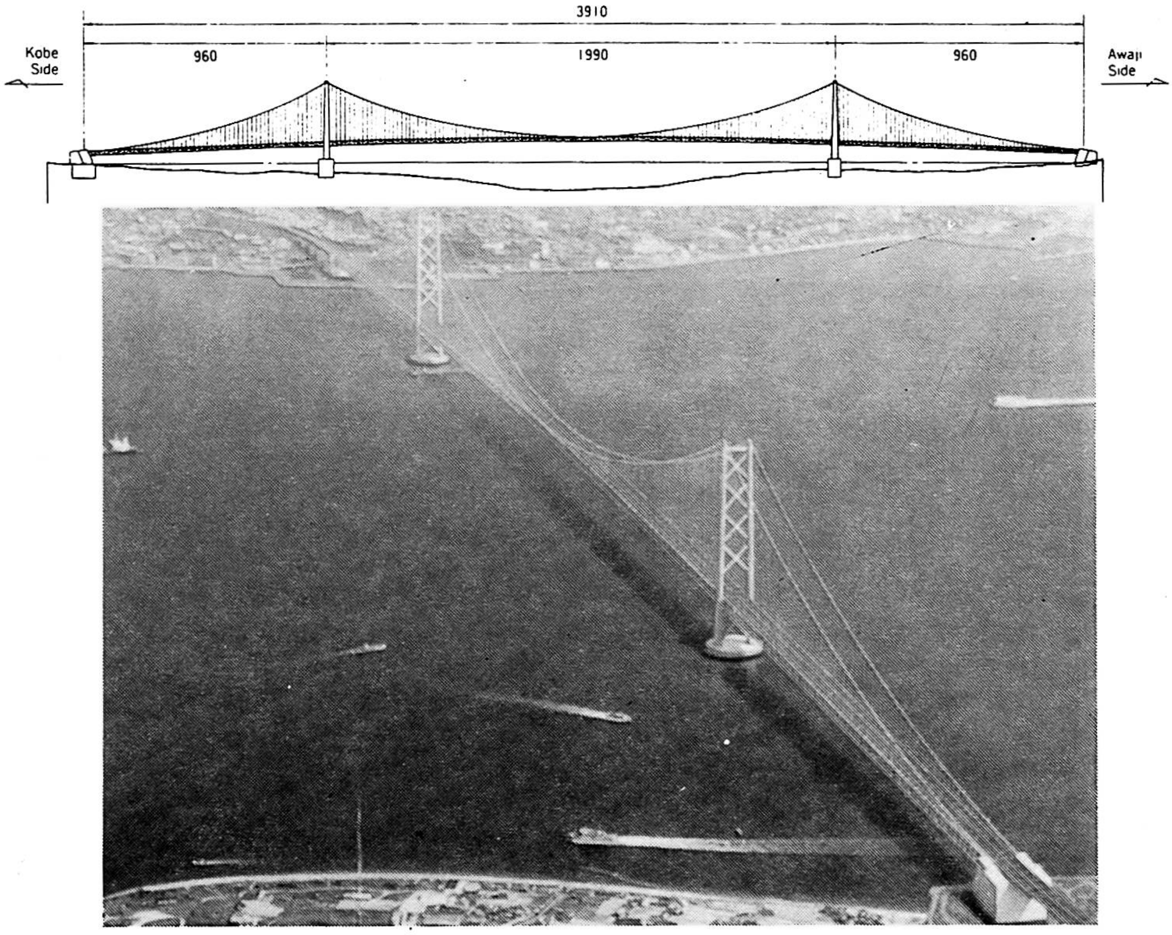

Fig. 11

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.

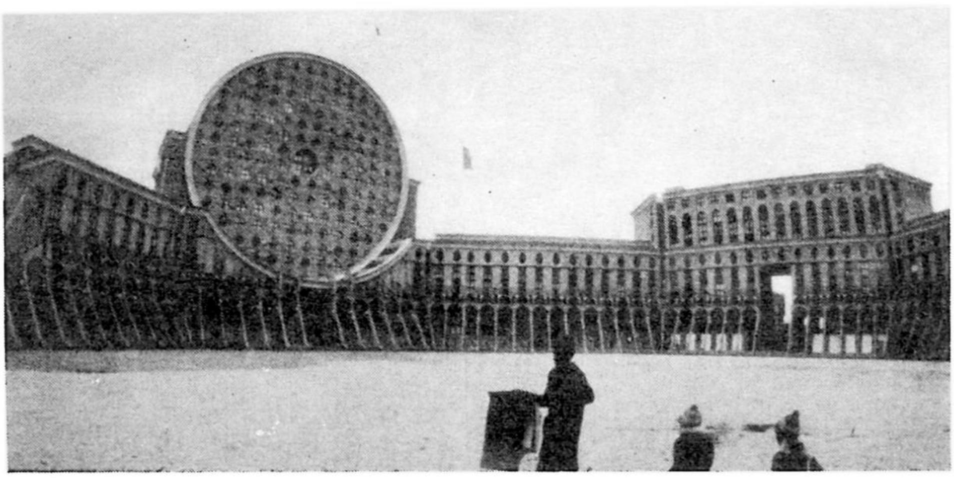

Fig. 13

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.

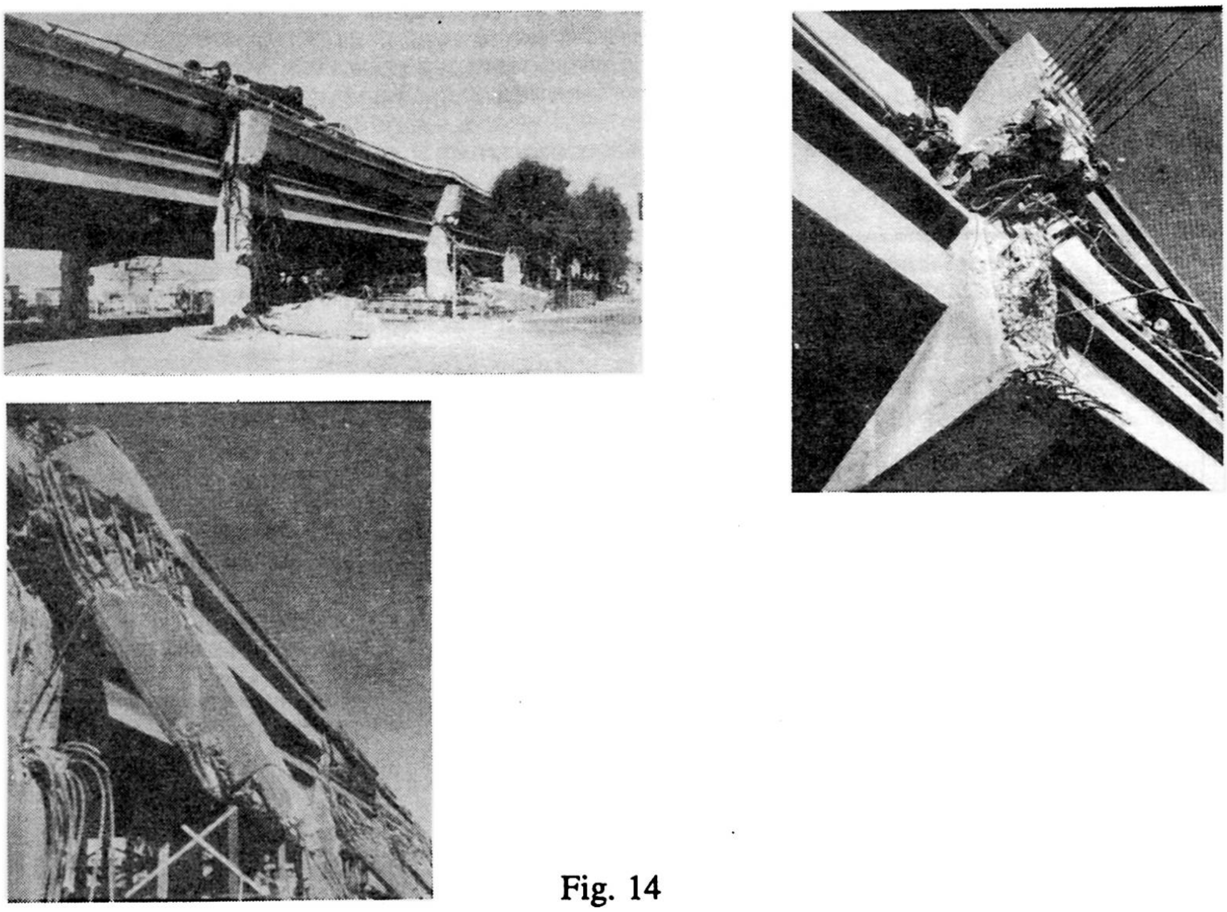

Fig. 14

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.