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Combined Highway-Railway Bridge with Double Composite Action

Pont route et rail avec double tablier en structure mixte

Strassen- und Eisenbahnbrücke mit Doppelverbund

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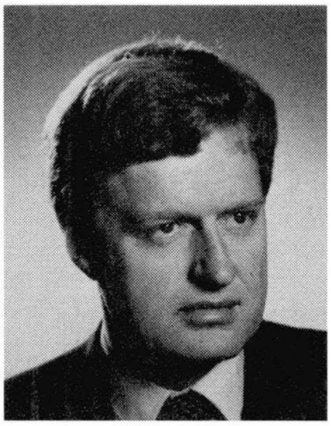
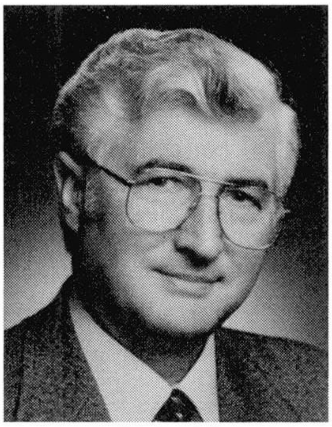


Reiner Saul, born in 1938, Dipl.-Ing. of Univ. of Hannover in 1963. Four years with a steel contractor, since 1971 senior supervising engineer with Leonhardt, Andrä & Partner. He was responsible for the design, technical direction and checking of numerous long-span bridges, also including major rehabilitation works.



Wilhelm Zellner, born 1932, got his civil engineering degree at the University of Vienna, Austria. For two years he was in charge of the supervision of a big prestressed concrete viaduct in the Vienna Woods. In 1962 he moved to Leonhardt & Andrä to Stuttgart and in 1970 he became partner in this firm.

SUMMARY

The Angosturita Bridge in Venezuela carries a single track railway and two carriageways with a main span of 213 m across the river Caroni. The two cell box girder has a bottom chord of steel at the centre, and of concrete at the piers. The roadway slab is non prestressed. Shear connectors are Perfobond strips. The steel structure was assembled behind the abutments and afterwards launched . Before pouring the bottom chord, the tip was lifted so that the weight of the steel structure and of the bottom chord act on the corresponding composite section.

RESUME

Le pont d'Angosturita sur le fleuve Caroni au Venezuela porte une voie ferroviaire et deux chaussées routières avec une travée centrale de 213 m. Le tablier est une poutre à double caisson. Le hourdis supérieur est en béton armé, le hourdis inférieur est en acier en travée, et en béton sur les appuis. Le tablier n'est pas précontraint. La liaison acier-béton est assurée par des connecteurs Perfobond. La structure en acier a été assemblée derrière les culées, et mise en place par poussée. L'extrémité libre du tablier a été soulevée avant le bétonnage du hourdis inférieur, de façon à faire agir le poids de la structure en acier et de la membrure inférieure sur la section mixte correspondante.

ZUSAMMENFASSUNG

Die Angosturita Brücke in Venezuela überführt eine eingleisige Strasse und zwei Fahrbahnen mit einer Mittelöffnung von 213 m über den Caroni. Der zweizellige Hohlkasten hat einen Untergurt aus Stahl im Feld und aus Beton über den Stützen. Die Fahrbahnplatte ist nicht vorgespannt. Der Verbund wird mit Perfobondleisten gesichert. Die Stahlkonstruktion wurde hinter den Widerlagern zusammengebaut und dann eingeschoben. Vor dem Betonieren des Untergurtes wurde die Kragarmspitze angehoben, sodass das Gewicht von Stahlkonstruktion und Untergurt auf den entsprechenden Verbundquerschnitt wirken.

1. INTRODUCTION

Ciudad Guayana, consisting of Puerto Ordaz on the left and San Felix on the right side of the Caroni near its mouth to the Orinoco river, is the Venezolanian centre of heavy industry.

Two road bridges across river Caroni were built in 1964 and 1978 by incremental launching. The increasing traffic required the construction of a third bridge which carries a single track railway and two 10,8 m wide carriageways. Local conditions required a main span of at least 200 m. In view of the local resources, a continuous girder with double composite action proved to be the most adequate solution .

2. DESIGN

2.1 Superstructure

2.1.1 General

The main structure is a continuous beam with spans of 45 - 82,5 - 213,75 - 82,5 - 45 = 478,75 m, Fig. 1. The construction depth of 5 m at ℄ and 14 m at the piers corresponds to slenderness ratios of 1:43 and 1:15 respectively, Fig. 2.

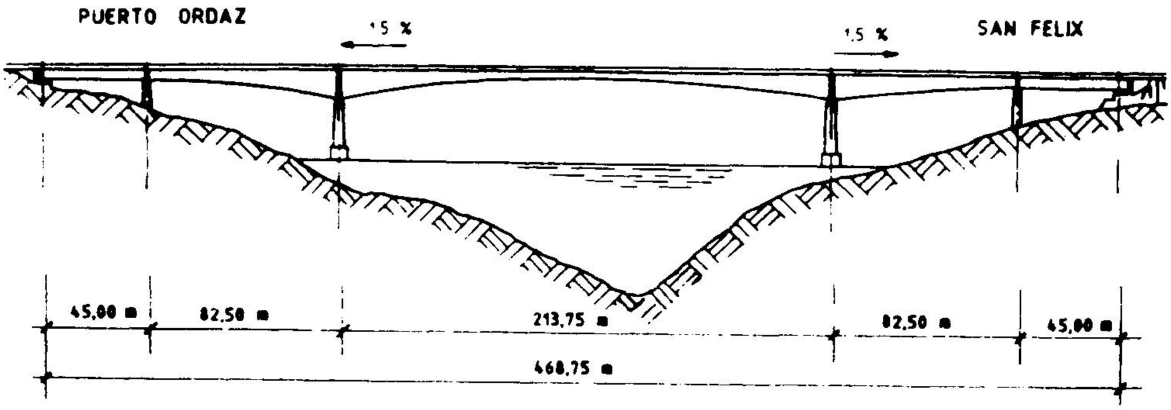


Fig. 1: General Layout

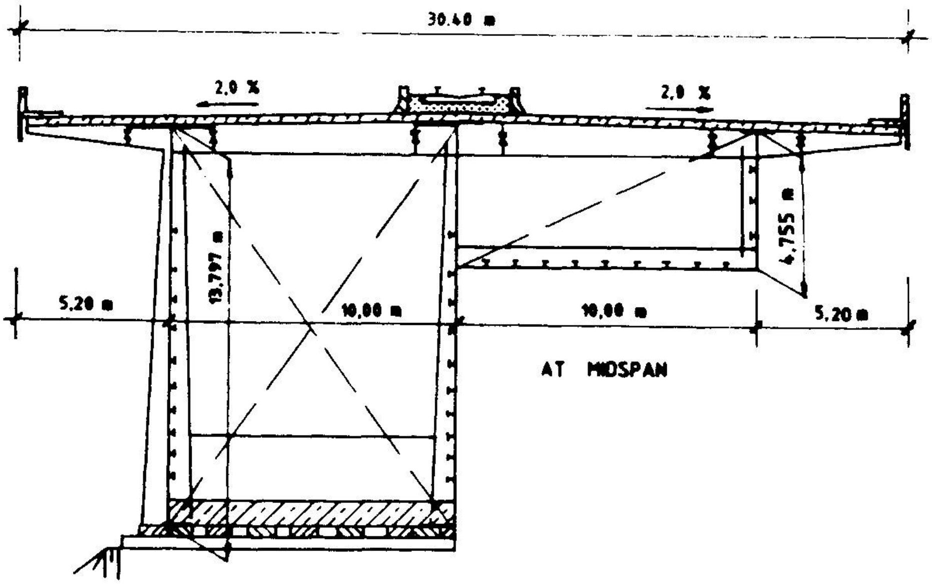


Fig. 2: Cross-sections AT PIER

The cross-section is a two cell box girder in the main span and the long side spans, and a I-beam with 3 webs in the short side spans.

The bottom chord is of steel in the area of positive moments of the main span and in the short side spans, and of concrete in the area of negative moments up to the side span piers.

The top slab is not prestressed, but heavily (up to 4,8 %) reinforced [1], as the big steel top chord required for construction and service stage would make prestressing uneffective.

2.1.2 Steel Structure

The steel structure consists basically of:
- The top chord with dimensions from 600 x 30 mm to 3000 x 80 mm
- The webs, with plate thicknesses varying between 12 mm and 24 mm, stiffened longitudinally by ½I profiles and vertically by welded ⊣ profiles at 3,75 m
- The bottom chord, with dimensions of 750 x 30 to 85 mm in the open part, and a thickness of 12 to 18 mm in the closed part, where it is stiffened longitudinally by ½ I profiles at 1,0 m distance and transversly by welded ⊣ profiles at 3,75 m
- The 0,34 to 1,17 m deep cross girders
- The transverse bracings.

In order to avoid painting of the steel structure, weathering steel, with about 0,3 % copper alloy, was selected.

2.1.3 Bottom Slab

The thickness of the bottom slab varies between 20 cm at the intermediate pier and ℄ and 85 cm at the main pier.

For the dimensioning of the slab, two situations had to be considered: during construction, only the deadweight of the slab is active, while in the final stage the upward deviation forces due to the longitudinal force and the curve of the slab are by far larger than the deadweight.

2.1.4 Top Slab

In order to save weight, the 24 cm thick top slab is supported by steel composite cross girders at 3,75 m intervals. Stresses due to main girder action and local wheel loads had, hence, to be added up. Static and fatigue tests with shear and simultaneous tensile forces showed, that for the given dense reinforcement, the shear strength is much higher than assumed so far [2], Fig. 3.

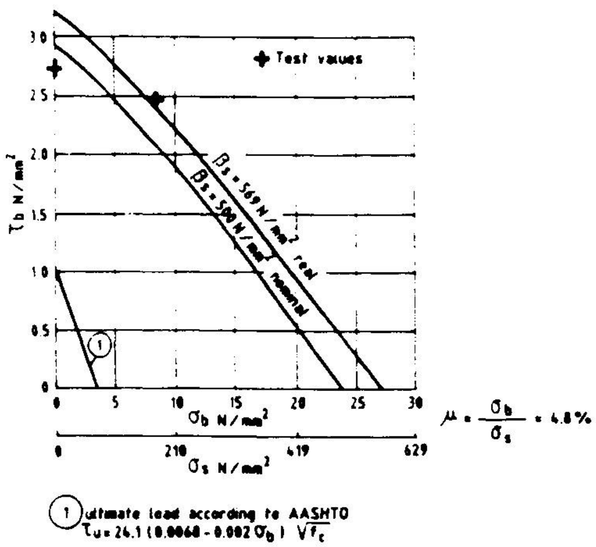


Fig. 3: Shear versus tensile strength

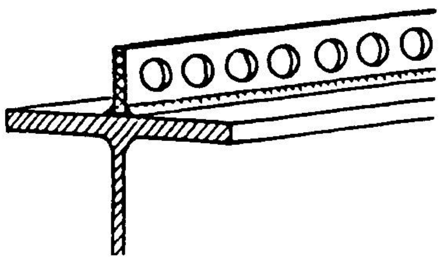


Fig. 4: Perfobond strips

2.1.5 Shear Connectors

The shear transfer between the steel structure and the concrete top and bottom chord is achieved by Perfobond strips, Fig. 4; that is by continuous steel plates ⌀ 70 x 12 with holes ⌀ 35 mm at 50 mm. Numerous tests have shown that these strips have an ultimate capacity of about 1800 kN/m, [3].

2.2 Substructure

The abutments are founded on competent rock. Breaking and friction forces are absorbed at the abutment on the Puerto Ordaz side.

The intermediate piers are hollow concrete piers and directly founded on competent rock. In order to cope with the uplift forces of the bridge deck, they are partly filled with ballast.

The main piers are also hollow concrete piers. They are founded on 6 bore piles ⌀ 2,63 m.

3. SPECIAL ASPECTS OF DIMENSIONING OF THE SUPERSTRUCTURE

3.1 General

The superstructure was dimensioned following the load factor design concept of AASTHO. The section forces and the capacity of the individual sections were calculated in accordance with the elastic-elastic procedure (DIN 18800 Part 1).

3.2 Section Forces and Stress Distribution for Permanent Loads

3.2.1 Section Forces

The deadweight of the load carrying structure was assumed to act onto a girder simply supported at the abutment and the main piers, and with the half main span as cantilever. The superimposed deadweight was applied to a 3 span girder; meaning that with the side span piers were left inactive.

3.2.2 Stress Distribution

The stress distribution of steel composite beams may be influenced, as is known, widely by the construction method, e.g. with or without auxiliary piers.

Here it was assumed, that the dead weight of the steel structure and the concrete bottom chord acts onto the corresponding composite section; and that the weight of the concrete top chord acts onto the section of steel structure, concrete bottom chord and reinforcement of the top slab.

3.3 Live Loads and Load Combinations

3.3.1 Live Loads

For the highway, the tender documents required 30 % higher live loads than AASHTO HS 20-44.

The railway live load was defined as train Cooper 72 according to AREA 1985. With axle loads of 327 kN and a distributed load of 107 kN/m, it is about 30 % heavier than the UIC 71 train.

3.3.2 Load combinations

The load combination followed table 3.22.1A of AASHTO. Governing was load combination I, that is 1,3 x permanent loads + (1,3 x 1,67 = 2,17) x live loads.

4. CONSTRUCTION OF THE SUPERSTRUCTURE

4.1 General

It was planned to erect the steel structure in the side spans on final and auxiliary piers and in the main span by free cantilevering with simultaneous casting of the concrete bottom chord; and to place the concrete top chord from the main piers towards ℄ and abutments.

With the aim of avoiding the welding of the big top chords during free cantilevering, the steel erector proposed to assemble the steel structure behind the abutment and to launch it. In order to come up, nevertheless, with the original stress distribution, a rather sophisticated construction method as outlined hereunder had to be developed, Fig. 5.

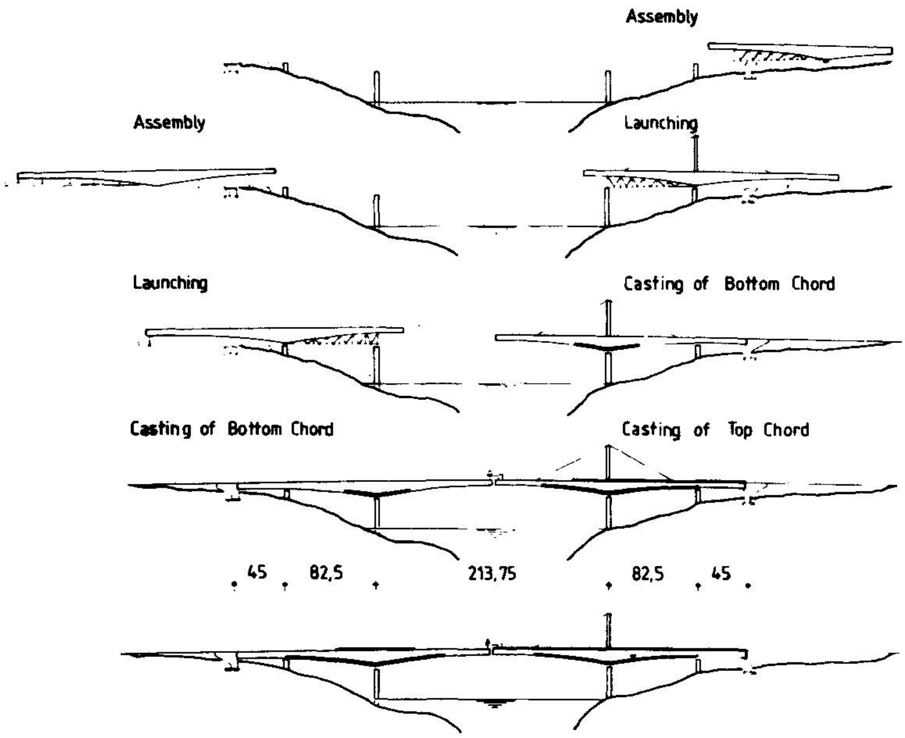


Fig. 5: General sequence of construction

4.2 Launching of Steel Structure

During launching, the rear of the bridge deck was supported by an auxiliary pier fixed to the bridge and sliding on a runway behind the abutment. The main span, instead, was sliding on the intermediate and main piers respectively, with the variable depth of the haunch compensated by an auxiliary truss girder.

During the launching, support reactions were introduced into the steel structures in other places than in the final stage. Positive moments occurred where in the final stage negative moments are predominant. Therefore, detailed checks of stability had to be performed and stiffeners and temporary bracings had to be added.

4.3 Construction of the Bottom Slab

Before casting the concrete of the bottom slab in lengths of about 14 m, the tip of the steel cantilever had to be lifted in order to reduce steel stresses virtually to zero. This was on the San Felix side achieved by an auxiliary stay cable system, and on the Puerto Ordaz side by a coupling device at ℄.

4.4 Construction of Top Slab

On the San Felix side, first the side span was cast from the main pier to the abutment and later - after casting the bottom chord on the Puerto Ordaz side - the main span from the main pier towards ℄ in lengths of about 15 m.

On the Puerto Ordaz side, the top chord was cast alternating in lengths of 30 to 90 m. In order to meet the assumed stress distribution, the tip had again to be lifted prior to casting.

5. ACKNOWLEDGMENT

Owner is the Republic of Venezuela, represented by the Corporación Venezolana de Guayana. Preparation of tender documents, general consultancy for the owner and site supervision was done by Paul Lustgarten y Asociados, Caracas, Venezuela. The design was prepared by Leonhardt, Andrä und Partner GmbH, Stuttgart, Germany, for the superstructure; and Wayss & Freytag AG, Frankfurt, Germany, for the substructure. Main contractor was Precowayss, Guayana, a consortium of Precomprimido, Caracas, and Wayss & Freytag AG, Frankfurt. Steel fabricator was Indùstrias Metalùrgicas Van Dam, Caracas and Ciudad Guayana; steel erector DSD, Saarlouis, Germany, and CGI, Ciudad Guayana.

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