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Bridge Aesthetics and Structural Honesty

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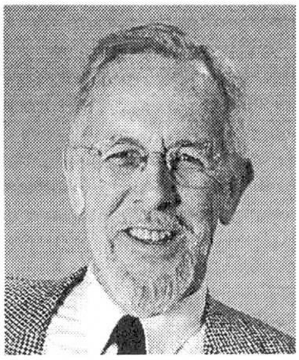


Niels J Gimsing, born 1935, is professor at the Technical University of Denmark since 1976. He has at several occasions acted as specialist consultant during the design of major bridges.

Abstract

In bridges the overall form must be chosen with due respect to the transmission of forces if efficient structures shall be created. The design must therefore be governed by experienced structural engineers - in some cases assisted by aesthetic advisers on specific issues.

In contrast to a structure forming a part of a building or a large roof where the structure is more or less covered by walls, floors, roofing and other non-structural elements, the structure of a bridge is generally visible in its entirety. So mistakes in composing the bridge structure will be clearly exhibited. However, with the development of modern high strength materials the designers can to a certain extent neglect structural efficiency without being warned by arriving at elements of ungainly dimensions.

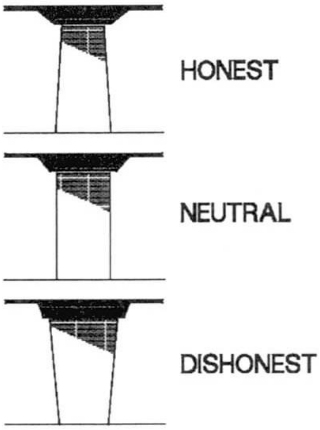


Fig.1 Pier shafts

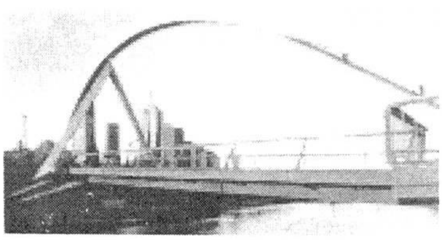
The term 'structural honesty' relates to structures designed so that the strength requirements are reflected in the form of the bridge as a whole and its individual elements. As an example Fig.1 shows three pier shaft configurations. They will all be subjected at the top to a large vertical force, a moderate eccentricity moment and a lateral force, e.g. from wind load. The latter will induce a bending moment that increases from top to bottom so it will be honest to vary the width of the pier shaft as shown at the top. With a constant width the form does neither emphasise nor contradict the structural function so it can be regarded as neutral. Finally, if the shaft is designed with the smallest width at the bottom where the highest strength is required then the form is obviously dishonest in relation to the structural function. Nevertheless, it is quite common to see the variation shown at the bottom in real structures.

For many centuries arches were the preferred structural form to be used in major bridges. This was, however, not a choice based on pure aesthetic considerations but much more because it is the most efficient form of a structure built of materials able to transmit only compressive forces. After the introduction of structural materials with large tensile strengths the arches were in many cases substituted by trusses, plate girders or box girders.

In recent times the arches have again become fashionable but in several cases they are chosen only for their aesthetic merits without considering the relation between form and structural efficiency. The result is that 'false' arches flourish in bridges designed without considering the structural function..

In reality the principles for choosing the shape of an arch are very simple:

- The arch shall be curved where it is subjected to a distributed load
- The arch shall have a sharp bend where it is subjected to a concentrated force
- The arch shall be straight where no load is applied.



An example on an arch bridge designed without considering the principles outlined above, is shown in Fig.2. Here the load from the bridge deck is transferred at one point so the correct form of the arch would have been two straight members leading directly to the supporting points. However, the designer apparently found a curved arch to look nicer so this form was chosen despite the consequences regarding material consumption.

This aspect is illustrated in Fig.3 showing a comparison between a correctly shaped arch (consisting of two inclined, straight members) and a parabolic arch - both made of steel. It is seen that the (unnecessary) bending induced in the curved arch results in a considerably larger cross section, with plate thickness of up to 60 mm, whereas the correctly shaped structure can be composed of more slender members with plate thickness of only 18 mm. As a result of this difference in dimensions the steel quantity will be tripled if the incorrect curved shape is chosen.

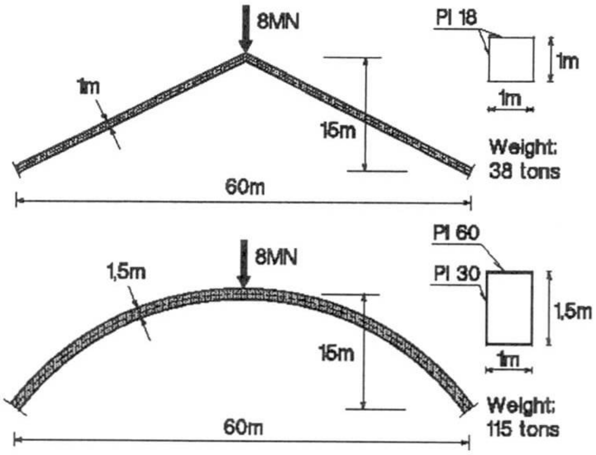


Fig.3 True and false arch with one concentrated force at midspan

Conclusion

Bridges should be designed in such a way that structural function and efficiency is expressed in the form. Modern high strength materials should be used to make the bridge light and graceful, not to shape it without considering the structural function.

Landscaping of Tokyo Wan Aqua-Line

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Abstract

The Tokyo Wan Aqua-Line (Trans-Tokyo Bay Highway, opened on December 18, 1997) is the last big project completed in Japan in this century and currently being the focus of both national and international attention. As a gateway to the capital Tokyo, it is exposed to the view of many people travelling on business or for sightseeing and recreation purposes. And it is also expected to become a valuable cultural heritage to be passed on to the next millennium. Furthermore, situated in the middle of Tokyo Bay, its construction needed great care to ensure the harmony with surrounding natural marine features and environments.

To satisfy these requirements, a special committee was set up to study the landscaping of the Tokyo Wan Aqua-Line in a series of meetings.

Not only was the Tokyo Wan Aqua-Line aimed to enhance the efficiency of marine traffic between Kawasaki City (Kanagawa Prefecture) and Kisarazu City (Chiba Prefecture), but it was also planned to be an integral part of the Tokyo metropolitan road network. Hence, its influence on economy and industrial affairs was expected to be considerable. In carrying out the landscaping studies, therefore, its basic roles were examined from various aspects such as traffic engineering, economy, industrial affairs, property values and psychological factors (symbolic function of the Tokyo Wan Aqua-Line).

As a result, "symbol", "harmony" and "quality" were defined as three conceptual terms representing the fundamental philosophy of landscaping i.e. "creation and harmonization of new metropolitan area toward the 21st century". The structures of the Tokyo Wan Aqua-Line including the bridge, Man-Made Islands and ventilation tower were all designed based on these conceptual terms.

The Val-Benoit Cable-Stayed Bridge

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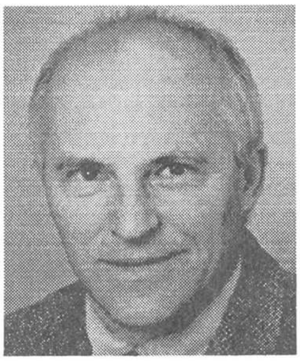


Jean-Marie Cremer, born 1945, received his Civil Engineer's diploma at the University of Liège, 1968. He presently carries on the function of managing director at the ENGINEERING OFFICE GREISCH. He performs the direction of the bridges department. Professor at the bridges chair of the University of Liège.

1. Choice of the type of bridge

Squeezed between two tunnels, the bridge crosses the Meuse river and roads on both banks at Liège in Belgium

The grade profile on the bridge does not allow slopes over 6,5 % to enter or exit the tunnels.

In addition to the sharp curvature of the river, the site is characterised by a sharp housing dissimetry. On the right bank, the outer side of the curve, the quite flat ground is mainly occupied by industrial constructions, dominated by the important railway junction. On the left bank, the inner side of the curve, the urbanistic texture is mainly made of habitations, squeezed between the river and the hill.

The numerous technical requirements and the site constraints have led to the choice of a cable-stayed bridge with a single pylon on the right bank.

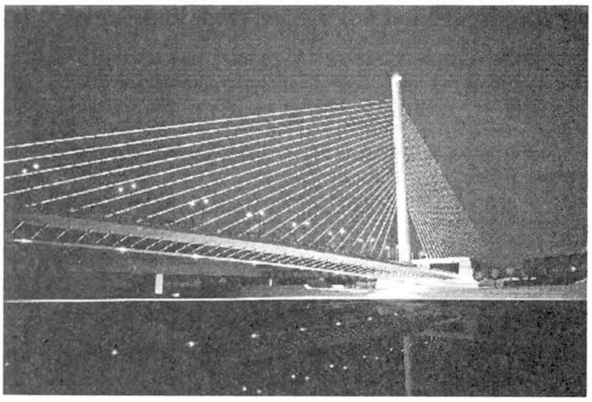
Its particularity of highway bridge in urban site has also led to the need to combine simplicity and impeccable appearance, with the following particularities :

- The necessary readability of the structure has led us to choose a single cable plane, located on the axis of the bridge.

- The search for thin structural elements bordered by more monumental abutments is satisfied by the stays and the very thin circular pylon, which slenderness is accentuated by the truncated cone shape.

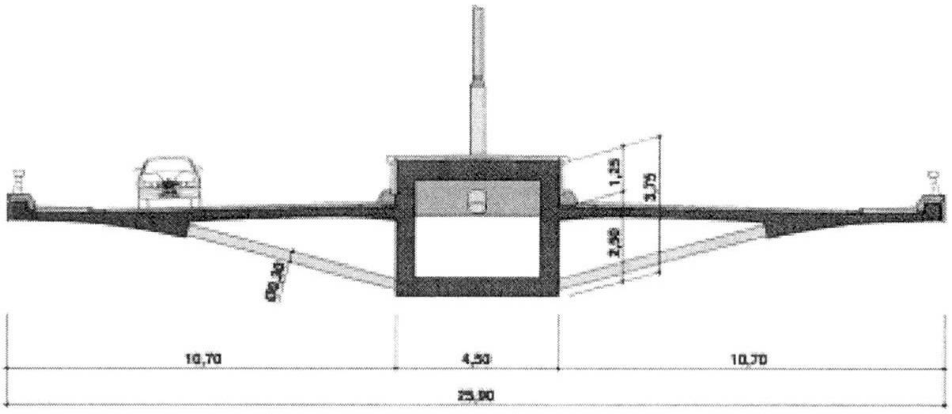
  On the contrary, the choice of a single cable plane thwarts this search for slenderness for the deck. Indeed, the height of the deck box-girder, required by the torsional stiffness, does not match this objective.

  However, the design of the cross-section allows to limit its visual impact. The deck slab is located around mid-height of the box-girder and is supported by very sloping lower steel tubes which improve the lower part and accentuate the impression of slenderness, as the upper part is hidden by the lateral security barriers.



- The balancing span replaced by a balancing abutment which, on the one hand, points out the entrance portal of the tunnel and, on the other hand, acts as an acoustical protection for the near by habitations.
- The visible concrete facings are concreted on site in plank-structured formworks; the lower face of the deck is particularly being taken care of as it is very closely perceived by the walkers.
- The faces of the abutments are realised with country natural stone as the roof of the balancing abutment is entirely covered with vegetation.
- The pylon, shaped as a slightly truncated cone, is covered with glazed glass, fixed with bolts.
- The sheathes of the stays as well as the external sleeve of the steel tubes supporting the deck slab are made of stainless steel.
- A specific lightning device points out the bridge and respects the habitation neighbourhood.

- Absorbent coverings are widely used to limit at best the acoustical nuisances.
- Landscaped arrangements such as pedestrian and cycle tracks, rest zones, street furniture and vegetation complete the urbanisation of the site, strongly perturbed by the monumental bridge.
- An esplanade, widely open on the river, clears the base of the pylon.



2.Technical description

The main span of the bridge over the river is 162 m long, in continuity with a short 31 m long span above the left embankment and a very short 12 m long span between the pylon and the balancing abutment. This abutment is 122 m long and is the first part of a tunnel that goes on under the railway junction.

The prestressed concrete deck, 25,90 m wide, has a rather uncommon cross-section, with a small central box-girder, 3,75 m high and 4,50 m wide, and two cantilever slabs, located 1,25 m beneath the upper level of the box-girder.

The prolongation of the box-girder above the cantilever slabs is necessary to obtain a torsion rigidity sufficient to resist to the transversal loads of balances. The cantiliver slabs are supported every 3 m by steel tubes with stainless steel sleeve, they are also transversally prestressed by 4T15 cables every 50 cm.

The pylon, located on the axis of the bridge, has a total height of 82 m. It is rigidly restrained to the deck. It is covered with granite. Its dubble foundation sole allows a slight translation due to the effects of shrinkage, creep and temperature variation in the part of bridge that separates the pylon from the fix point in the middle of the balancing abutment.

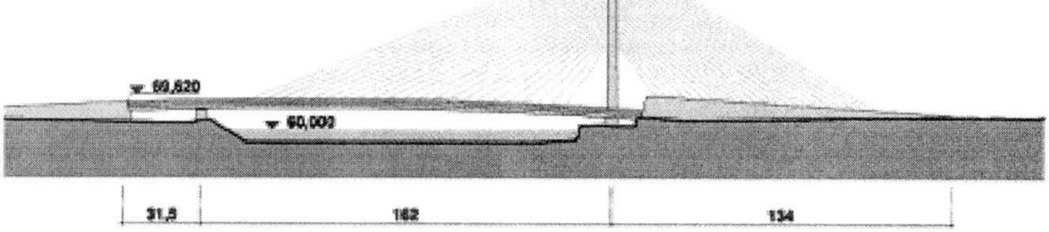
The deck is supported, above the river, by 22 stays, balanced on the pylon by 22 other stays which are anchored in the balancing abutment. The 44 stays are made of sheathed greased galvanized strands in an external 2 mm thick stainless steel sleeve.

At the lower part of the stays, a 5 m long dubble sheath, filled with wax, insures an excellent dumping towards parasital vibrations.

3.Execution

The deck is positionned by incremental launching. He is made of 18 pieces, out of which 16 ones are 12 m long, and is built on a fix site located on the right bank and positionned by incremental lauching 12 m at a time.

The pylon, cuminating 70 m above the deck, He has a circular cross-section, slightly in the shape of a cone frustum. The granite facing is planned for the end of the works.



Combining Aesthetic and Structure for the Large Domes in Isfahan

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Abstract

Isfahan Cultural Center comprises a building complex of 150,000 m^2. Several types of building are being constructed among which a number of special structures exist. The architectural and structural design requirements for these special structures are the main subject of this paper.
Since the complex is located in Isfahan, a very famous old city with several beautiful and ancient buildings, it was necessary for the proposed design to be harmonious with the existing situation. In general, the arch and dome-shaped forms were used in the most important parts of the building with special attention to the application of new material and technology. Both concrete and steel structures were utilised in the complex for the following two important special structures.

1. Main Court (Praying Hall): The architectural design required a column-less roof over 9,600 m^2 (160m x 60m) area of the court. The structural system for this large area had to comply with both architectural appearance and structural performance. The architects suggested a dome-shaped roof which normally have a circular or square plan. The rectangular area of the court was therefore divided into two 60m x 60m squares and two 20m x 60m rectangles (one between and one outside the squares). The covering system for square parts of the plan were two spherical domes supported on four edge beams. The maximum rise from the corner supports of the edge beams and spherical dome are 12 and 20 meter respectively. The corner supports are themselves located 15 meters above the ground level to give a 35m height for the top of the dome. The roof for the other rectangles (20m x 60m) is a type of tire-shaped structure supported on the edge beams of the adjacent spherical domes. As for the structural material, the first decision was the use of reinforced concrete shell but due to a number of parameters including : **a)** very large formwork surface, **b)** a large amount of scaffolding, **c)** special problems encountered for a cast-in-situ thin shell concrete placement and curing and finally the construction time, it was decided to use a steel structure for this part of roof system. Two alternatives were considered for this structure : space truss or space frame (both in dome shaped). The required structural depth for space truss was about 3 meters with a rather unpleasant and congested bar elements, while a space frame required a shallow depth (600mm) consisting of curved steel box sections. To provide a suitable harmony and agreement between these steel frame grids and the existing traditional architecture of Isfahan, different shapes were surveyed and finally a famous symmetrical design was adopted from an existing eight-hundred-year old mosque in the city. The frame elements have the same shape and design of the old mosque (Fig 1).

2. Concrete Shell Roofs: The praying hall is surrounded with a total area of 8,400m^2 consisting of 21 square chambers each covering an area of 400m^2 (20m x 20m). The structural engineers proposed a concrete-shell spherical dome for each unit. The design was changed later from a spherical to an ellipsoid dome to provide a more attractive appearance. The main design problem for the dome was that the plan area to be covered was a 20-meter square while the horizontal cross-section of the dome was a circle. The optimum solution was then to use four elliptical edge beams on the sides of the square. The sell is a half ellipsoid with small and big diameters of 20 and 28 meters respectively. The

shell thickness at most parts is 100mm and near the edge connection 150 mm . Each 20m x 20m chamber consists of three stories and the mentioned ellipsoid concrete shell covers its third floor (Fig 2).

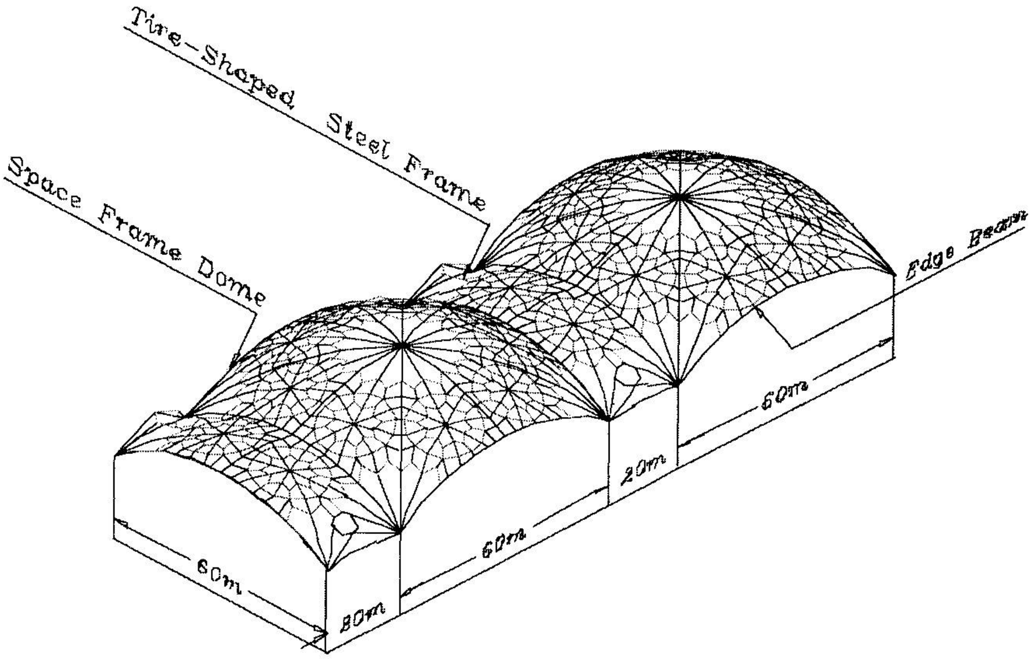

Fig. 1 Steel grid dome roof for the praying hall

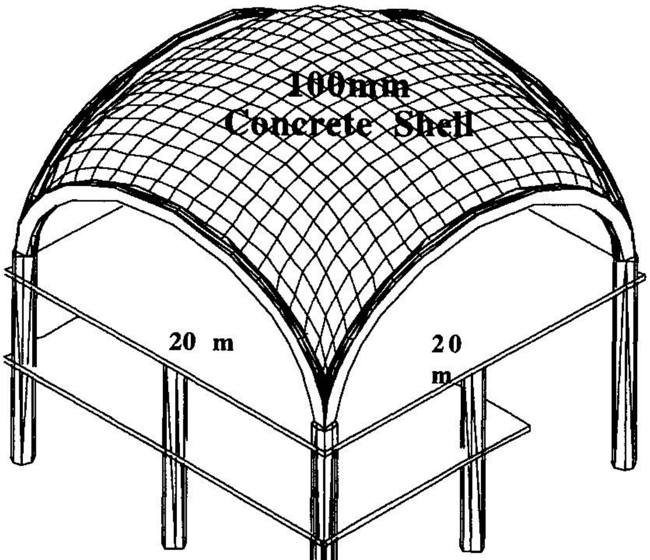

Fig. 2 A three-story 20m x 20m chamber unit with its ellipsoid100mm concrete shell roof

Cable-Stayed Mariansky Bridge in Usti nad Labem

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Milan Komínek, born 1947, received his civil engineering degree from the Czech Techn. Univ. in Prague in 1970. He is currently the head of the bridge and transportation department of CityPlan Ltd.

Summary

A paramount question for mankind in the next millennium is the quality of environment in which we will live. The most important components of the environment, clean air, water and soil, are impacted by transportation. Making transportation efficient and environmentally friendly often requires a sophisticated infrastructure, of which bridges are the most noticeable part. The cable-stayed bridges with its pylons are one of the most dominant and preponderantly used structural forms of the modern era. The shaping of its pylons and the arrangement of its cables is very important for the overall conceptual design. The resulting successful work should be a quality structure resulting from an optimal balance of economics, appearance and suitable structural design. The designers of the new cable-stayed bridge in Usti n. L. tried to follow this path with the pursuit of quality in the design and the construction, with focusing on the function and the aesthetics.

1. Conception of the Design

On July 30, 1998 a new bridge was ceremonially opened in Usti n.L. in the presence of important people from the Czech Republic and abroad. This bridge project was very important for the city since it had spread out along both sides of the river, with only one old road bridge connecting both banks. The City of Usti nad Labem could not count on the help of the Czech Government to finance this new bridge, so it decided to finance it independently. These circumstances are important reasons why the city put so much emphasis on the appearance, aesthetics, and structural consequences of the bridge. The resulting structure confirmed the importance of those aspects.

For a variety of reasons, the bridge had to be located opposite a massive cliff on the left bank. On the right bank the bridge connects to pre-existing infrastructures - a road bridge over railroad lines and a road traffic circle. Construction space was thus limited on both sides - on one by a natural geological formation and on the other by pre-existing structures. The location of the bridge in the middle of the dramatic surrounding terrain to a certain degree presented a challenge to the authors of the final design (Milan Kominek and Roman Koucky) and had an impact on the conceptual design. At the beginning of every successful bridge project should be clear conception of the structural design including construction method. The following criterias had major influence on the design of this bridge.

The first basic idea of the conceptual design was to minimise the mass of the bridge ramps below the Marian Cliff and the main cable-stayed span and to move all the structurally necessary mass to the right bank opposite the mass of the cliff. This led to the idea of a single inclined pylon that would correspond to the angle of the inclination of the cliff (Fig 1).

The second basic idea of the conceptual design was to avoid using backstay cables in order to keep the space on the right bank as open as possible, given that is already constricted by the existing road network. The 123,3 m-long main span was designed in steel to minimise weight. This span length and the shape of the pylon made it possible to transfer the forces caused by the cables-stayed main span without recourse to back stays in the back span (Fig 3). If the main span about 15 m longer, the masses and shape of the pylon would not have been so favourable, and with an even longer span it would be necessary to use backstays, and the shape of the pylon would have been different.

The third basic conceptual idea was the balancing of forces between light main span and stiff back span. The shortened back span, with the pylon serves as a statically stabilizing part of the structure. The gentle curve of the main suspended span across the river originates from the structural demands on the back span (Fig 2). The fourth basic conceptual idea focused on the construction method. The back span with the pylon as a fixed part of the bridge was considered from the beginning as an important part of the structure for the method of construction to serve after its erection as the base from witch the remaining superstructure of the main span would be constructed because the only available space for the building yards was on the right bank.

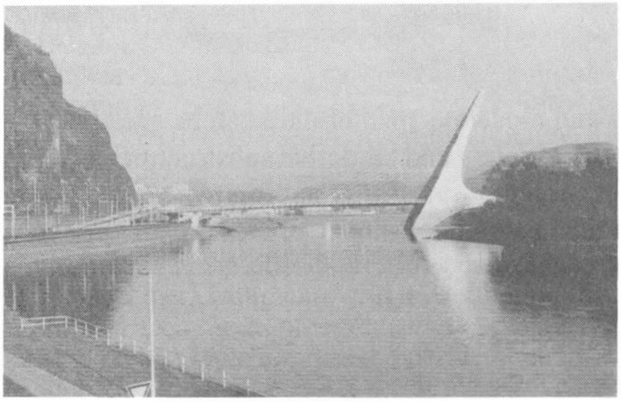

Fig. 1 Longitudinal view

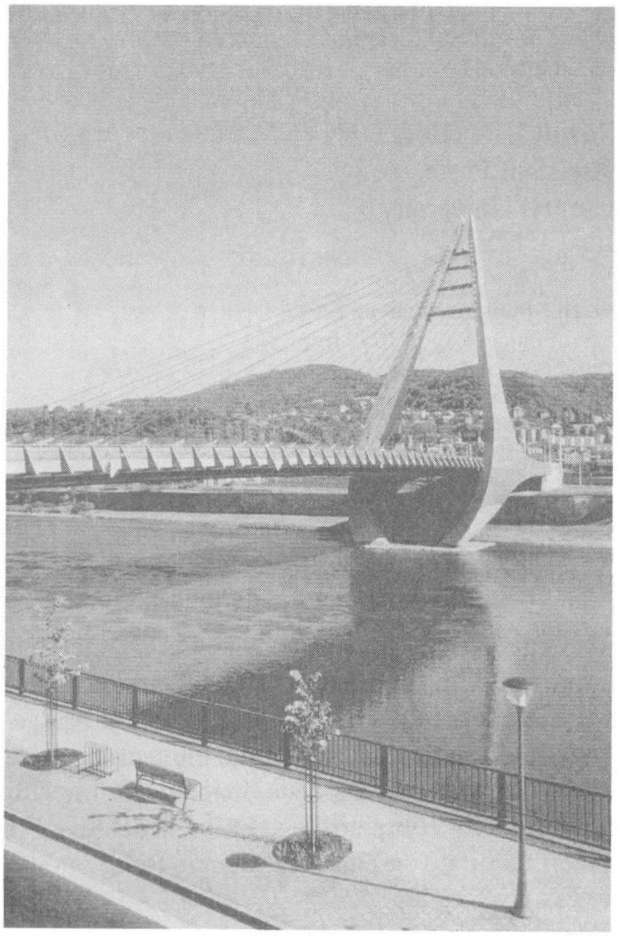

Fig. 2 View from the Marian Rock

2. Conclusion

Bridges are part of the cultural heritage of mankind and are testament to human skill. They were as indispensable in ancient times as they are today. Their shape can be strictly functional, common, or on the contrary, unusual. But the one thing they all have in common is that they are all products of their environment and each shows the specific circumstances and limitations of the time of its creation and the effort and will of the people involved.

In the case of the Marian Bridge it was on one hand the close cooperation of the bridge and traffic engineers with the architect and on the other hand the will of the city to build the bridge, which has next to the medieval castle become a new symbol of the modern era as a part of the environment and everyday life of city residents and its visitors.

Fig. 3 Overall view towards the Marian Rock

Development of a New Substructure System for Standard Bridges

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Abstract

Recognising that the performance of standard short- and moderate-span bridges can be greatly improved with more thoughtful substructure design, an efficient and attractive substructure system has been developed for use with standard bridge superstructure systems. The proposed substructure system of match-cast segmental elements post-tensioned together on site combines prestressing steel with high performance concrete for improved durability and structural efficiency. An economically competitive solution is achieved through attention to fabrication and erection details, which facilitate standardisation and rapid on-site construction.

This paper focuses on the development of a precast substructure system for standard bridges focusing on element shapes, substructure configurations and the construction and erection options. The process of choosing the final system and its details is presented through a review of decisions regarding aesthetic appearance, efficient use of materials and economical construction practice. Particular attention is given to decisions pertinent to potential standardisation of the system with a focus on introducing a creative, economical option.

The process of developing this system is presented to emphasise ways in which creativity can be introduced into standard short- and moderate-span bridge design - a branch of structural design that has stagnated with unattractive results in many parts of the world.

Stainless Steel Structures of Zepter Palace in Belgrade

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Dragan Budjevac, born 1954, received his civil engineering, M.Sc. and Ph.D. degree from the University of Belgrade. He is author of numerous books, scientific and technical papers related to steel structures. He is designer, expert and consultant in steel structures

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Branislav Mitrovic, born 1948, received his architect engineering degree from the University of Belgrade. He is the president of the Serbian Architect Association. He is author of numerous building designs for which he received seventeen awards.

Summary:

Stainless steel has became a trend in architectural detailing of contemporary buildings, because of the progress in metallurgy and structural detailing, but more than anything, as fascination of architects and structural engineers, caused by possibilities of this material. Structures made from stainless steel have to be rationalised, because of high price of basic material. Adequate detailing and emphasising of connections results in special aesthetic effect. This trend, that is present in the whole world during last few years, has been expanded in Yugoslavia, so in Belgrade has been built Zepter business building in King Petar street, which, in an especially attractive way makes affirmation of application of stainless steel in buildings.

Key words: stainless steel, aesthetics, constructions, structural detailing

1 Introduction

The trend which is up-to-date during the last few years in the world hit Yugoslavia so Zepter business building (Fig. 1), which in exceptionally attractive way establishes appliance of stainless steel in buildings, was built in Belgrade in King Peter's street. This street is from architectural inheritance aspect the richest in Belgrade. To build in such environment obligates in lots of ways and forces to think. Great challenge to authors of the building was how to place it into wider context of the street and, at the same time, to fit it to the closest buildings. Authors' determination was to dialogue with the wider context of the street, fitting with the neighbouring buildings, different, height regulations, levels of fascias, and architectural styles.

Architectural solution is inspired by close and distant past, meditation about a wall, Byzantium, monastery complexes and architectural elements such as: second floor porch, knee brace, eaves, etc. Between the two period buildings the new one was inserted in such a way that monolith (the wall) is moved away from its neighbours, so required distance was accomplished and, at the same time building was made self-sufficient. Contact with the neighbouring buildings is made by the means of steel beams - cornice. Basic products of the contractor - Zepter Company are dishes made of stainless steel, which inspired the choice of the material to overbuild weight of the wall. Besides that, style decrees of the buildings on the opposite side of the street from this building and quality of accomplished architecture obligates to dialogue. Repetition as a mimicry doesn't exactly represent dialogue, so architects authors determined architectural details to be made of steel, which was the predominant characteristic of the secession, so trying to materialise common line with the past (or the style transposition).

The building develops itself, widening it's functions towards the depth so making the space for it's internal functions, and the narrow front on the main facade facing the street is portal, a sign of a hand reaching towards passengers. The usual monotony of a glass facades on the backyard part author tried to break by the row of columns to which steel structure to carry the roof footbridge is connected, by means of semicircular end plates and brackets.

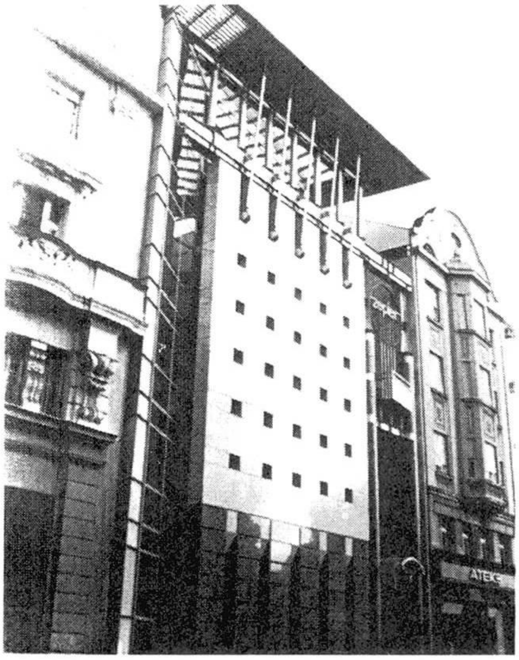

Fig. 1 Facade to the King Peter's street

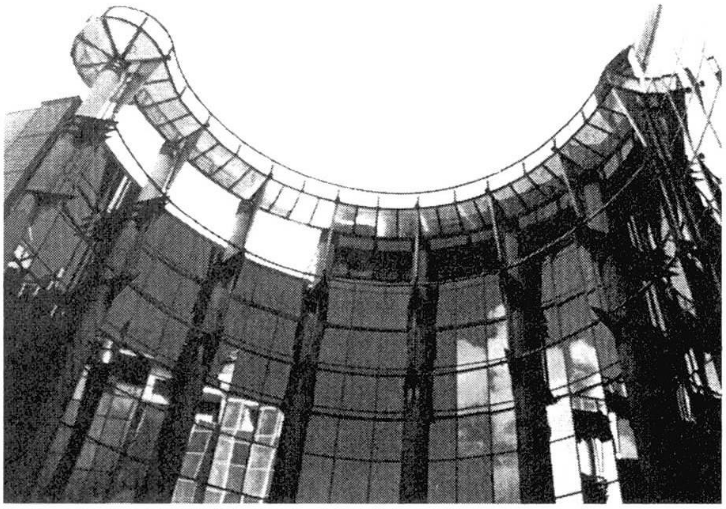

Fig. 2 Backyard facade - curved roof footbridge with transparent grill footpath

2. Stainless steel structures

In this building, which was marked as real top of the world's architecture by the expert opinion and as one of most important buildings of this kind in the twentieth century architecture in Yugoslavia, stainless steel was used in the fascinating way for various parts of load bearing structure. Approximately 30 tones of stainless steel structure was used for: entrance bridge and canopy with portal, balcony, series of columns and girders for carrying roof eaves, structure for stability provision for facade wall, roof lantern, spiral foot bridge, roof with perimeter ring over the stairway, fences and many other parts of interior. Appearances of the main street and backyard facades are given on the Fig. 1 and Fig. 2. All stainless steel structural details were separately analysed and solved in the close co-operation of architect and structural engineer so to gain aesthetically and structurally most suitable solution. Stainless steel structure was manufactured and erected by the BELIM Company of Belgrade. In this paper only some of the most important details are presented.

3. Discussion

Instead of the conclusion a statement can be made that by refined detailing of the structure, no matter classic steel structures or stainless steel structures were in question, outstanding effects can be achieved, of course by close co-operation of architects and structural engineers. That is why it should be noted when structures like this are in question, beside undoubted statically aspect, also aesthetic aspect is important, which is by all means yet another challenge to structural engineers, who have to bear in their minds the ideas of architect and in an adequate way make their visions become reality.

Aesthetics in the Past and the Future of Airship Buildings

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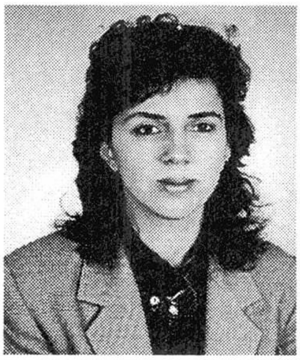

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Summary

Airship buildings are the most outstanding design areas for both architects and engineers. To make a house for an aircraft lighter than air puts some different difficulties in front of the designers, such as always fighting with wind while launching the airship inside the building. For the function of the building requires an empty space inside and because of the huge dimensions of the buildings, the designers are in need of overcoming the structural forces in the economic meaning without losing the elegant appearance of the building. This means that every type of structural form could be used while designing the framework of the building even with ground slab or without. The envelope of the building should be light enough in the meaning of dead load, but also should be hard against bending moments. The gates are from the most important parts of the building. Airship buildings are the important samples which it could be easily seen that aesthetic follows the structural quality.

Keywords: airship buildings, steel structural systems, envelope, framework, airship, aesthetic

1. Introduction

Genius is a word all humans **Love**. This ineffable **Quality**, in an airship building composer, both **Architect** and **Engineer**, ensures entry into the pantheon of the composers of the remarkable buildings in the **Universe**.

During the time, from 1852-the time of the creating of the first airship by Henry Giffard, till now, the structures of the airships have changed from timber via metal to carbon fibre framework.

And parallel to airships, the material for airship buildings changed from timber to steel. In past, some of the airships were used during the war, then they were used for passenger aviation. Now, they are used eg., for environmental friendly transportation of heavy loads and for searching seismic movements in the oceans.

While the construction technology is developing and going forward, the forms and the structures of the airship buildings are being differed.

2.Aesthetics and Structural Quality

Aesthetics and **structural quality** are peculiarly susceptible to the changing demands of space, time and technology precisely because they entail the construction of spatial representations and artefacts out of the flow of human needs.

The only certainty in the future are surprises, some of which will be very surprising surprises. Ultimately, it is likely that the design limits will be set not by the capability of the technology involved, but by the depth of their creative imaginations in the aesthetics and structural quality as it is seen in fig.1.

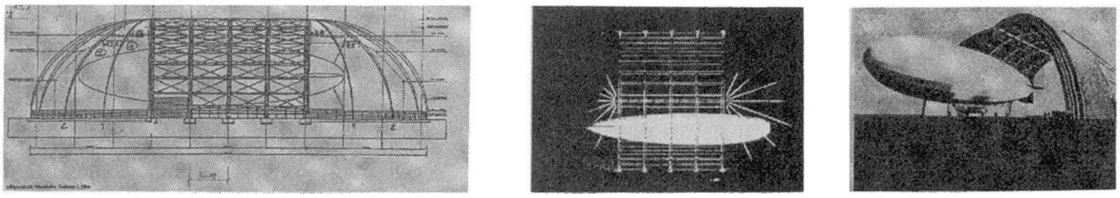

Fig.1 in near future, in Brand(between Berlin and Cottbus) , Germany, the New hall, made of fixed arches with a cross section consists of 4 tubes, with b/h/l-210/ 107/ 340m, steel weight of more than 10 000t.

There is a nice **Harmony** in between the combination of the arch and the tubes of the new hall, which allows a large span of 210m, on one hand side, and the airships on the other.

At the new hall, it is very clear to observe the development of the envelope, from function to aesthetics.

3.and the Conclusion

As a result, while designing of an airship building both with architectural identity and also with engineering identity, the most important point is the Integrity of designs.

From the point of the structure, when it is needed to have large spans, it is always a challenge for engineers, surely more than architects. And the structures of airship buildings are the best examples for this struggling point with the framework.

All of us may agree, much of the excellence of built airship buildings is a tribute not only to their creators but to the Genius of human beings in the universe.

By the way, the structure of an airship building has a chance to present the state of the Art of Structural Quality as Aesthetics.

And perhaps the most Outstanding Design Area for an architect and an engineer to find A Surprise is in the Quality of designing an airship building with the help of contemporary material, Steel.