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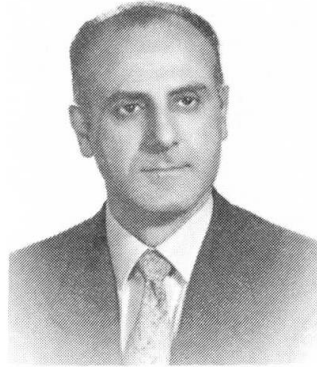
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## A Bowstring Railway Bridge Designed for Durability

Réalisation d'un pont-arc ferroviaire projeté en vue d'une haute durabilité

Eine Eisenbahn-Bogenbrücke, entworfen für hohe Dauerhaftigkeit

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### SUMMARY

The paper describes a railway bridge, overpassing a highway, which serves a new double track railway Udine – Tarvisio, in an area of severe climatic and seismic conditions. The layout is designed mainly to meet the needs of durability and maintenance : structural shape and construction techniques were selected in order to keep concrete mainly under compression and well protected. The construction of the bridge has been recently completed and tested.

### RÉSUMÉ

La contribution traite d'un pont-arc ferroviaire à deux voies, enjambant une autoroute, sur la nouvelle ligne Udine – Tarvisio. Il est construit dans une région à conditions climatiques sévères et situé dans une zone sismique. Le projet est étudié principalement pour satisfaire les exigences de durabilité et d'entretien : la forme et la technique d'exécution sont choisies de façon à solliciter le béton essentiellement en compression et à le protéger des influences climatiques. Le pont vient d'être achevé et soumis à des essais de charge.

### ZUSAMMENFASSUNG

Der Beitrag beschreibt eine Eisenbahn-Bogenbrücke über eine Autobahn der neuen, zweispurigen Verbindung Udine – Tarvisio. Das Bauwerk liegt in einer Erdbebenzone und ist strengen, klimatischen Bedingungen unterworfen. Das Brückenprojekt wurde ausgearbeitet unter besonderer Berücksichtigung von Dauerhaftigkeit und Unterhaltung : durch die gewählte Form und die Art der Ausführung sollte der Beton geschützt und vor allem durch Druckspannungen beansprucht sein. Die Brücke wurde vor kurzem beendet und durch einen Belastungsversuch geprüft.



## 1. INTRODUCTION

The durability of a structural work is generally defined as its ability to resist weathering action, chemical attack, abrasion and other processes of decay.

From a structural point of view, this means the ability to preserve optimum service conditions, during its economical lifetime, without any decay of mechanical and physical properties that would demand expensive maintenance operations.

The principal phenomena related to bridge durability are the following:

- Cracking and porosity of concrete.
- Fatigue of materials.
- Deformability related to dynamic actions.

Thus, to be durable, reinforced or prestressed concrete structures must have:

- Low tensile stresses.
- Compression stresses  $< 0.5 f_{ck}$  under concentrated forces.
- Concrete of low permeability and large steel cover.
- Low deformability under live loads.
- As few as possible factors that can cause impact load, such as structural joints.

Therefore design for durability means to choose structural shape, materials, and construction procedures that reduce or eliminate the phenomena affecting durability negatively, so that maintenance will be unnecessary; i.e. the best way to plan durability is to design structural works with no maintenance needs.

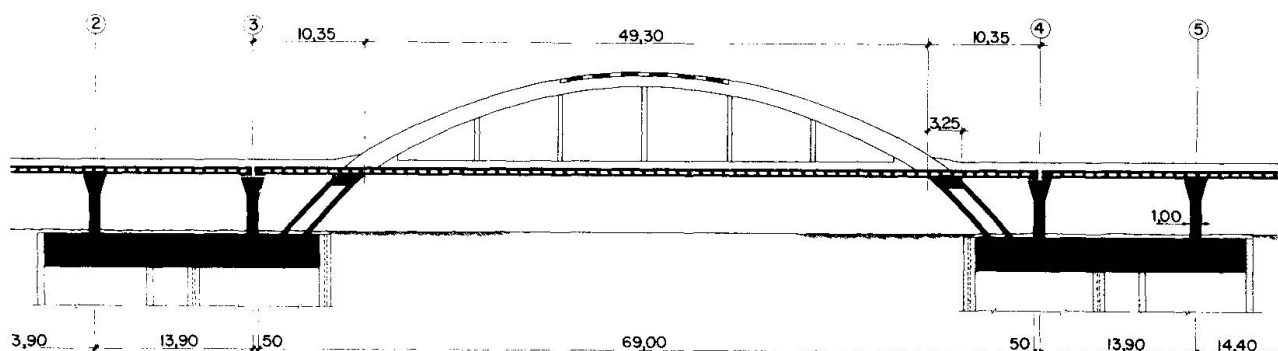


Fig. 1 - Longitudinal section of the bridge.

The bridge, as sketched in figure (1), is a modern interpretation of the classic scheme of a 1930's through arch bridge. Modern because, on one hand, safety and durability requirements are much more strict today than in the past, and on the other, new possibilities are provided by modern concrete and construction technologies, especially precasting and prestressing.

Design layout was devoted mainly to meeting the needs of durability and maintenance. Thus, structural scheme and construction techniques were selected in order to give low deflection and to keep concrete mainly under compression and well-protected.

In fact, arches and deck are composite members of cast-in-situ concrete and well-compacted prefabricated structural moulds, whereas the open surface of the cast-in-situ concrete is protected by layers of waterproof products.



## 2. DESCRIPTION OF THE STRUCTURE

The bridge serves a new double track railway line (Udine-Tarvisio), in an area of severe climatic and seismic conditions.

The bridge has a total length of 70 m and is composed of twin arches, sustaining the deck by means of five concrete hangers each (fig.2). The reinforced concrete arches have a parabolic profile following the dead-load static line. The arch span is 64 m and the rise 15 m. The rectangular arch cross-section above the deck has a constant 1.20 m width, with depth varying from 1.90 m to 1.20 m at the crown. Below the deck, the arches are connected by two flanges, forming a single box element 1.90 m deep and 11.20 m wide.

Over a length of about 15 m the two arches are shearbraced in the crown area by a 0.2 m thick frame which follows the arches' upper profile. See fig. (1).

The deck is composed of: two longitudinal girders lying in the plane of the arches; the transverse track-support slab; cantilevered slabs for sidewalks. Each girder (0.90 x 1.50 m) is prestressed over its full length by four cables of 25 0.6" stabilized strands lying in approximately straight lines; there are also two 'cap' cables, at each intersection with the arches, of 9 0.6" strands. The reinforced concrete transverse slab support has a clear span of 8.9 m. It is made up of an upper and a lower flange, connected by a series of in-situ-poured reinforced concrete ribs (0.35 x 0.45 m) spaced 1.25 m. The lower flange, 0.1 m thick, is made of precast reinforced concrete; the upper one, varying in thickness from 0.15 m

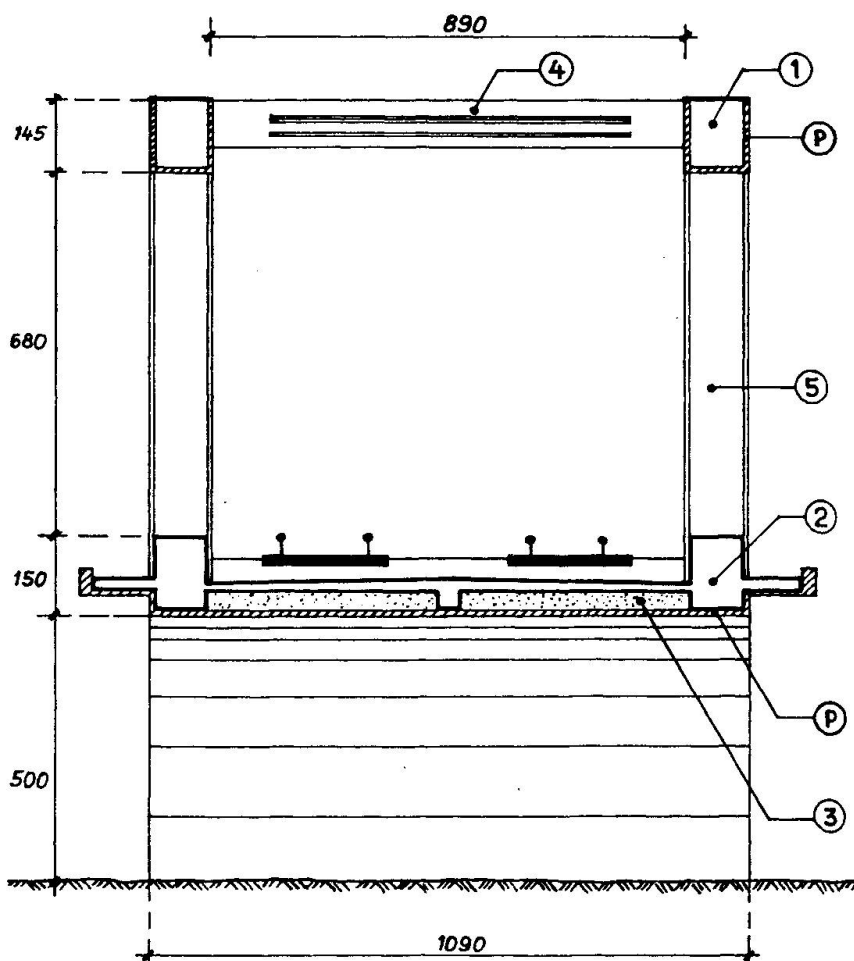


Fig. 2 :

Transverse section

### LEGEND

- 1- Arch.
- 2- Longitudinal girder.
- 3- Transverse track support slab.
- 4- Frame.
- 5- Hanger.
- 6- Prefabricated units.



to 0.25 m, is cast-in-situ. The hangers have a rectangular cross-section of 0.40 x 0.90 m, prestressed by two straight-line cables of 10 $\phi$ 0.6" strands. The caisson type foundations are laid on a gravel bed at 12 m below the site plane.

### 3. CONSTRUCTION PROCEDURES

The cast-in-situ concrete of arches and deck was poured in prefabricated moulds, which also work together to provide structural strength.

Several reasons dictated this choice:

- Durability, since the concrete of the prefabricated moulds, of higher strength ( $f_{ck} > 45 \text{ N/mm}^2$ ) and waterproof, provides high resistance to weathering and therefore a surer durability.
- Perfect finish of the fair-face surface.
- Saving in formwork and scaffolding, further speeding up the work.

The structural elements were built according to the following construction procedures:

- Arch lower part

The box-section of the arches, below deck level, were poured in 0.06 m thick prefabricated moulds.

- Deck

Considering the bridge's low level above ground, scaffolding was not used. An earth embankment was raised and the precast elements forming the lower part of the deck were laid upon it. Polystyrene blocks were positioned on the precast elements to realise the slab's box cross-section.

The reinforcing and prestressing steel was then placed, and the complete deck was poured.

After 14 days of curing, the cables were tensioned.

During this phase structural continuity between deck and arch was effected for one side only, the other being given a temporary sliding bearing. This was done by setting two graphite-clad steel plates below the deck girders and by sheathing the reinforcing bars of the lower part of the arch. Crossing through the girders, these bars would later provide continuity with the upper arch.

This expedient was necessary in order to prestress the deck in isostatic conditions.

Once prestressed, the deck was left free to deform due to creep, shrinkage, and temperature changes, from June, when the cables were tensioned, through October, when temperatures were running below 10°C.

- Arch upper part

The arches were poured in a mould of 0.06 m thick precast plates (fig. 3).

Continuity between the upper part of the arches and the girders was now realised by grouting the sheathed reinforcing bars; the joint between the girders and the lower part of the arches was sealed with high resistance, non shrink, reoplastic mortar. This phase was carried out while temperatures were running below 10°C.

- Hangers

The hangers were poured prior to the upper arches, and prestressed after the arches had been cured. As the cables were tensioned, the weight of the deck began to be shifted from the embankment to the arches. The full weight was transferred when the earth embankment was removed.



#### 4. SPECIFICATIONS

The Railway Administration had laid down the following specific design requirements for durability:

Prestressed elements: no concrete tensile stresses

Reinforcing elements: allowable stress for steel =  $180 \text{ N/mm}^2$

For the maximum service load the design stresses in the concrete and steel of different structural elements were respectively :

- Deck-girder:  $\sigma_c$  min. =  $0.1 \text{ N/mm}^2$  (compression)  
 $\sigma_c$  max. =  $13.8 \text{ N/mm}^2$  (compression)
- Deck-slab :  $\sigma_s$  =  $175.0 \text{ N/mm}^2$
- Arch :  $\sigma_s$  =  $15.3 \text{ N/mm}^2$
- Rods :  $\sigma_c$  =  $2.2 \text{ N/mm}^2$  (compression)

The measured deflection under test with  $440 \text{ kN/m}$  loading resulted:  
 $\delta = 9.1 \text{ mm} = (1/7000)$  of span .

#### 5. CONCLUSION

The structure was designed to meet safety and durability requirements on the basis of prescriptions as to service and use conditions, and, at the same time, to take into account architectural appearance and environmental impact.

Within this overall picture, importance was given not only to construction techniques, careful execution, and proper design of the structural members but , above all, to the structural shape, which governs the structure's behaviour and the stress state of the materials.

Durability, which in a concrete structure is of most concern in the tensile zones, is especially well satisfied. Owing to its shape, in fact , the arch is prevalently under compression, as are the main girders and hangers, due to their being prestressed.

Construction technique and careful execution of the design thus had a greater influence on durability than on safety. In fact, pouring concrete in precast concrete moulds means both a better, more perfectly finished concrete exposed to the weather, and a better-protected reinforcement.



Fig. 3 - View of the bridge.

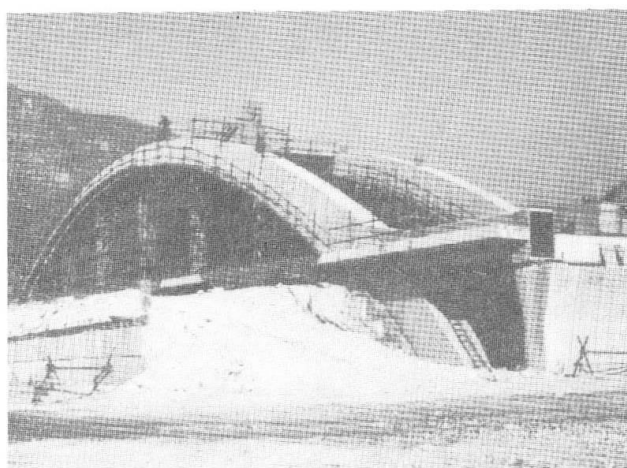


Fig. 4 - Bridge under construction.

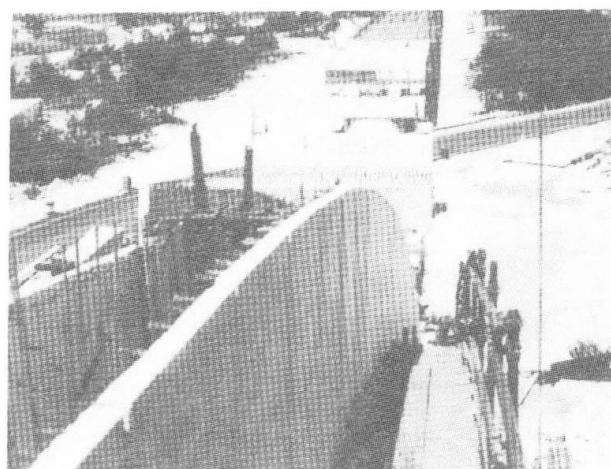


Fig. 5 - Detail of prefabricated units of arch.