

Zeitschrift: IABSE proceedings = Mémoires AIPC = IVBH Abhandlungen
Band: 7 (1983)
Heft: P-63: Developments in prestressed concrete structures: part II: Journées d'études AFPC-1982

Artikel: Construction of box girders with the help of prefabricated webs
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DOI: <https://doi.org/10.5169/seals-37497>

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Construction of Box Girders with the Help of Prefabricated Webs

Construction de structures en caisson
à l'aide d'âmes préfabriquées

Bau von Kastenträgern
mit Hilfe vofabrizierter Stege

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SUMMARY

The construction of box girders with the help of prefabricated webs and slabs poured in place makes the building of sometimes complex structures possible while reducing the importance of lifting equipment. The bridges of Brotonne, Clichy and Sermenaz illustrate the advantages and drawbacks of this construction technique.

RÉSUMÉ

La construction de structures en caisson à l'aide d'âmes préfabriquées et de hourdis coulés en place permet de réaliser des structures parfois complexes, tout en réduisant l'importance des engins de manutention. Les ponts de Brotonne, Clichy et Sermenaz sont une illustration des avantages et des inconvénients de cette technique de construction.

ZUSAMMENFASSUNG

Der Bau von kastenförmigen Konstruktionen mit auf der Baustelle vofabrizierten Stegen und Verbindungsplatten ermöglicht die Ausführung komplexer Bauten unter Verwendung leichter Hebezeuge. Die Brücken von Brotonne, Clichy und Sermenaz veranschaulichen die Vor- und Nachteile dieser Bautechnik.



FOREWORD

Certain bridge decks having a particularly complex geometry cannot be built by traditional methods. This observation led the company Campenon Bernard to precast the webs and to cast in place the rest of the voussoirs for the construction of the Brotonne bridge and the Clichy viaduct. The same idea was applied by the company Bouygues for the construction of the Sermenaz viaduct.

BROTONNE BRIDGE

This structure is a cable-stayed bridge extended on each end by access viaducts. The deck, having a constant section over the entire length of the structure, was built by cantilevering. It is made up of a box girder with two webs inclined about 50 degrees with respect to the vertical and two rows of inclined struts connecting the base of the webs to the centre of the upper slab (Figure 1).

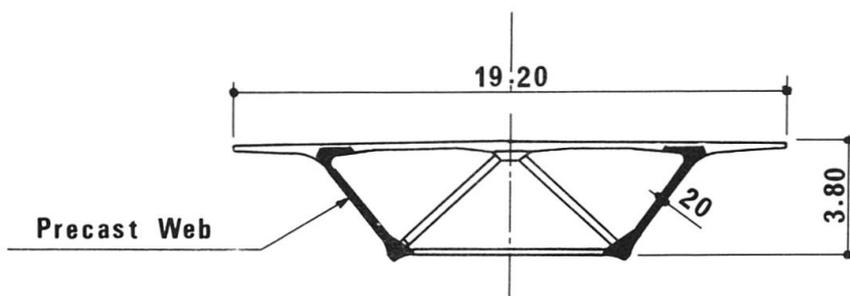


Fig. 1 - Brotonne bridge.
Cross section.

The pouring of the webs in place was practically impossible in view of :

- their inclination
- their thickness (varying from 20 to 40 cm)
- the presence of prestressing ducts.

The webs were poured flat in a precasting area, the rest of the voussoir being poured in place by means of travelling formwork. The webs were prestressed by means of active 4 \varnothing 8 stirrups equipped with ball-type anchors pretensioned on the precasting bench (Figure 2).

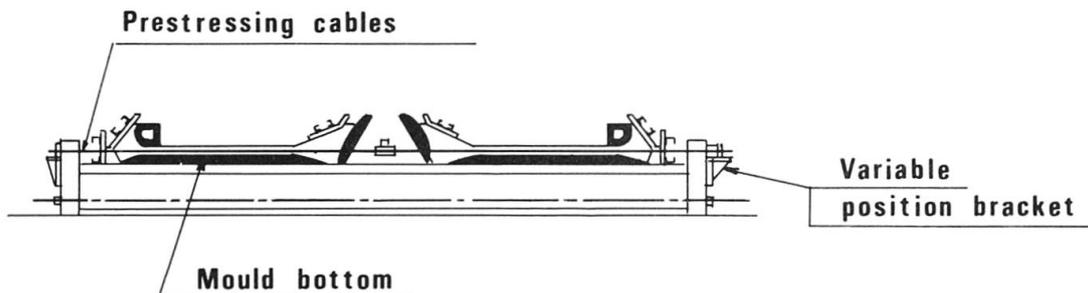


Fig. 2 - Brotonne bridge webs precasting



Photo 1 - Brotonne bridge.
Web reinforcement.

The connection between two webs involved the use of a caulked joint, wrung by compression between the two web ends equipped with multiple keys. Each web was placed inside the travelling formwork (Figure 3), adjusted and lashed on the preceding one by means of prestressing bars and two flat jacks inserted in the joint which was then caulked. After 6 hours of setting, the pressure was released in the flat jacks, causing the wringing of the caulking concrete by compression under the effect of the lashing bars (Figure 4). Once lashed, the webs were secured to the travelling formwork and participated in its rigidity. The slabs were then poured in the usual manner.

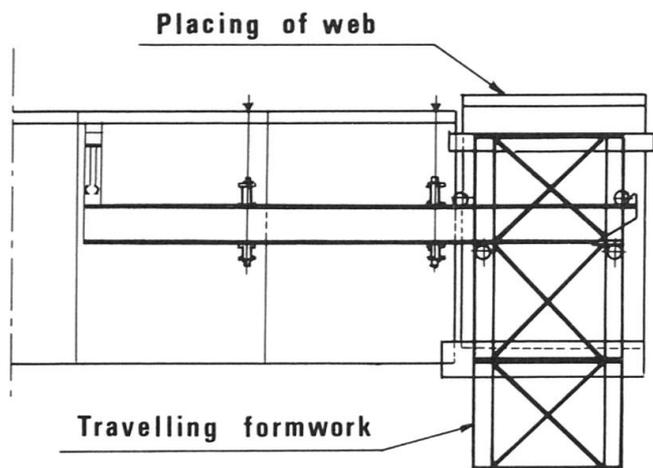


Fig. 3 - Brotonne bridge.
Placement of precast webs.

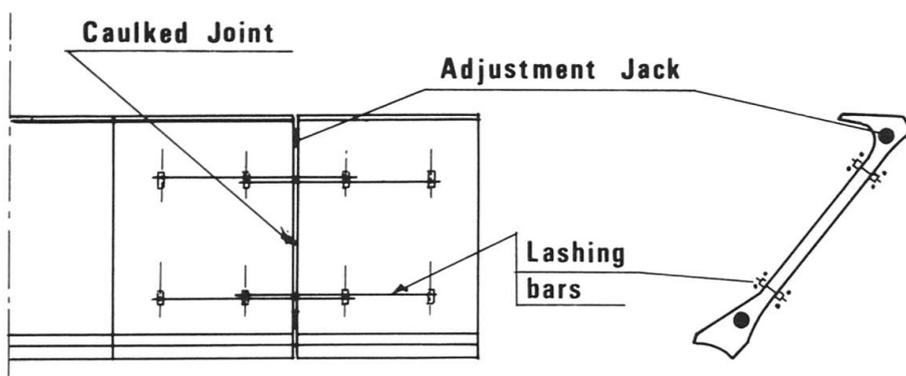


Fig. 4 - Brotonne bridge.
Lashing of pre-cast webs.

R.A.T.P. BRIDGE IN CLICHY

The extension of line No. 13 of the Paris Metro required the construction of a viaduct crossing the Seine at Clichy. The structure, of cantilever construction, has seven spans; the three main spans have a variable height, the other spans have a constant height. The deck is made up of three thick webs connected by two slabs, the upper slab being located 2 m under the upper fibre of the webs (Figure 5). This unusual design was used for three reasons:

- heavy railway loads
- need to lower the longitudinal profile of the track as much as possible while complying with navigation clearances on the Seine
- need to minimize noise, the upper part of the webs acting as an acoustic screen.

The company Campenon Bernard decided to precast the webs and to pour the slabs in place. The webs were poured flat in a traditional cell, the joints being combined with multiple keys. The main construction phases were the following:

- placement and lashing of webs.
- pouring of lower slab.
- pouring of upper slab.

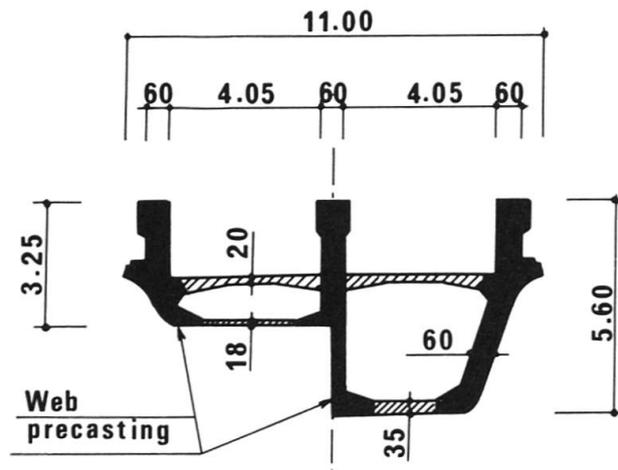


Fig. 5 - Clichy bridge. Cross section.



Photo 2 - Clichy bridge. General view of a pier-head beam.

It was the construction of the on-pier voussoir which constituted the most difficult part of the project. The order of the operations was the following :

- Placement and lashing of six lateral web panels (three on each side) on a metallic scaffolding fixed on the pier head.
- Adjustment of these webs to avoid any divergence either in the vertical plane or in the horizontal plane.
- In place pouring of lower slab, spacer, first section of central web and upper slab.
- Temporary fixing of first voussoir thus completed on pier.
- Placement of intermediate webs and continuation of cycle (the junction between the first precast central web and the part cast in place being provided with a caulked joint).

SERMENAZ VIADUCT

The structure allows the crossing of the Rhône northeast of Lyons by the future A.46 motorway. The structure was designed to carry five traffic lanes. In the transverse direction, the deck is made up of two parallel box girders supporting an upper slab 19 m wide. The company Bouygues proposed the following adaptations :

- Use of a prestressing arrangement located entirely outside the concrete, enabling a reduction of 40 to 32 cm in web thickness.
- Precasting of webs and in-place pouring of slabs (Figure 6).

The choice of a precast-web solution is due to three essential considerations :

- The launching beams used normally for this type of structure are not self-propelled on the slope of 5 % constituting the longitudinal profile.
- It is possible to deliver precast elements to the base of each pier.
- The light weight of the precast webs allows a considerable reduction in the cost of placement and lifting equipment.

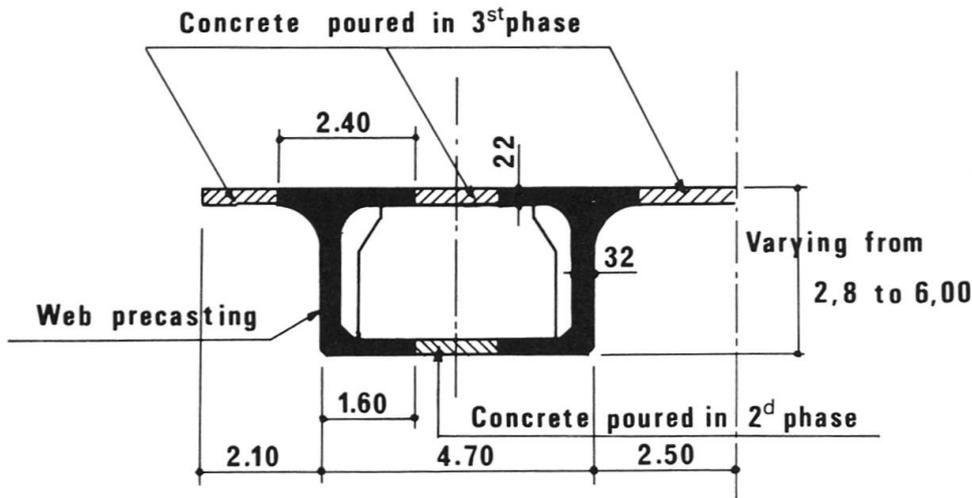


Fig. 6 - Sermenaz viaduct.
Half cross section.

The construction phasing is the following :

- Setup of web elements constituting the two on-pier voussoirs.
- Pouring of lower slabs and spacers.
- Placement of the precast webs of the four voussoirs symmetrically with respect to the pier.
- Casting of corresponding lower slab sections.
- Construction of pier-head beams.
- Casting of upper slab.

The casting of the upper slab, after the complete construction of the pier-head beam, entailed two types of difficulty :

Differential shrinkage - The first studies conducted on the phasing of slab casting and tensioning operations gave the following results, taking into account the worst assumptions :

- The section is entirely compressed without a load.
- Under the combination of the most unfavourable load, there remains a tensile stress of about 20 bars on the over-pier sections of the slab.
- Neglecting the tensioned part of the upper slab in the strength of the structure, the stresses applied to the rest of the structure remain largely within the permissible range.

Construction of open-section pier-head beam - During the construction of a pier-head beam, the resistant section of each voussoir line is an open section assimilable to a U. Finite element calculations using the L.C.P.C. Rosalie program have made it possible to demonstrate :

- that the transverse bending and twisting stresses due to offcentered loads and to the inclination of the voussoirs remain largely within the permissible range,
- that in the most unfavourable case a maximum spreading of 8 mm is observed in the two branches of the U and a relative deviation in the level of 10 mm in the two webs of the same box girder (the inclination of the box girder with respect to the horizontal accounting for about 70 % of the deformations).

In order to ensure the best possible geometry, it was decided to set up temporary braces between the two branches of the U constituting a voussoir.



Photo 3 - Sermenaz viaduct. Precast web of an on-pier voussoir.

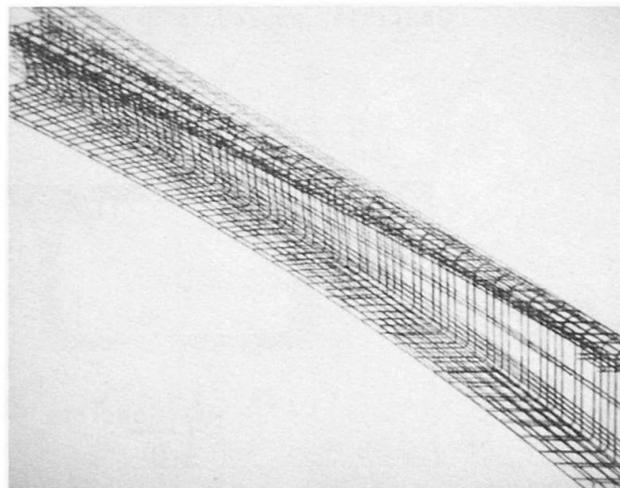


Photo 4 - Sermenaz viaduct. Schematic diagram of a half-beam using finite element analysis and of the deformation curve under offcentered loads.

CONCLUSION

If an attempt is made to assess the advantages and drawbacks of the technique, the following observations can be made :

Advantages

- Very clear reduction in the amount of jobsite equipment required (precasting unit, travelling formwork, lifting equipment). This advantage is illustrated by the following table which compares the weight of a precast web with the weight of the corresponding voussoir.

		Webs	Voussoirs	V/W
BROTONNE	Min.	10,0 t	66,0 t	6,6
	Max.	14,5 t	75,0 t	5,2
CLICHY	Min.	9,2 t	38,6 t	4,2
	Max.	15,4 t	59,0 t	3,8
SERMENAZ	Min.	18,9 t	49,1 t	2,6
	Max.	34,8 t	85,6 t	2,5

- The prestressing cables were tensioned on precast elements, thereby limiting creep and the risk of cracking under the effect of diffusion.
- The continuity of the passive reinforcement in the slabs cast in place improves the tensile strength compared with the same structure precast in a traditional manner.
- Precasting is much simpler because it is possible to easily design self-stripping forms or to provide for flat casting.
- The multiplication of the number of identical parts lowers the profitability threshold of precasting operations.
- The apparent facings are precast, giving improved quality.

Disadvantages

- Complex technique requiring much care and in particular a good geometry.
- The presence of concrete of very different ages in the same section raises calculation problems and requires careful phasing to limit the effects of differential shrinkage.
- Construction is slower than in the case of a traditional precast structure, yet faster than one cast in place.