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Composite Bridges with Corrugated Steel Webs — Achievements and Prospects

Ponts mixtes à âmes plissées — Réalisations et perspectives

Brücken in Verbundbauweise mit Wellstahlstegen — Durchführungen und Perspektiven

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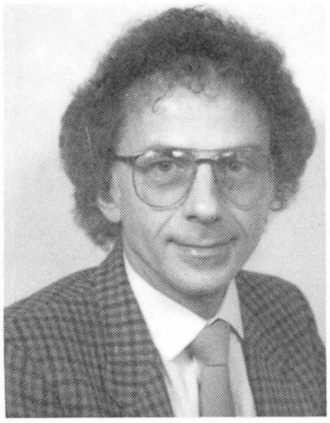


SUMMARY

This paper presents a description of the design studies and the projects that have led to the construction of composite bridge superstructures with corrugated steel webs. Bridges of this type already completed are briefly reviewed and the prospects for further development of this major innovation are discussed.

RÉSUMÉ

Le présent article fait le point sur les études et les travaux qui ont conduit à la réalisation de tabliers de ponts mixtes à âmes plissées. On rappelle quels sont les ouvrages de ce type déjà réalisés et quelles sont les perspectives de développement de cette innovation majeure.

ZUSAMMENFASSUNG

Dieser Artikel berichtet über den Stand der Studien und Arbeiten, die zur Konstruktion von Brückenträgern in Verbundbauweise mit Wellstahlstegen führten. Es werden bereits ausgeführte Brücken dieser Art angesprochen und die Entwicklungsperspektiven dieser bedeutenden Innovation erörtert.

I - INTRODUCTION

More than ten years ago Pierre Thivans (CAMPENON BERNARD) thought to use webs made of corrugated steel plates for prestressed concrete bridge superstructures with box girdered cross sections. After considerable theoritical analysis and model testing several bridges using corrugated webs have been constructed. Through the experience acquired the field of competitivity of corrugated webs has been investigated and more clearly defined.

II - PRINCIPAL ADVANTAGES OF CORRUGATED STEEL WEBS

Corrugated steel webs have been used for prestressed composite bridges with upper and lower slabs in concrete, as well as for conventional composite bridges with steel bottom flanges. Consequently their advantages have to be evaluated either using concrete webs or using flat steel webs with traditional stiffeners.

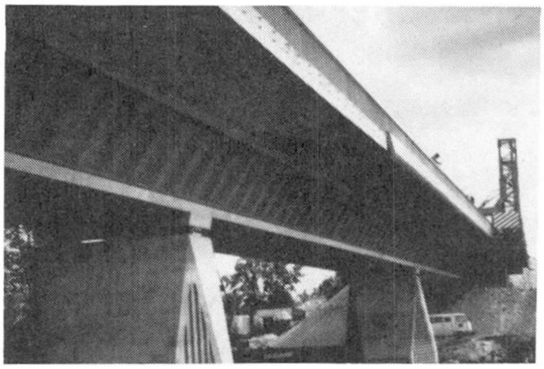


Fig 1 : Cognac Bridge

Compared to concrete webs, the advantages of corrugated steel webs are :
- *Self weight is decreased* thus allowing a lengthening of the feasable maximum span length and savings on piers when they are founded on poor soil or when earthquake is a design criterion.
- *The right material is at the right place* ie concrete to sustain bending moments and steel to carry shear.
- *The elastic lever arm is increased* to its maximum value .
- *The difficulties linked with the casting of deep concrete webs are avoided.*
- *Construction equipment is simplified.* For instance, in segmental construction, the weight of freshly poured concrete for bottom and top slabs can be supported by the already placed web element.
- *Construction pace is faster.* For instance in segmental construction, the cast-in-place box element is approximately three times longer.

Compared to plane steel webs the advantages of corrugated webs are :
- *An important decrease of the web thickness.*
- *Elimination of all the web stiffeners.*
- *Reduction in the number of intermediate diaphragms.* Transverse loads, due to wind pressure for instance, are directly transmitted to the top slab owing to the high inertia of the webs.
- *A much lower sensitivity to premature buckling* because of geometrical defects.
- *Longitudinal prestressing forces are not dissipated into the webs.*
- *Incremental launching of composite bridge deck is possible.*
- *Steel top flanges are considerably reduced.*
- *Three dimensional flexibility* facilitates the construction of curved bridges, it also makes tight tolerances unnecessary for assembling web panels.

III - MAIN PROPERTIES OF CORRUGATED WEBS

A considerable research program has been accomplished since 1980. It has included theoritical analysis, computer analysis and model testing. Part of this program has been sponsored by French Authorities : MRT, ANVAR ,SETRA and LCPC. The outcome of this research work has been that in many respects girders with a corrugated web behave like tradionnal composite structures with orthotropic plates. However the three following specific behaviours have been identified and analysed :

- *Diffusion of concentrated forces* (for instance vertical reaction at an intermediate support of a continuous girder).
  In order to render compatible strains in the steel web and in the concrete slabs , local bending appears in the top and bottom slabs together with vertical forces applying at the slab to web connections.
- *Torsional behaviour* [Ref.1]
  The lack of longitudinal stiffness of corrugated webs induces a torsional behaviour quite different to that observed in traditional box girders (concrete or composite). An external torsional bending moment applied to a box girder with corrugated webs generates horizontal transverse forces applying in one direction to the top slab and in the opposite direction to the bottom slab. Practical effets are the appearance of in-plane bending moment in the slabs, and additionnal torsional shear stress in the webs.
- *Buckling under shear stress* [Ref.3]
  Most of the advantage in corrugated webs comes from their excellent buckling behaviour.
  It is easy to obtain high safety coefficients against buckling at negligible extra costs by increasing the amplitudes of the folds. However for deep webs it has been necessary to investigate buckling conditions more thoroughly.
  The different buckling modes have been identified by computer analysis. Knowing the mode shapes it has been possible to develop analytical formulas giving the critical shear stress for each mode. Finally, tests performed on corrugated panels gave results in agreement with the theoritical analyses.
  Three different types of buckling modes have been identified and calculated :
  . the *local buckling* mode corresponding to the stability of a steel strip simply supported between two folds.
  . the *intermediate buckling mode* characterised by a sudden snap and a non-reversible steel plastification along the folds.
  . the *general buckling mode* similar to the one observed in an orthotropic plane plate .

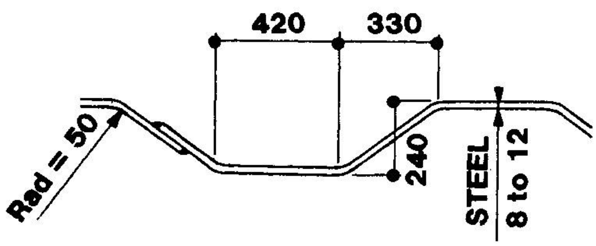


Fig 2 : Typical cross section of corrugated web

IV - EXAMPLES OF BRIDGES WITH CORRUGATED WEBS (Fig.5)

Three bridges with corrugated webs, all designed according different concepts, have been completed. Two others are at the preliminary design stage. A brief description of these projects is given hereunder :

Completed bridges

- Cognac bridge (Fig.1).
The bridge deck is a composite trapezoidal box girder. The longitudinal prestressing external to the concrete is deviated at the diaphragms. The concrete upper and lower slabs have been cast in place on falsework.

- Maupré viaduct at Charolles.
The bridge deck is a triangular box girder. The corrugated webs, which slope at 45°, are welded on a steel tube acting as a bottom flange. This tube is grouted with concrete. Longitudinal prestressing tendons are external to concrete. The construction method was by incremental launching.

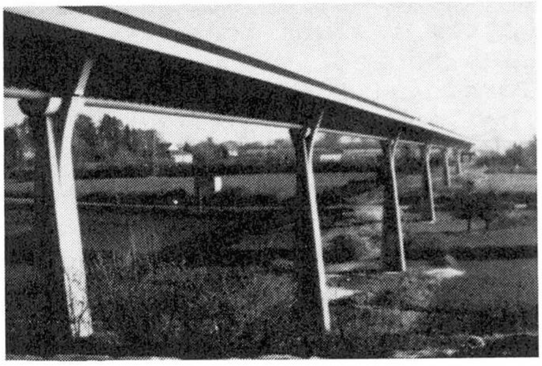


Fig.3 : Maupré Viaduct

- Asterix bridge.

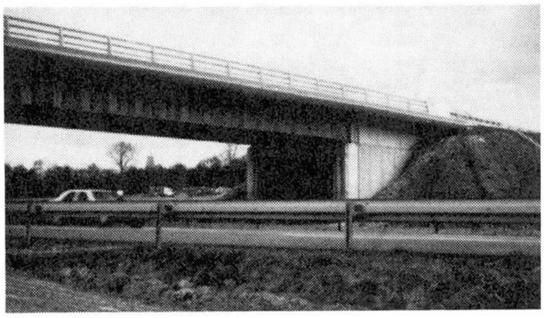


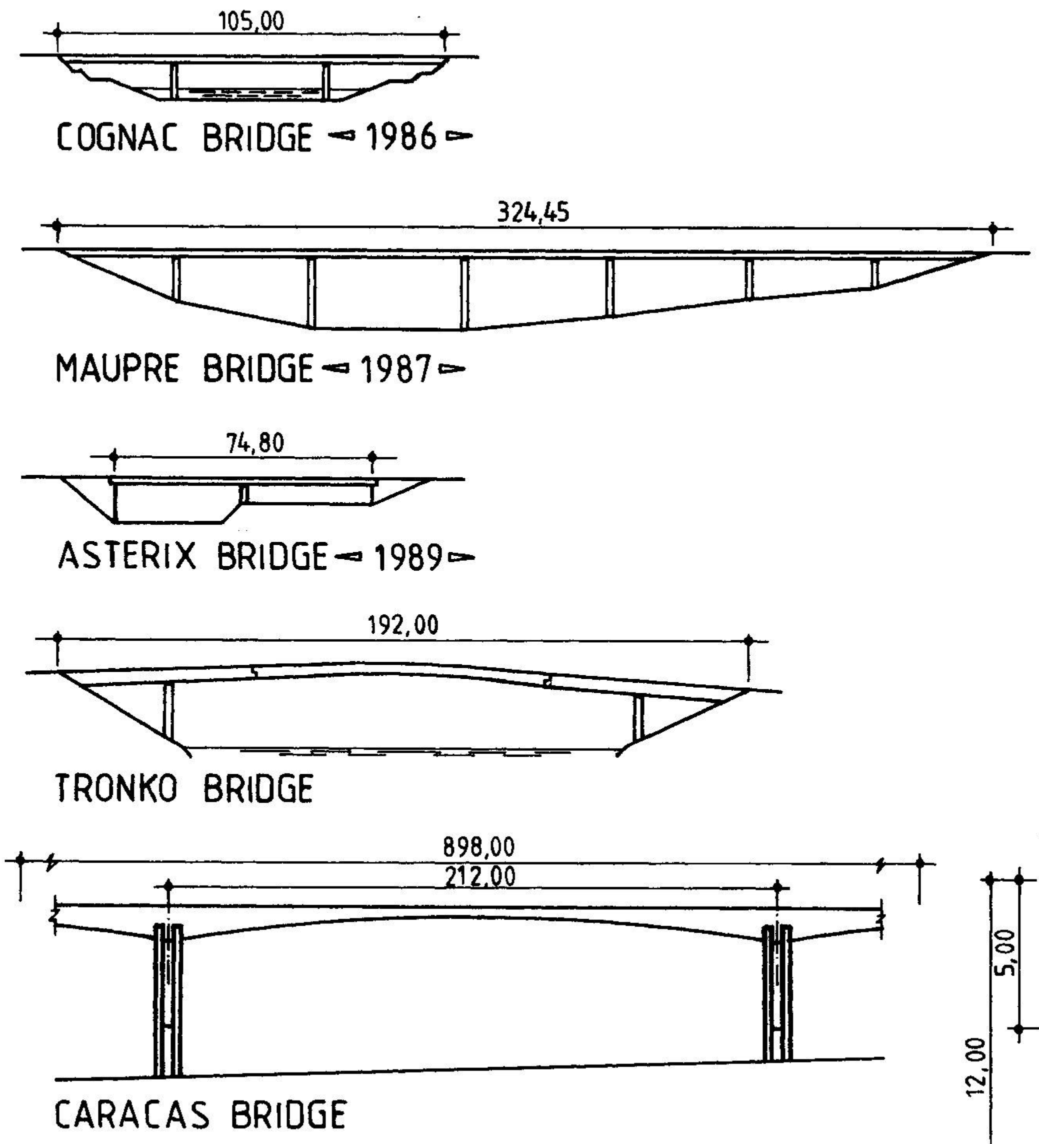
Fig 4 : Asterix Bridge.

The upper slab is stiffened by prestressed transverse girders. The corrugated webs are vertical. Bottom flanges are traditional steel plates. There is no intermediate diaphragm or bracing. The bridge was constructed at the abutment and launched accross the freeway. There was no welding done in situ.

Proposed Bridges

- Tronko bridge - Norway.
The bridge will have two cantilevered side spans with longitudinal prestressing in the top slab, and a simply supported central span. The corrugated steel webs, variable in depths, will be welded on steel bottom flanges. The three spans will be prefabricated. They will be put in place with a large size marine crane. The only works to be done in situ are the casting of the concrete counterweights and the second phase prestressing.

- Caracas bridge - Venezuela.
The bridge will be a composite trapezoidal box girder with a variable depth. The upper slab will bear upon prestressed transverse girders. Longitudinal prestressing will be external to the concrete.
The construction method will be the cast-in-place cantilever method. The bridge is designed against earthquake.



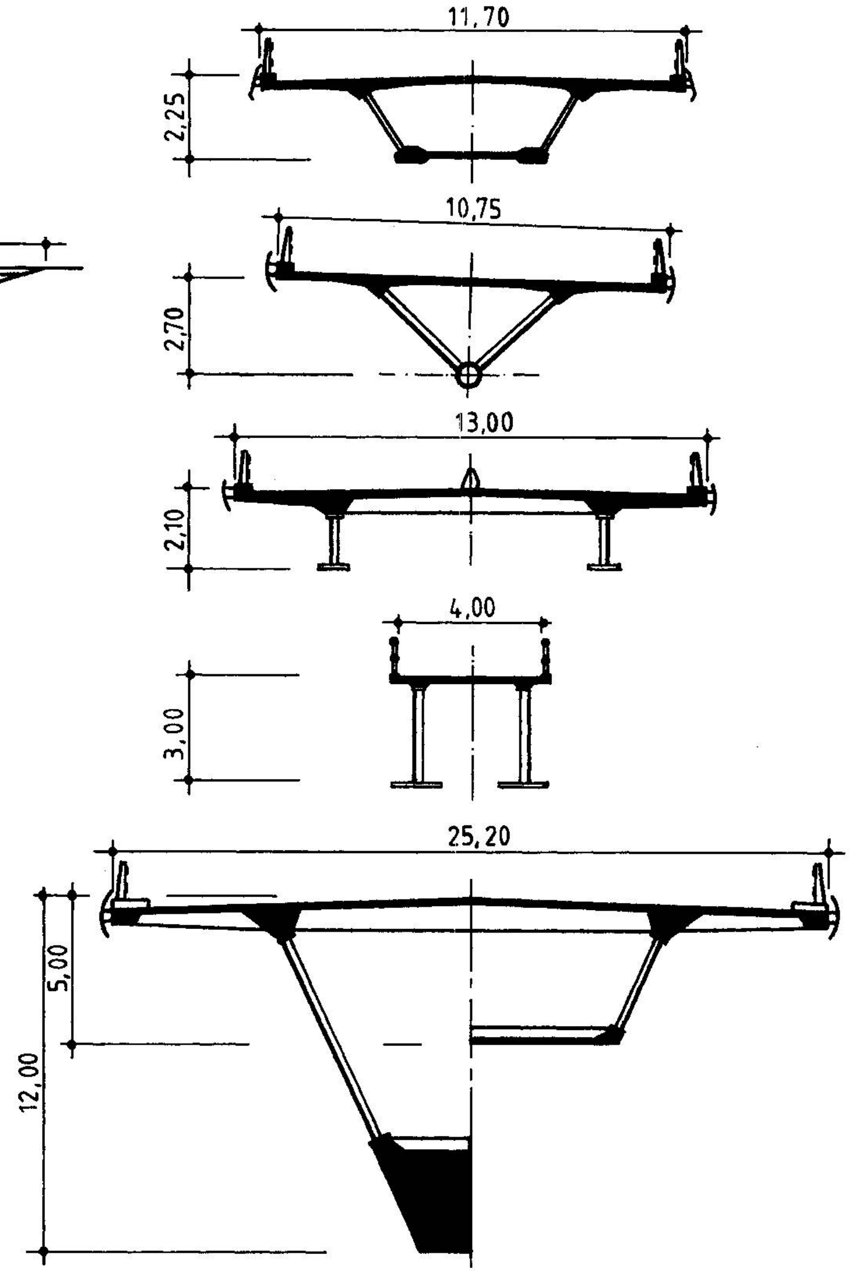


Fig 5 : Examples of bridges with corrugated webs

V - CONCLUSION

The three bridges now opened to trafic were built without any major technical problem, they have been successfully tested and they give full satisfaction to the Owners.

Technical problems regarding design and construction have been overcome and from now on, the change from a conventional design to a corrugated web design should no longer be considered a risky operation.

Concerning the competitivity of such a technique one must consider several aspects : construction cost, construction time, maintenance, aesthetics etc...It seems that two types of corrugated web bridges can successfully compete with traditional designs.

Caracas bridge gives a good illustration of the first type. That is, a bridge with a very long main span, a minimum number of spans and a wide deck. Existence of seismic loads and poor soil conditions for the pier foundations are also factors treated more favorably.

Asterix bridge and Tronko bridge illustrate the other type of competitive solutions for corrugated webs. These are composite bridges with steel lower flanges. For continuous spans the deck may be prestressed. Welding on site must be limited to a minimum. This can be obtained by launching the bridge or by setting it up with heavy handling equipment.

VI BIBLIOGRAPHY

1- Journée d'étude AFPC-ITBTP -CESDA du 28 novembre 1985 : Innovation dans le domaine des structures mixtes. M. VIRLOGEUX, P. THIVANS, B. GODART, J.A CALGARO, M. CHEYREZY, J.COMBAULT, G. CAUSSE - Annales de l'ITBTP - Octobre et Novembre 1987.

2 - IABSE symposium Paris-Versailles - September 2-4, 1987 - Maupré Viaduct near Charolles - G. CAUSSE, M. DUVIARD.

3 - 3ème colloque Génie Civil et Recherche Paris - Juin 1987 - Ponts mixtes - Analyse des conditions de flambage des âmes plissées - M. CHEYREZY

4 - AISC 1988 National Steel Construction Conference - Miami Beach - Florida
The Maupré Viaduct near Charolles - France - J. COMBAULT.

5 - Journées d'études AFPC - ITBTP des 15 et 22 mars 1989 : Le pont d'Asterix, M. CHEYREZY, M. GUICHARD, B. LECROQ, D. DUVAUT.