The evolution of the concrete "channel" bridge system and its application to road and rail bridges

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Summary

In the early 1990s the first precast segmental channel bridge system was developed by Jean Muller in France as a new concrete cross sectional shape for freeway overpasses. One or two span bridges provided a minimum depth solution for spans up to 30 m with only 300 mm between the road surface and the soffit. In the mid-1990s bridges of this type were built in the USA and wider applications were being considered in France with the first channel bridges for rail. In 2001/2002 the first "channel" viaduct, the 460 m Sorell Causeway Viaduct, was constructed in Australia and rail viaducts were under design. This paper covers the history, design and construction techniques for this type of structure which has important advantages to offer for economy, durability and environmental sustainability.

Keywords: channel, segmental, construction; precast; prestressing; concrete; overpasses.

1. Introduction

Jean Muller commenced work in 1989 on the development of the channel bridge which was a logical progression in the use of industrialized overpass structures which started with the AREA (Autoroutes Rhône Alpes) match cast segmental overpasses in the 1970s.

Up until the AREA overpasses, the dominant industrialized or semi-industrialised form of construction had been the pretensioned beam in its various forms. These structures had the disadvantage of second and even third phase in situ concreting for the deck and the footpaths and crash barriers. The slenderness ratios were also relatively large, being generally of the order of 1/16.

The AREA overpasses used the advantages of match cast segmental construction to eliminate second phase concreting on site and developed a family of two span segmental box girders, voided slabs and double Ts, all assembled on site in short time periods using scaffolding, temporary prestress and repetitive procedures. The fully industrialized overpass for spans of up to 30 m was born.

There was, however, a further step to take. The existing overpass systems did not adapt well to high degrees of skew and had relatively deep sections below road level which required high approach embankments. A new section was required. The channel bridge, a variation of the classic through girder, fulfilled the necessary criteria.

2. The "channel" bridge concept

The concept of the "channel" bridge is simple - two longitudinal beams or parapets with a deck spanning transversely between them. It is the previously unrecognised advantages of this through girder section that have made the "channel" bridge such a versatile and important structural form. Figure 1 below shows the first channel bridge, the Champfeuillet Overpass[1], under construction.

2.1. Span and skew variations

The support points are beneath the longitudinal beams each of which acts with a relatively high degree of structural independence and allows varying spans and various types of bridge articulation. Skew is no longer a difficult structural problem as the support positions can be placed appropriately with little other adaptation required.

For two span bridges the structure is fully continuous over the central pier but for multi-span bridges the continuity is limited to the deck slab made flexible with movement joints every four or five spans in what is now the traditional span-by-span segmental configuration.

2.2. Roadway width

Useful roadway width, for two traffic lanes plus footpath space, between the longitudinal beams or parapets, started at around 9.0 m on the first examples but increased slightly to just over 10.0 m in later projects.

2.3. Structural efficiency

From a purely mechanical viewpoint the “channel” - ie an elongated U section - does not appear to be particularly structurally efficient and this is debated in detail in reference #2. It is seen that the other advantages largely outweigh any shortcomings in theoretical efficiency.

Fig. 1 The first channel bridge overpass under construction - Champfeulliet Overpass on the A48 in France

2.4. Advantages of the channel section

There are a number of advantages that combine to make the channel section a particularly useful addition to the range of bridge types. These advantages can be separated into two categories - design and construction.

2.4.1. Design advantages

Minimal effective structural depth with the road surface approx 300 mm above the underside of the bridge

Approach embankments are reduced in height with a consequent reduction of the volume of earthworks or clearances increased. The longitudinal profile of the road can be flattened with improved sight distances and larger radius vertical curves - see reference #3.

Transverse slab design is independent of the longitudinal design provided that the parapet beams are parallel

The section shape with low centre of gravity produces minimal curvature due to temperature gradient and, consequently, minimal effects from temperature induced hyperstatic moments on continuous bridges

Highly skewed supports are easily accommodated

The parapet beams serve as integrated crash barriers which are particularly robust and of above normal height therefore increasing containment and effectiveness

Possibility of lateral footpaths outside the roadway zone; this provides high level protection for pedestrians and a potential location area for utilities that can be easily accessed for maintenance

2.4.2. Construction advantages

Elimination of second phase in situ concreting

Elimination of third phase in situ concreting for the crash barriers and associated superstructure elements (footpaths, kerbs etc)

Use of match cast segmental construction for the superstructure and precasting for all substructure elements means that the structure can be virtually constructed off site and off the critical path for construction

Erection methods can be easily adapted for safe and rapid construction over existing roadways by having the support beams within the depth of the parapet beams and therefore not encroaching on traffic clearances - see the left hand photo in Figure 2 below. The ideal erection method is to have the segments supported under the parapets/webs - see the right hand photo in Figure 2 below.

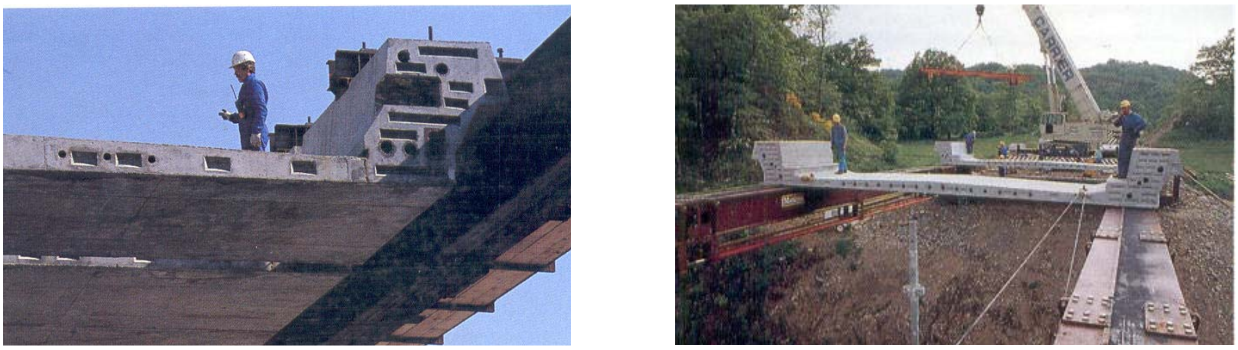

Fig. 2 Erection of segments using lateral support beams or under deck beams

3. Evolution of the structure

Over the decade since the Champfeuillet overpass was built[1], there has been an evolution of the cross sectional shape and also in the way in which the deck slab is configured and prestressed. An early paper[4] described the essential features of the first examples of the channel bridge.

Figure 3 below summarises of the evolution of the cross sections over the past 10 years.

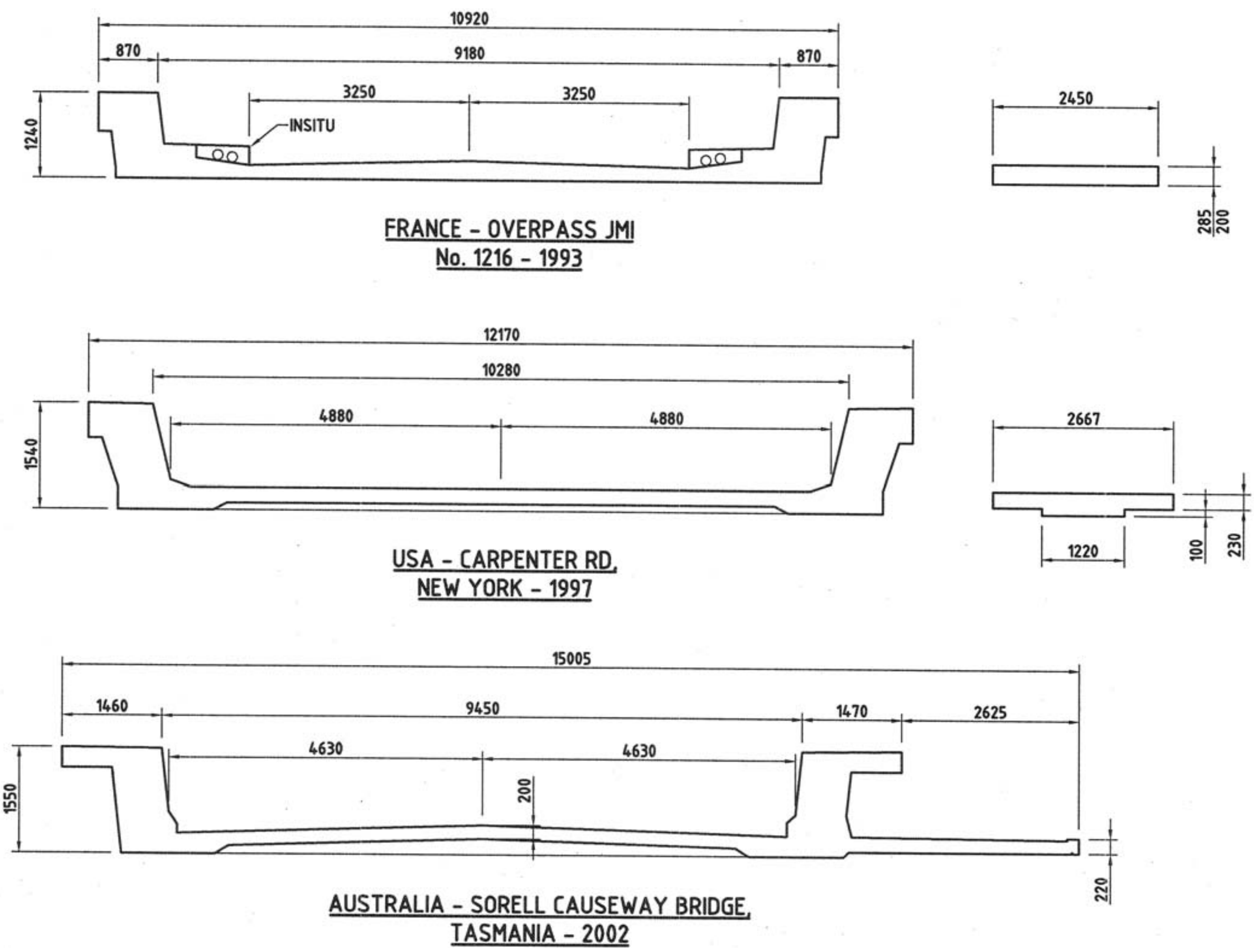

Fig. 3 Evolution of channel bridge cross sections from 1993 to 2003

In the mid-1990s there was an extensive research evaluation programme carried out in the USA by the Highway Innovative Technology Evaluation Centre[5]. This work included diagnostic load testing of completed bridges and confirmed the predicted behaviour of the structures.

The principal evolutionary steps have been the change from a solid deck slab to a ribbed profile; the subsequent replacement of the monostrand transverse prestress by multi-strand tendons and the placement of the footpath on the outside of the structure. Between 2001 and 2003 the Sorell Causeway Viaduct[2,3] was designed by GHD and built by John Holland Construction in Australia. This bridge incorporates all the main evolutionary features of the channel bridge and at 460 m in length became the first channel bridge viaduct built anywhere in the world. It was designed to draconian durability criteria, being situated in a marine environment, and used precast elements for all parts of the structure - pile caps, piers and deck. Figure 4 below shows some views during construction.

The erection system for the Sorell Causeway Viaduct had some unusual features - segment placing by 150 t crawler crane sitting on the bridge deck already erected and segment support under the deck slab rather than under or on top of the parapets/webs. These two features combined to make construction the most severe design load case for transverse flexure and other local effects. They also affected the construction sequence in that the transverse prestress could not be tensioned in the storage yard but only after completion of the longitudinal post-tensioning and seating on the permanent bearings.

Fig. 4 Sorell Causeway Viaduct under construction in Tasmania, Australia

4. Rail bridge applications

In the rail industry the through girder bridge, principally in steel, has been a common feature of rail infrastructure. A more refined approach using the channel bridge concept is making its appearance in France and in Australia. One important advantage of the concrete channel bridge is the integrated provision of acoustic barriers which are now becoming mandatory in urban areas.

In France, the specialist rail consultant, Systra, has developed a channel type bridge constructed using a combination of precast and cast in situ elements. Its first application was the 5.6 km Line 5 viaduct of the Santiago Metro in Chile which was successfully completed in 18 months.

The Wodonga Rail Bypass project in Australia will use a simplified channel bridge concept with both viaduct and two span overpass structures. Figure 5 shows the bridge cross sections proposed for the Wodonga Rail bypass.

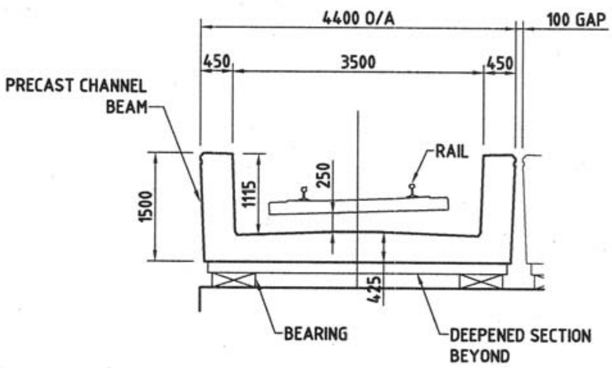

Fig. 5 Cross section for the Wodonga Rail Bypass bridges in Australia

5. Commercial and proprietary aspects

The channel bridge concept is covered by patents in the USA and in Europe with Jean Muller International and Freyssinet being joint holders. A licensee, Bridgetek, offers the system in the USA and precast products specialist Matière has produced channel bridges under license in France.

6. Economy and sustainability

6.1 Unit quantities

Early examples of the channel bridge had typical unit quantities of the order of

- Concrete 0.45 m^3/m^2
- Post-tensioning 95 kg/m^3
- Passive reinforcing 105 kg/m^3

6.2 Construction costs

Costs per square metre for completed bridges have progressed from approximately US$1100/$m^2$ in 1993 to approximately US$1500/$m^2$ in 2002.

6.3 Whole of life performance

The excellent durability and low maintenance profile of this type of structure has been recognised by the State Government of Tasmania, Australia, in choosing the channel bridge alternative for the Sorell Causeway Bridge as a more sustainable and low environmental impact solution in preference to the more traditional forms of construction.

7. Conclusions

The segmental channel bridge has now been in use for 10 years but its inherent advantages are only just beginning to be fully understood. As each new bridge is built, new advantages are being revealed which add to the value of the channel bridge as an industrialized and innovative solution to many more bridge problems than its initial purpose as a freeway overpass.

8. Acknowledgements

The authors would like to acknowledge the encouragement and assistance of Freyssinet in France, Austress Freyssinet and John Holland Construction in Australia and especially the vision and creativity of M. Jean Muller whose work continues to provide inspiration to us all.

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