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# Precast Concrete Integrated Deck System for Highway and Railway Bridges

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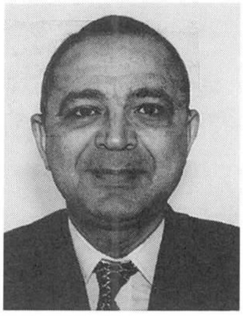

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## Summary

The aim of this paper is to share information and design experiences gathered by the authors relating to the use of integrated deck system for highway, railway and pedestrian bridge superstructures. Instead of a comparison between different codes, a number of selected projects dealing with either the North American Model or the Asian Model and involving the use of high-performance concrete are presented. Each case study discusses the rationale for selecting the structural system over other alternatives. After model restrictions have been taken into account, the final selection of a particular structural type usually hinges on economic factors.

## 1. Introduction

The first precast prestressed concrete Railway Bridge was constructed in 1954 for the Chicago Burlington and Quincy Railroad, Missouri. Since then, many short and medium span bridges constructed by using prestressed precast concrete girders have been successfully built in North America [1,2]. Many prefabricated elements and systems have been standardised for integrated deck bridge construction. These prefabricated elements and systems can be used with less disruption at the job site, can reduce much of the environmental impact in the surrounding areas during construction, can reduce design effort, and can speed up field construction, saving time and cost. Details regarding the different standard elements can be found elsewhere [3,4].

In recent years, the accelerated deterioration of bridges and the cost of their repair and rehabilitation have been become a major concern. Many steel bridges in South East Asia were constructed in the last decades under European standard specifications. Regional social culture and other environmental parameters have created geographical "corrosive areas" within which these specifications have proven sub-optimal when considering the life-cycle cost of the bridge. On Java Island, Indonesia, the primary concern for the railway bridge superstructures is the deep corrosion in many steel bridge decks that result from exposure to human waste and from insufficient routine maintenance.

Through his recent experience with the government-owned Indonesian Railway System, the first author suggests an optimised methodology for bridge superstructure replacement and the construction of new short and medium span bridges in corrosive areas. This involves the construction of prestressed precast high performance concrete girders. The durability of the material and the reduced erection time provide economical benefits.

This state-of-the-art design is based on an integrated deck system for highway, railway and pedestrian bridge superstructures. This calls for the use of prestressed precast high performance concrete solid slab, channel sections, hollow box girders or Bulb-Tee girders, for spans ranging from 7 to 35 meter long. The compressive strength of high performance concrete ranges from 50 to 70 MPa. Details concerning these alternatives and the use of precast concrete slabs with ballasted deck on steel railway bridges are given in this paper.

## 2. Case Studies

Some projects involving the use of precast high performance concrete integrated deck systems, which are familiar to the authors, are selected. These projects are used to illustrate different factors, which have influenced the use of the structural system for economic reasons. In each case, a general description that touches, among other things, the suitability of using high-performance concrete for that particular application is given. The selected case studies, which are considered under either the North American Model or the Asian Model, are described hereafter.

### 2.1 The North American Model

*2.1.1 Example 1 – Roadway Bridge*

In 1992, an existing short-span bridge located in St-Eustache, Qc, Canada, was evaluated. The original bridge consisted of a steel beam girder with a cast-in-place concrete deck slab. The steel beams showed signs of significant corrosion and the deck slab had suffered deterioration. An evaluation and bridge rating procedure was carried out and it was found that the deterioration was such that the bridge would either have to be posted, rehabilitated or replaced. Because of the repair costs together with the short future life of the original bridge, it was determined that it was more economical to replace the bridge superstructure.

Two alternatives, a composite steel girder superstructure and a precast pre-tensioned girder superstructure, were studied. The precast pre-tensioned girder solution utilised high-performance concrete in the girder and was the more economical solution. One of the key features in the economical study was the extended life of the high-performance concrete used to construct the girders [5].

Fig. 1 shows the cross section of the final solution. The bridge spans 17 m centre-to-centre of bearings. The girders are supported on neoprene bearing pads. The channel-shaped girders each contained 24 – 15-mm pre-tensioned strands that had straight tendon profiles. Diaphragms were placed over the supports only. Each channel-shaped girder is 950 mm deep and 1200 mm wide. The surface created by placing the girders side-by-side eliminated the need for formwork for the cast-in-place deck slab. The concrete for the precast pre-tensioned bridge girders had a specified 28-day compressive strength of 70 MPa. It is important to note that the structural design of this bridge did not require a high-performance concrete. The stresses in this short-span bridge were well within acceptable limits, even with normal strength concrete. The reason for using the high-performance concrete was to improve the durability and therefore extend the expected useful life of the bridge.

The deck slab had a 28-day specified compressive strength of 30 MPa. The deck slab was made composite with channels by roughening the top surface of the channels during casting and by providing small shear keys in the corners of the precast channel members. A waterproof membrane was applied to the top surface of the deck slab before asphalt was added to the surface.

### *2.1.2 Example 2 – Pedestrian Bridge*

In 1992, an existing pedestrian bridge, crossing a six lane highway (3 lanes in each direction plus a central median and 2 shoulders), was examined in Laval, Qc, Canada. The original concrete pedestrian showed signs of significant concrete deterioration and reinforcement corrosion. A decision was taken to replace the bridge and precast elements solution offered the most economical solution.

Fig. 2 shows the cross section of the new pedestrian bridge made with high-performance concrete. The bridge spans 35 m centre-to-centre of the neoprene bearings. The cross section consists of two Z-shaped precast girders with the shape providing a bottom ledge for supporting the precast panels for the deck slab. Each of the Z-shaped girders was pre-tensioned with 40 – 15-mm diameter strands. The depth of the precast pre-tensioned girders is 1370 mm and the widths are 250 mm. One of the key features of the design was the need for rapid erection to cause the least amount of disturbance to the traffic flow under the pedestrian bridge. The girders were erected in one evening to limit the disruption of traffic. The Z-shaped girders are structurally interconnected at both supports and at midspan by casting concrete in 300-mm thick reinforced concrete closure strips. These closure strips produce a U-shaped cross section at these locations and serve as structural diaphragms. The diaphragms served to connect the girders to enable sharing of vertical loading and to interconnect the Z-shaped girders to aid in resisting torsion.

The precast concrete panels were pre-tensioned with 13-mm diameter strands and were supported by the lower ledge of the girders. A latex modified concrete was cast-in-place to form the wearing surface of the bridge deck. The specified 28-day compressive strength of the concrete for the girders and the panels was 70 MPa.

### *2.1.3 Example 3 – Railway Bridge*

The bridge is located at mileage 40 of the Drummondville subdivision, Qc, Canada, over the main line of the Canadian National (CN) Railway [6]. During periodic inspection of the structure, it was found that the open-deck bridge steel span, built originally in 1914, had become badly corroded and that immediate replacement was needed. The substructure, which consists of stone masonry abutment and wing-walls, was found in a good condition.

To promote competition and to achieve the most-cost-effective solution, two structure types were designed and tendered. The first alternative was a steel deck plate girder (DPG) span with a ballasted precast prestressed concrete deck slab (Fig. 3). However, CN Rail awarded the job to the lower bidder, who submitted a quote on the second alternative, which consisted of precast prestressed concrete box girders. Besides a substantial economy in the basic cost and long term maintenance costs, the choice of precast prestressed concrete boxes allowed a more shallow structure that if the steel girder were to be used, a choice which proved to be very helpful in improving a restricted vertical clearance.

The single-span simply supported bridge spans 23 m, and it is designed for Cooper E-85 Railroad Loading. It is the longest precast prestressed span ever used by CN Rail. It is composed of 4-precast box girders (Fig. 4). Each girder is 1.70-m deep and 0.90-m wide, with transverse diaphragms at the fifth points. The girders were tied together by using 26-mm diameter DYWIDAG thread bars having an ultimate strength of 1034 MPa at diaphragms location, to carry a load of 240 kN each after seating of anchorages. After the transverse tie assemblies were in place, the anchors were grouted with non-shrink grout.

Each box girder was provided with 50 pre-tensioned 15-mm diameter stress-relieved strands having an ultimate tensile strength of 1860 MPa. The centre of gravity of these strands was set to be 330 mm from the bottom. In order to prevent tensile cracks at top of girder, caused by camber at release, the effective prestressing force had to be reduced. This was achieved by debonding 18 stands for a determined development length $l_d$ where:

$$l_d = \text{Transfer Length} + \text{Flexural Bond Length}$$

### 2.2 The Asian Model

Through a World Bank funded Railway Efficiency Project for the Indonesian State Railway (Perumka), a bid package has been prepared in 1998 for the construction of several bridges in the double track section between Giganea and Sukatani corridor at central Java. Prestressed precast concrete girders, integrated system, have been proposed at the designated "corrosive areas" zone. Three different ballasted deck girder types were designed, according to their span length.

- Type 1: Prestressed Precast Concrete Box-Type Girder for span lengths of 16 to 19 m (See Fig. 5).
- Type 2: Prestressed Precast Concrete Channel-Type Girder for span lengths of 10 to 15 m (See Fig. 6).
- Type 3: Prestressed Precast Concrete Bulb-Tee Girder for span length of 20 m (See Fig. 7).

For these cases, the Railway bridge Live Load is in accordance with the Indonesian Load Scheme 1921.

## 3. Concluding Remarks

Premature deterioration of bridges has become a major problem in the last 30 years. The use of standard prestressed precast concrete integrated deck as a replacement of older superstructures or for new constructions offers an attractive alternative to insure a long-term durability especially in corrosive environment. It allows also achieving substantial economy, by minimising the disruption of traffic during construction. Furthermore, the use of high-performance concrete will allow the design of smaller sections, and with its low permeability and higher strength should result in improved durability and hence extended service life for bridges.

## 4. References


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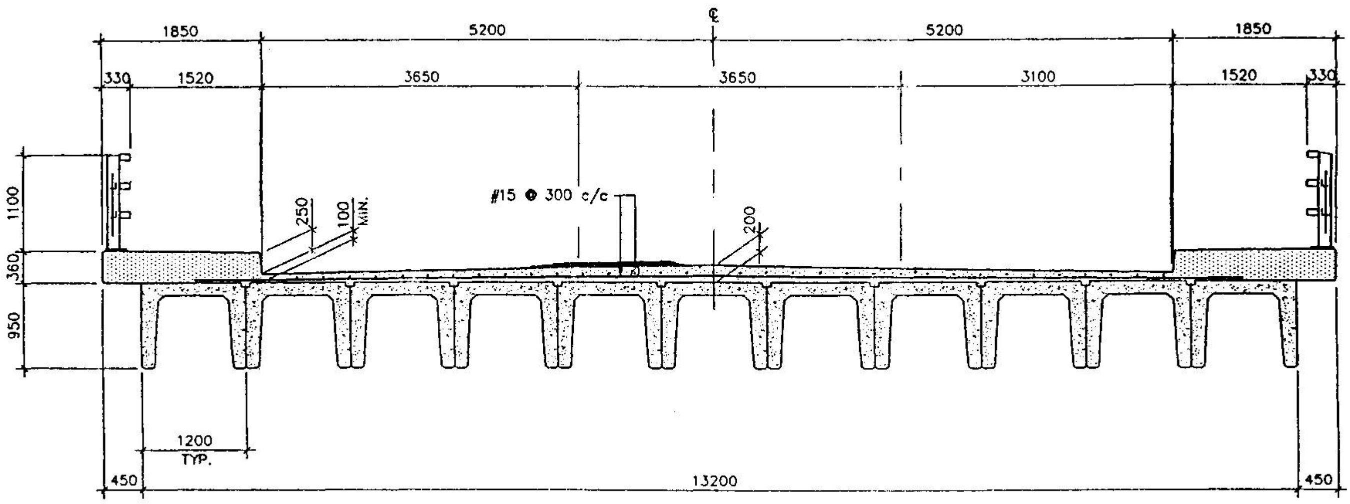
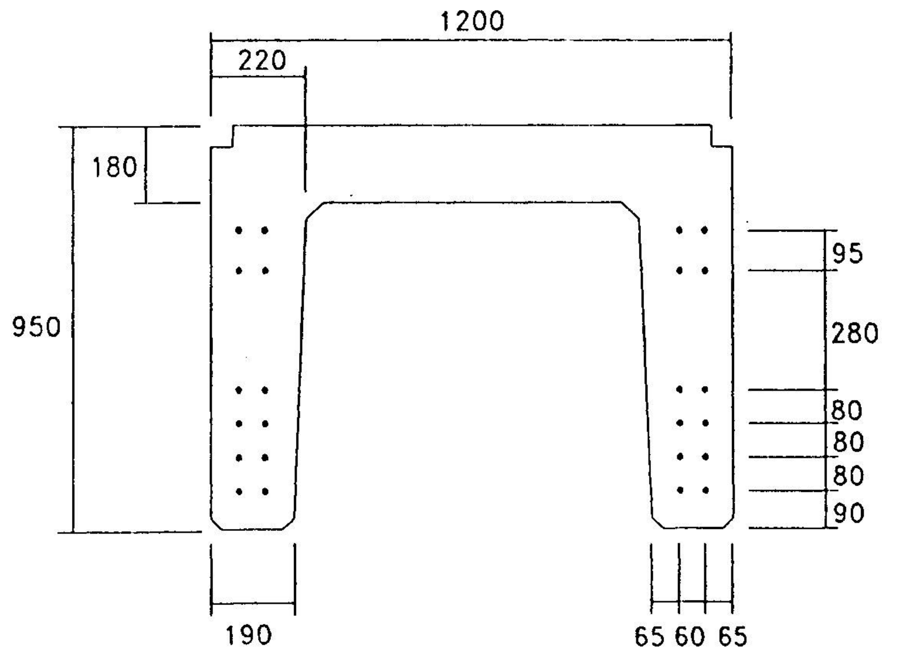
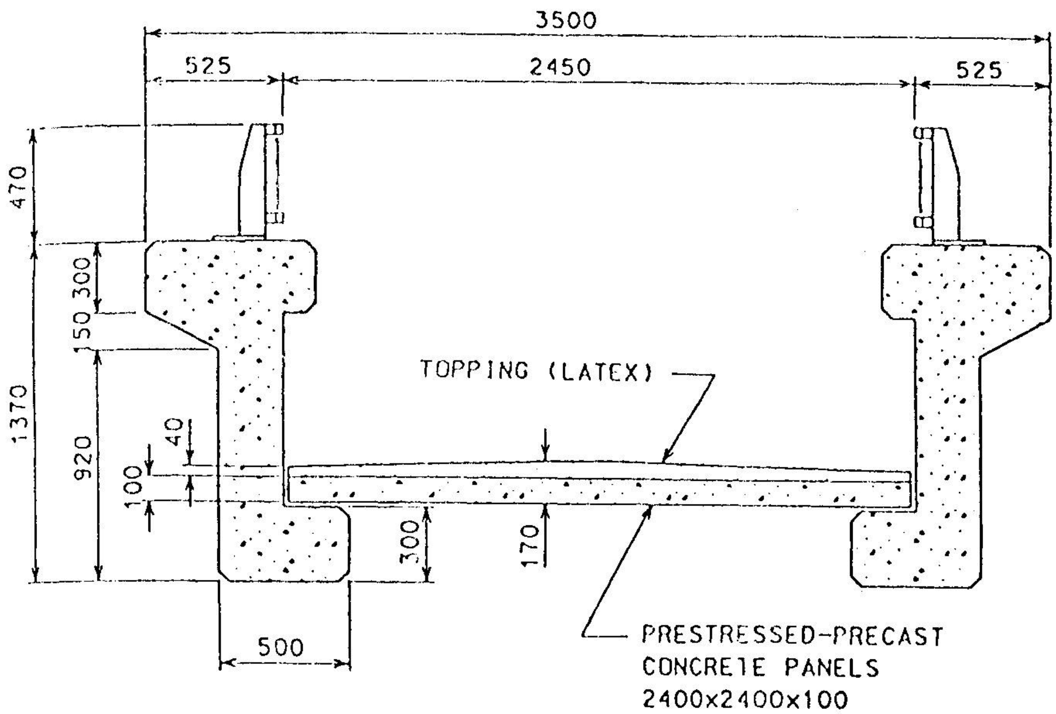



(a) Cross section of bridge

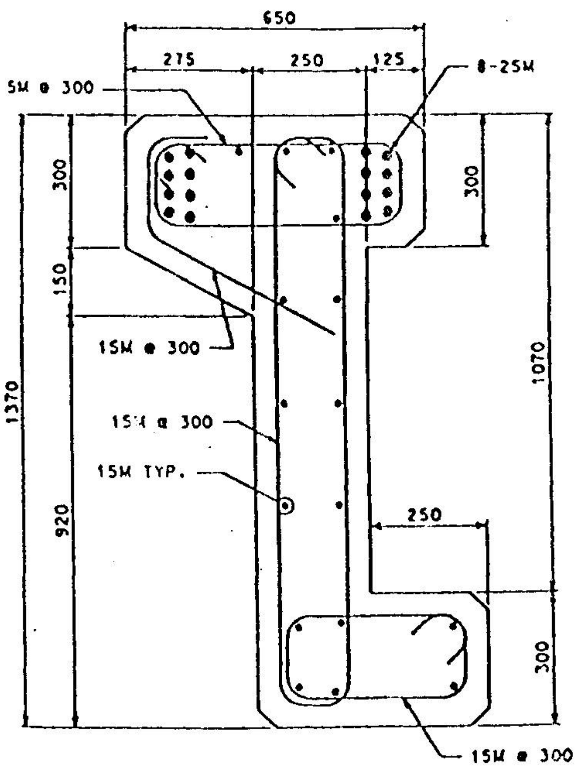



(b) Strand pattern (15 mm diameter strands)

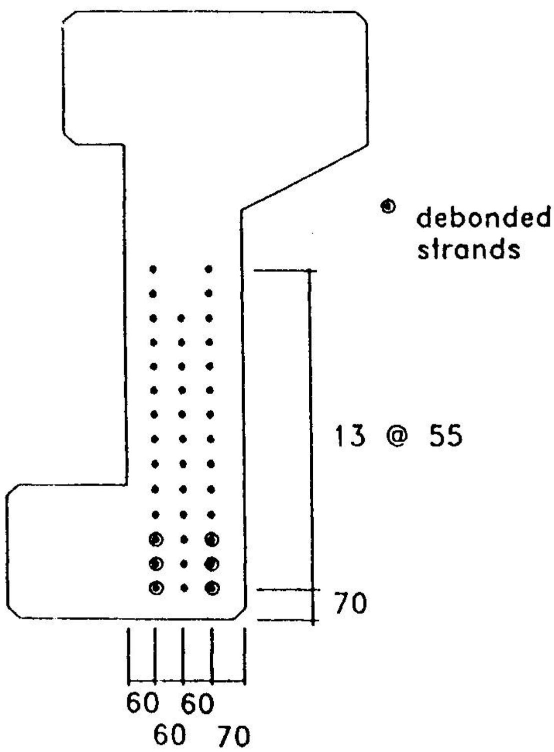
Fig. 1 – Roadway Bridge




(a) Cross section of bridge




(b) Reinforcement




(c) Strand pattern (15 mm diameter strands)

Fig. 2 – Pedestrian Bridge

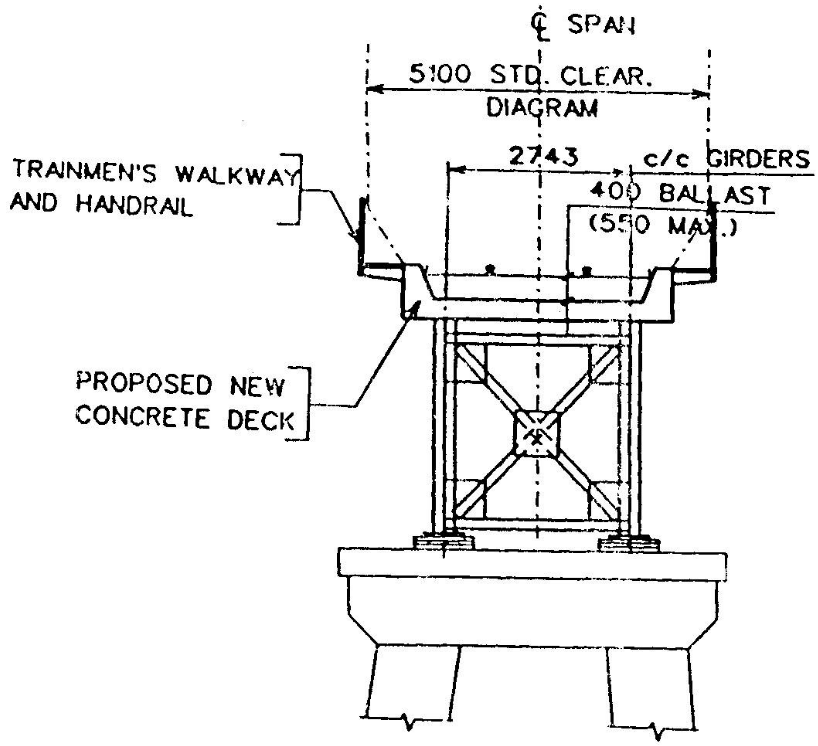



Fig. 3 – DPG Railway Bridge

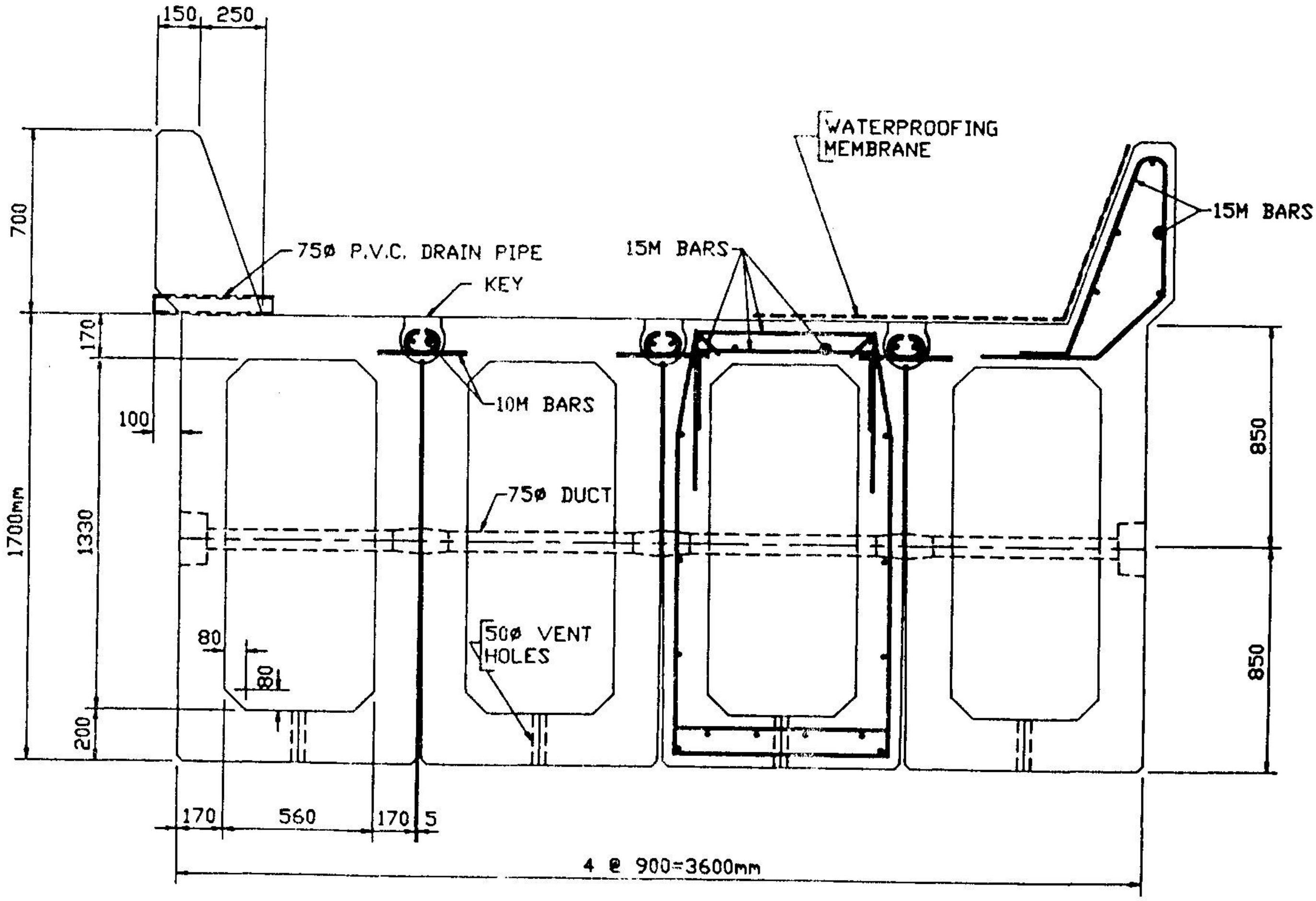
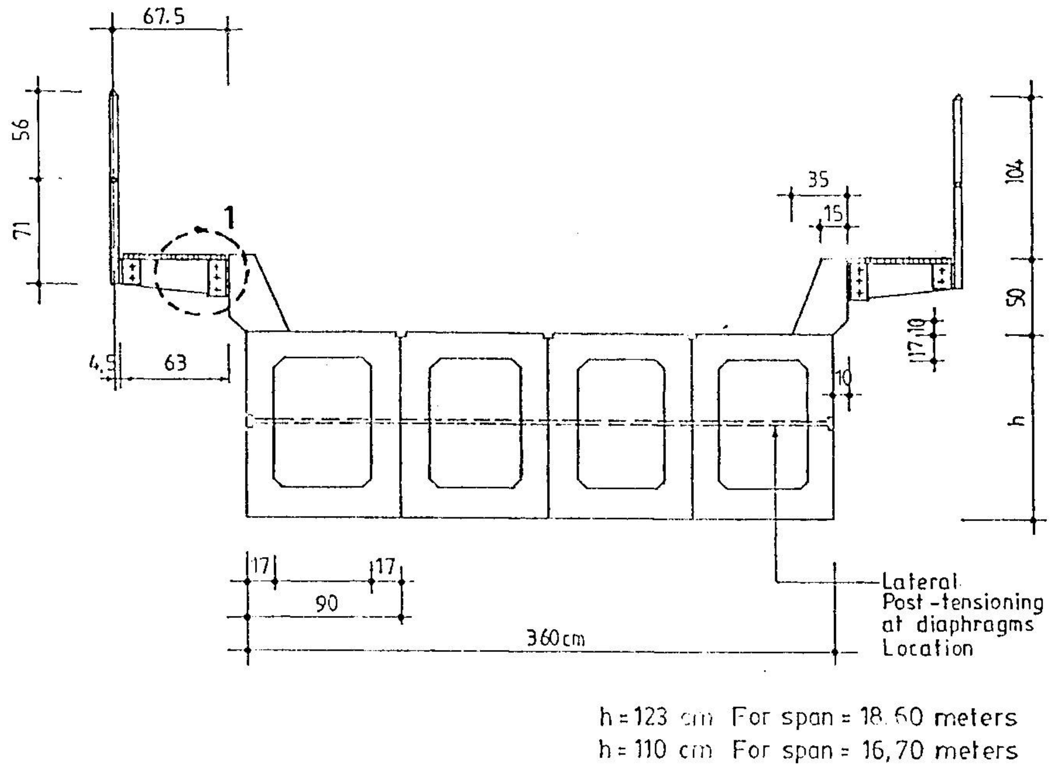
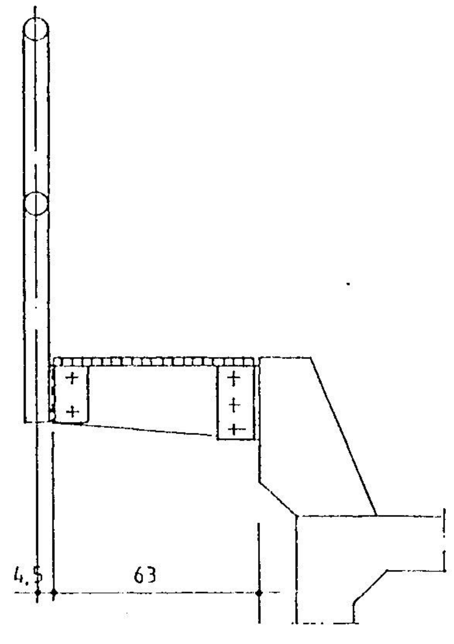



Fig. 4 – Box Girder Railway Bridge




DETAIL 1

Fig. 5 - Box-Type Girder Bridge

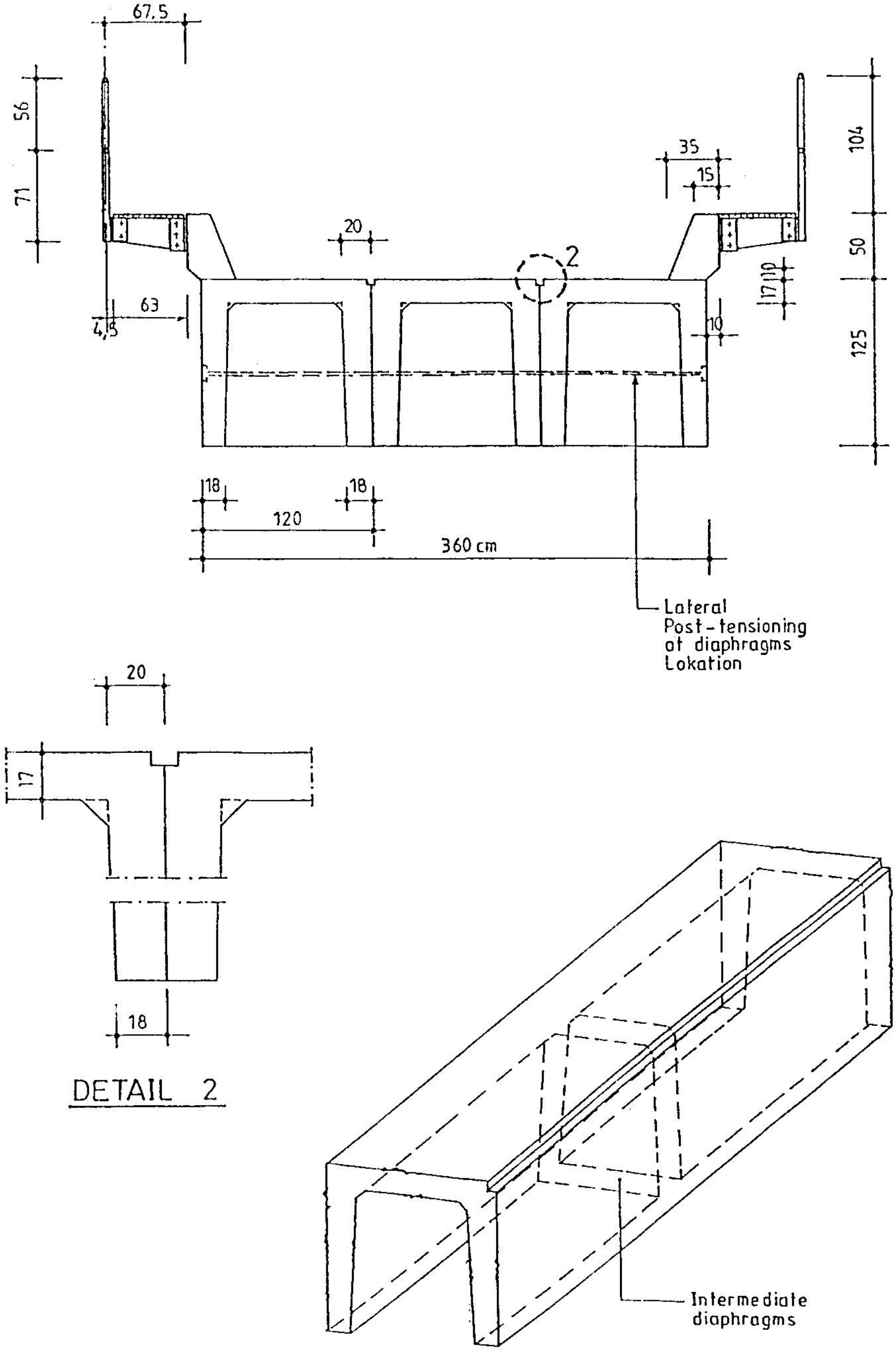
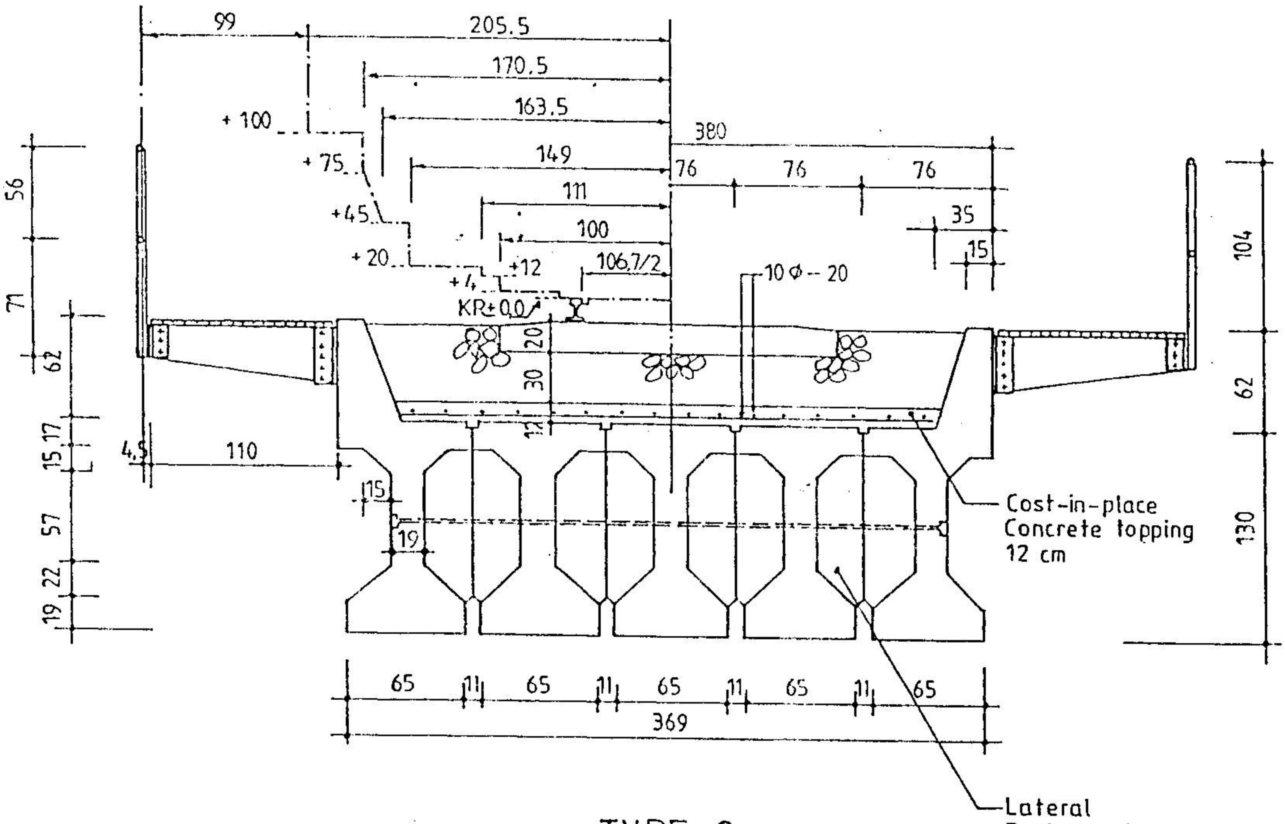



Fig. 6 – Channel-Type Girder Bridge




TYPE 3

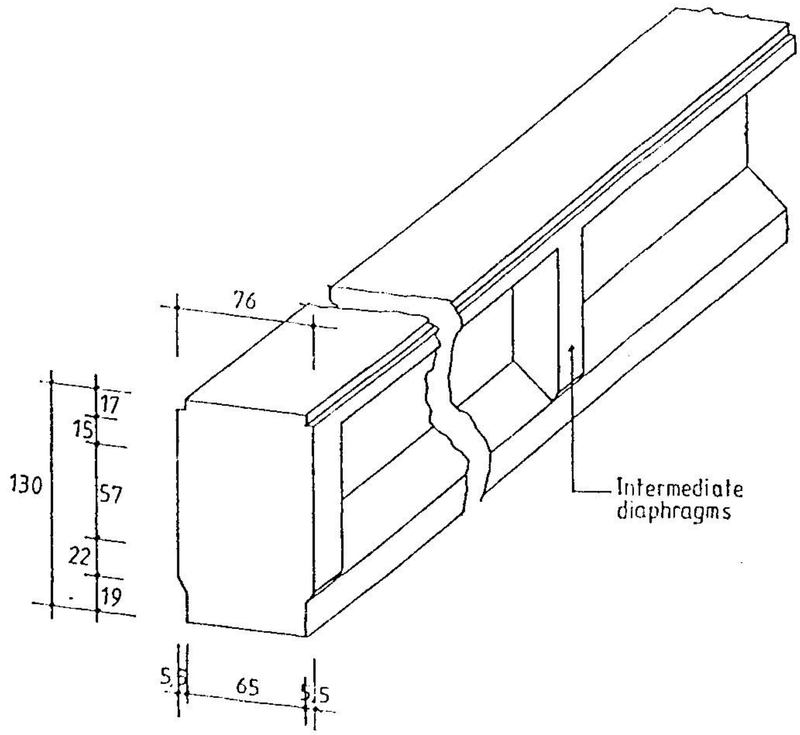



Fig. 7 – Bulb-Tee Girder Bridge