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Special Techniques for Construction of Viaducts in Singapore

Techniques spéciales pour la construction de viaducs à Singapour

Spezielle Bauverfahren für Brücken in Singapur

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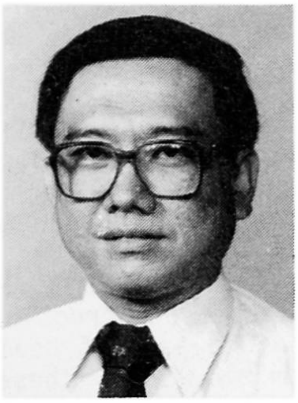

Ewe Chye Lim obtained his Civil Engineering degree from University of London. He worked for five years with Consulting Engineers and has spent the last ten years as an academic. His main interest is in Civil Engineering Construction, in particular bridges, tunnels, high-rise buildings and deep basements.

SUMMARY
This paper describes techniques adopted in the construction of viaducts using precast concrete post-tensioned longitudinal beams and examines the use of different types of purpose-built erection equipment to suit various site constraints. Methods used in the construction of viaducts for the recently built Singapore Mass Rapid Transit system are discussed. Emphasis is on the use of special equipment to transport precast beams from casting yards onto viaducts, installation of beams into their final positions and the forward advance of launching girders.

RÉSUMÉ
Ce travail décrit des techniques adoptées dans la construction du métro de Singapour, le Singapore Mass Rapid Transit, pour le montage des viaducs utilisant des poutres longitudinales en béton préfabriquées, et avec posttension. Il examine l'emploi de différents équipements de montage en fonction de contraintes locales. L'attention est portée sur le systéme de transport des poutres préfabriquées du chantier à l'emplacement des viaducs, ainsi que leur mise en place définitive avec la poutre de lancement.

ZUSAMMENFASSUNG
Der Aufsatz beschreibt das Verfahren der Brückenkonstruktion aus vorfabrizierten Teilen. Die Eignung verschiedener Montagesystme wurde speziell untersucht. Die Methoden, die für die Brückenerrichtung von Singapores Transit System angewendet wurden, werden diskutiert. Besonders wichtig ist die Verwendung von speziellen Maschinen zum Transport von vorfabrizierten Balken für deren Versetzen in die endgültige Lage.

1. INTRODUCTION

The building of viaducts for roadways and rail systems is an important aspect of Civil Engineering Construction. With advances in technology, engineers are building viaducts in shorter times by the use of precast concrete elements. However, the use of long span precast concrete beams will give rise to transportation problems should these units be carried by articulated vehicles and launched by mobile cranes. The construction of flyovers which comprise several spans and require the installation of up to about fifty precast beams, is manageable by the above technique, especially if these units can be transported during off-peak hours. Where many kilometres of viaducts are to be constructed, Engineers must device special purpose-built erection equipment to enable hundreds of precast beams to be installed without interruption to existing road traffic. Advanced launching techniques are available for "off-the-road" transportation and erection of viaduct beams to great satisfaction of all parties involved.

A spectacular feature is the viaduct construction for the Singapore Mass Rapid Transit System, in which over 3,300 precast beams were concreted and launched within a three-year period from mid-1985. These precast beams make up almost the entire 42 km length of elevated viaduct, which forms some 64% of the total 66 km route of the Singapore Mass Rapid Transit network.

2. STRUCTURAL CONCEPTS

In building precast concrete viaducts, the precast components are of significant numbers and most large contracts have precasting yards adjoining the viaduct under construction. Purpose-built gantry cranes are normally chosen to lift and transport the heavier units within the site, although mobile track or wheel mounted cranes are frequently used to handle smaller precast beams.

Where the location of the casting yard and the viaduct are advantageously positioned, it is possible to design the casting yard crane so that it can lift a beam directly from its mould onto the viaduct for direct delivery to the erection point. This combines the functions of the casting yard gantry and the transfer gantry. The latter is so named because it is used to transfer the precast beam to the viaduct.

The erection gantry, more commonly known as the launching gantry, is the most complicated member of the family of equipment needed on major projects. The launching gantry has not only to install beams onto cross-heads with high accuracy, it has also to launch itself between cross-heads, up and down slopes, manoeuvre curves and has frequently to offer stability to the viaduct structure.

3. PURPOSE-BUILT ERECTION EQUIPMENT

3.1 The Casting-yard Gantry

Precast concrete beams are manufactured in specially planned casting yards for various contracts and transported onto the viaducts. Location of the casting yard determines the method to be used in transporting the precast members. The arrangement of the beams on sites are divided into two main categories:

(i) casting yard with individual casting beds parallel to the viaduct,
(ii) casting yard with individual casting beds perpendicular to the viaduct.

Sites separated from the viaduct by a road pose a challenge in that the beams have to be moved over the road with minimal interruption to vehicular traffic.

Several alternatives are available:

(i) a rail-mounted gantry (Fig. 1) for the yard and a transfer gantry (Fig. 2) to lift the beam onto the viaduct.

(ii) a long-rail girder to serve both the casting yard and to load the beams onto the viaduct (Fig. 3).

(iii) C-type frame to serve both the casting yard and to load the beams onto the viaduct (Fig. 4).

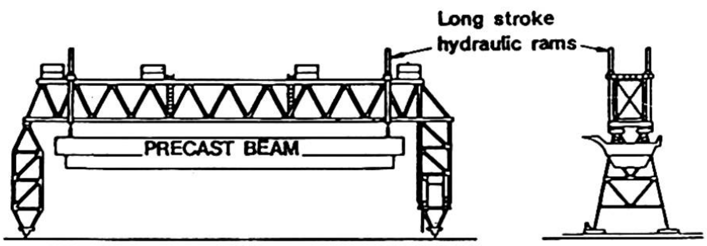

Fig.1 CASTING YARD GANTRY

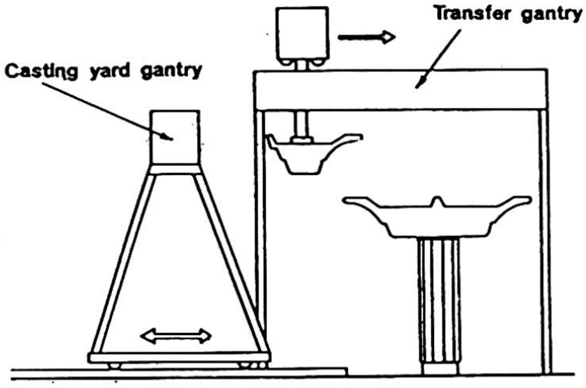

Fig.2 TRANSFER GANTRY

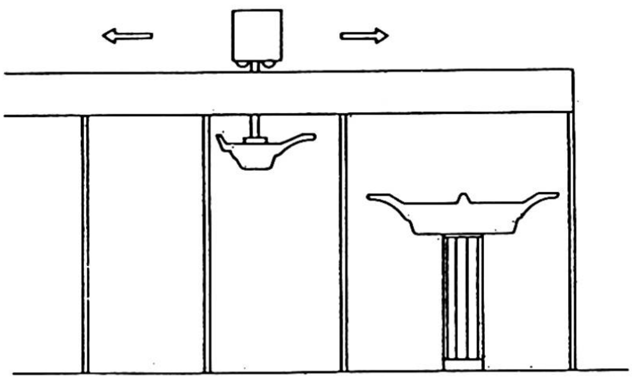

Fig.3 LONG-RAIL GIRDER

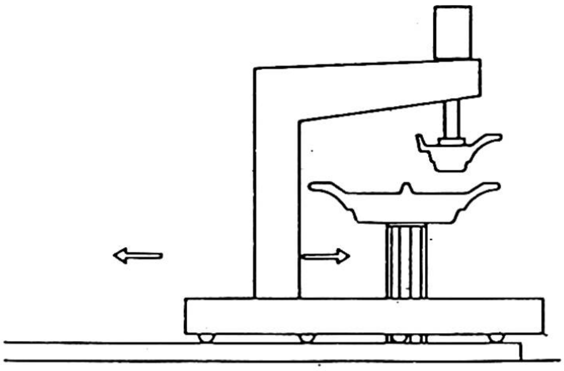

Fig.4 C-FRAME CASTING YARD GANTRY

The typical casting yard gantry mentioned in (i) above is a simple pinned portal frame with a lifting height capacity sufficient to lift a beam element out of and clear of its mould. The usual lifting height is about 5 m and the operation is executed inexpensively using long stroke hydraulic rams as opposed to electric or hydraulic winches. Beams that are concreted on casting beds perpendicular to the viaduct have to be rotated 90^{0} on a turntable to bring them parallel to the viaduct.

The transfer gantry is a massive piece of fabrication and has to provide clearance for the casting yard gantry, precast beams and the beam launching gantry. The transfer gantry usually comprises a pair of elevated truss or plate girders supporting a mobile overhead crane beam transporting the precast components. The lifting mechanism on the transfer gantry is usually expected to carry beams at heights in excess of 10 m.

The long-rail girder serves both the function of the casting yard gantry and the transfer gantry. It is basically an extension of the transfer gantry in that it covers the whole precasting yard and does away with the casting yard gantry.

Where the casting yard is adjacent to and casting beds are parallel to the viaduct, C-type gantries can be mobilised to lift the precast units directly onto the superstructure. To perform this task, the gantry must cantilever over the superstructure and place the beam on a transport vehicle on the viaduct. This is the most economical way of lifting the beams and transferring them onto the viaduct.

3.2 Launching Gantry

Various types of beam launching gantries are used in different countries and generally they are expected to place four or more beams side by side. Within each span the beams are parallel but the gantry has to alter horizontal alignment between spans to cater for horizontal curvature.

4. SINGAPORE MASS RAPID TRANSIT VIADUCT CONSTRUCTION

4.1 Viaduct Structure

The viaduct configuration generally adopted consists of two lines of post-tensioned precast concrete box-girders (Fig. 5) supported by reinforced concrete cross-heads which cantilever from single columns. Half-joints are introduced to carry the beams on the cross-heads and the box-girder profile is maintained through the cross-heads. Horizontal curves are possible by profiling the top side cantilevers of the beams to the required geometry. The box-girder soffit is kept to a straight profile between supporting cross-heads to keep construction costs to a minimum. The ends of the box-girders with the highly stressed half-joints and the tendon anchorages are solid.

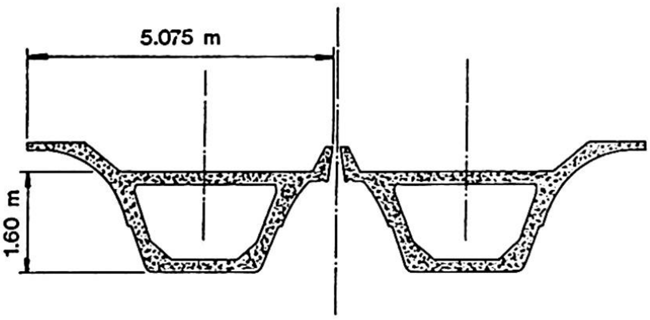

Fig.5 TYPICAL VIADUCT CROSS-SECTION FOR SINGAPORE MRT SYSTEM

The average precast box-girder weighs 170 tonnes, has an overall depth of 2100 mm and its top flange cross-sectional width is 5075 mm. The viaduct is typically situated either in the median of a dual carriageway road or alongside a road. In the median, the support structure is restricted to the space available between the carriageway gauges.

4.2 Construction Configuration

The substantial numbers and large sized precast beams to be transported daily to the various installation points would cause major traffic disruptions. In addition very large beam loads on roadways would need examination of existing bridges, culverts and drains along the viaduct route. The acceptable solution was to transport beams on a temporary rail track along the newly installed viaduct and place the beams into position using a self-travelling launching gantry mounted on the viaduct itself. This method allowed for the rapid building of the viaduct to meet tight construction schedules.

Casting yard sites were strategically located alongside viaduct routes to facilitate the launching gantry techniques. The most appropriate casting yard layout was to provide beam casting beds parallel to the adjoining viaduct. At casting yards where the beams were manufactured perpendicular to the viaduct, turntables were provided before they were placed onto the viaduct.

4.3 Launching Techniques

The launching system consisted of basically three sets of equipment:

(i) a loading system to transport the beams from the casting yard onto the viaduct,

(ii) a rail transport system to deliver the beams to the point of launching,

(ii) a launching gantry which lifted the beams from the rail cars, conveyed them longitudinally into the next span, lowered them to their final position, and advanced itself to the next span.

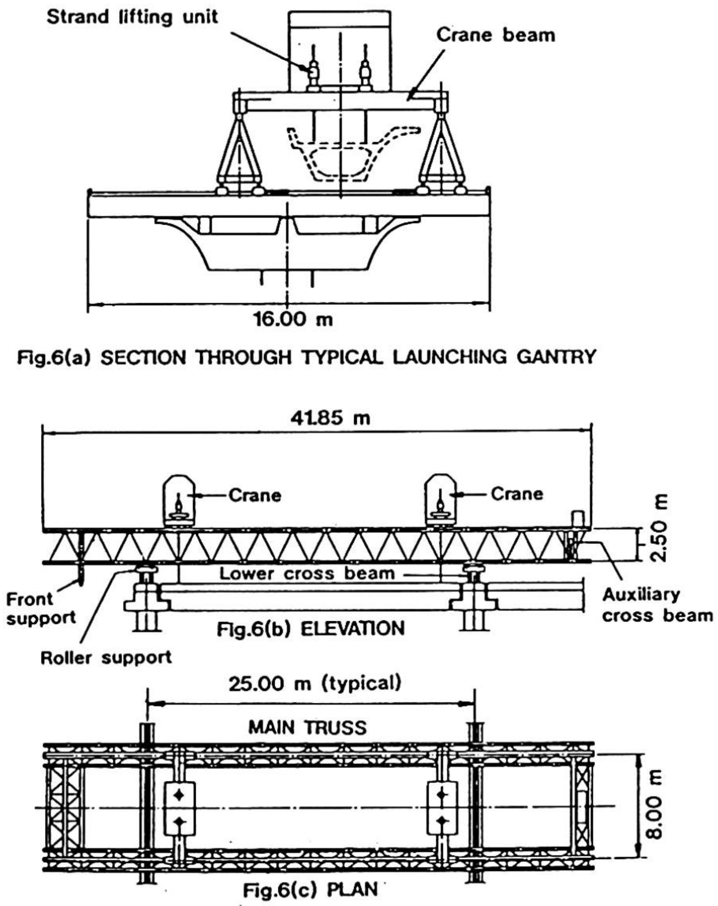

Fig.6(a) SECTION THROUGH TYPICAL LAUNCHING GANTRY

Fig.6(b) ELEVATION

Fig.6(c) PLAN

TYPICAL LAUNCHING GANTRY FOR SINGAPORE MRT SYSTEM

In the Singapore MRT system, precast beams were erected singly or in pairs. The launching girder had to be able to manoeuvre and operate safely along a minimum 400 m radius and a gradient up to 2.5%. From records obtained from completed sections of the MRT system, a launching girder could comfortably place one beam per day within normal working hours. Faster rates of placement were also achieved and on exceptional occasions up to three beams were launched in one day, with long working hours and night work.

One type of purpose-built launching gantry used on several viaduct contracts is illustrated in Fig. 6. Each launching gantry consists of two main trusses which are able to move longitudinally and laterally on two lower cross-beams. Two crane beams which support the lifting equipment move on top of the main trusses. The launching gantry lifts the precast beam off the rail cars, transports it longitudinally into the next span, lowers and keeps the beam suspended until the load can be transferred to the permanent bearings.

When the launching girder advances itself into another span, it is firmly connected to the beam which rests on the rail cars. The beam acts as a counter-weight for the free cantilever of the launching gantry while the rail cars provide the driving force for the forward longitudinal advance. The principle of using the beam as a counter-weight while advancing the launching girder longitudinally is to allow a reduction in the total length of the gantry to a little over 40 m. The gantry is able to move forward with all its equipment without any assistance of a mobile crane.

The launching gantry is also able to install beams for the parallel viaduct (i.e. two beams side by side) by sliding laterally on its own lower cross-beams. In moving longitudinally, the launching girder relies on roller supports which rest on the lower cross-beams.

The average cycle time is as follows:

o	Loading of beam from casting yard onto railcars	2.5 hrs
o	Rail transport (speed 400 mm/sec; say 1 km to launching gantry and same distance back to loading installation)	1.5 hrs
o	Beam launching	2.0 hrs
o	Advance of launching girder	4.0 hrs

5. CONCLUSIONS

The use of precast concrete beams and the adoption of purpose-built construction equipment have facilitated speed of construction of viaducts. This method of construction has permitted installation of beams with minimum traffic disruption and excellent safety records. A variety of purpose-built erection equipment is available to the engineer and the contractor. The final choice of equipment must depend on contract period, location of casting yard, route of the viaduct and configuration of the superstructure.

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