

## Fast track construction of 9.5 km long elevated expressway by largescale, prefabrication of superstructure

S. Sengupta

Span Consultants Pvt. Ltd., Bangalore, India

**ABSTRACT:** The traffic volume on existing national highway no. 7 from Bangalore city to Hosur city in southern India has substantially increased in recent years to an extent much beyond the capacity of the 4-lane highway. Apart from being a common stretch to the Golden Quadrilateral and North-South corridor of national highway network in India, this stretch provides daily access to large number of Information Technology and Bio-Technology professionals in Bangalore who commutes daily to the Electronic city appx. 9.5 km away from the downtown area. Due to the severe traffic congestion and consequent loss of precious man-hours on the road, the authorities had decided to construct an elevated expressway all along the road with full access control and tolling for providing a dedicated fast access on this corridor.

The four-lane superstructure takes off just after an existing flyover recently built and run straight into the Electronic City, Phase I & II approx. 9.5 km away. The elevated viaduct alongwith a multilevel interchange at the terminal point is being constructed on Build Operate & Transfer (BOT) basis using large – scale precast prestressed concrete (PSC) segmental, glued, matchcast technology and erected by Overhead Launching Girders without using any ground scaffold to avoid any traffic disturbance at GL. The four-lane superstructure is supported on single row of piers to be constructed along the central median of the highway. This is presently the longest flyover under construction in India. Fig. 1 shows a general view of the elevated expressway.

### 1 PRECAST/PREFAB CONSTRUCTION

For the elevated viaduct superstructure, largescale precast segmental construction has been adopted.

The precast construction will have following advantages.

- reduction in construction time due to concurrent working for foundations and superstructure.
- minimal interference to flowing traffic at ground level.
- superior quality control due to factory condition of concreting in precasting yard.
- environment – friendly as no site concreting work is involved for the superstructure.

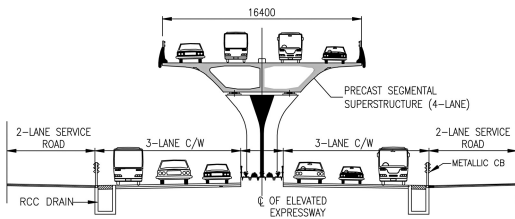


Figure 1. General view of the elevated expressway.

For this project, fast track construction is of extreme importance since the project is financed by BOT Concessionaire and he can start earning the toll revenue only after the facilities are opened to traffic. In addition to the precast segmental superstructure (grade M50), prefabrication has been adopted for several other structural elements e.g.

- precast crash barrier, total length 22 km, grade M40
- precast central median, total length 22 km, grade M40
- precast closed box drain, total length 18 km, grade M30
- precast fascia panels of reinforced earth walls, grade M30
- precast PSC contiguous I-girders, grade M50
- precast sacrificial RC planks for deck, grade M30

### 2 STRUCTURAL ARRANGEMENT

The existing highway crosses numbers of cross-roads at GL and major junctions all along the length. The span configuration of the elevated viaduct has been finally evolved after a number of trials to cater to these locations of existing cross roads and other site specific constraints viz.

- Existing subsoil conditions and maximum capacity of the piled foundations.
- Maximum repetitions of modules to effect savings in time and cost.
- Constraints in width of pile cap on existing central median.
- Feasible method of precast superstructure erection as per site condition.

After considering various alternatives, the span arrangement has been worked out in the range of 29m to 34m. Major part of the precast segmental viaduct are with continuous span modules of  $29\text{m} + 6 \times 34\text{m} + 29\text{m} = 262\text{m}$  as a standard module. There are 28 nos. of such modules and also 15 nos structure modules with different span configurations in the entire 9.5 km stretch. The multilevel interchange at the terminal point comprises sharply curved PSC box girders in the loops. The interchange is being constructed with a combination of in-situ and precast technology.

### 3 PRECAST SEGMENTAL SUPERSTRUCTURE

Figure 2 shows cross-section through a typical precast segment. The overall width of the precast segmental box girder is 16.4m accommodating 4-lane carriage-way with a central median and precast crash barriers on each edge. The PSC girder is a twin-cell one with inclined external webs and a central vertical web. The permanent PT bonded tendons are of size  $19 \times 0.6''$  and are distributed in all the webs. The elevated PSC box structure is having uniform depth with a minimum clear height of 1.70m with unhindered access for internal inspection all along the 9.5 km length.

The deck slab has been designed as transversely post tensioned units to ensure lesser congestion of rebars and easy handling of the wide cantilevering slabs. The stressing of these short tendons (size  $4 \times 0.6''$  in flat HDPE ducts) are to be made in the precasting yard before despatch to site for erection.

Alternatively, option without any transverse PT has also been given to the BOT Concessionaire. However, in that case the rebar content in deck slab

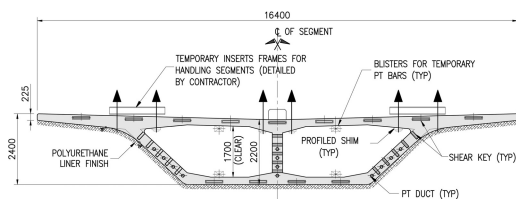


Figure 2. Section thru typical precast segment.

would increase. The final choice is left to the BOT Concessionaire.

For reasons of aesthetics, the external surface of the precast box girder and precast crash barriers are provided with polyurethane liner finish with pre-selected texture.

Overall shape of the in-situ PSC curved box girder is kept identical to that of the precast portion for aesthetics.

### 4 PRECASTING METHOD FOR SEGMENTS

The elevated corridor passes through heavily built-up area almost all along the 9.5 km route. However, it was possible to arrange two separate precasting yards of adequate area so as to plan the daily transport of the segments to the erection site with optimum length of travel. The casting yards have following activities/facilities.

- Long line or short line moulds area on jacks with survey control stations for matchcasting
- Rebar cage fabrication area
- PT hardware fixture area
- Storage area for cement, aggregate, sand and other materials
- Batching plant
- Curing area
- Segment storage area with multiple-tier stacking
- Concrete lab and offices, first aid, conference hall, design office etc.
- Heavy duty Goliath cranes, Straddle Carriers, mobile cranes etc.

Prior to finalising the precise geometric control for concreting of the segments and finalising the erection sequence, following construction stage analysis of the superstructure is carried out:

- calculations for pre-camber correction required in the precasting moulds/beds taking care of all PT forces, effects of temperature, creep and shrinkage.
- construction stage stress check for the superstructure during all stages of erection using Overhead Launching Girders as per finalized erection sequence.

### 5 RAMP SPANS WITH PRECAST UNITS

There are two ramps, one up and one down, superstructure of which is of 8.3 m width and constructed with precast post-tensioned contiguous girders of average 25 m spans which can be speedily erected by mobile cranes. The in-situ composite deck slab is to be supported by sacrificial precast RC planks to be erected between top flanges of the precast girders. Live load

continuity over 5 or 6 spans are ensured through in-situ RC diaphragms at the pier locations.

## 6 BASIS OF LAUNCHING SCHEME

The cardinal principles adopted for evolving the launching/erection method for such largescale precast units at the site are as follows:

- i) Under no circumstances, shall traffic flow on the existing highway at ground level be disturbed.
- ii) The minimum carriageway width on the highway at ground level during the entire period of construction shall be maintained 8.75 m in each direction, except while widening the existing carriageway, when this can be 7.50 m minimum. Also construction of service lanes in such lengths shall be completed prior to start of widening of existing carriageway.
- iii) No ground scaffold shall be erected during the entire construction period for construction of superstructure.
- iv) For construction of interchange near Electronic City, adequate number of casting trusses of adequate spans shall be used for construction of in-situ box girders without erecting any ground scaffold affecting the traffic flow.
- v) For constructing the elevated road, maximum width of the barricaded zone at the existing central median shall be limited to 8.5 m.
- vi) The entire construction should be completed in 24 months.

## 7 ERECTION OF PRECAST SEGMENTAL VIADUCT

Appx. total nos of precast segments : 3200  
 Maximum weight of one segment : Normal : 80t  
 segment

The elevated bridge deck shall be erected span by span by Overhead Launching Girders with no disturbance to traffic at ground level. In order to avoid traffic disturbance, the precast segments are planned to be delivered to the Launching Girders on top of the already erected bridge deck. For the transport, Low Bed Trailers shall be provided on top of the deck. The segments are to be loaded on the trailers by means of Transverse Gantry Cranes spanning across the road at

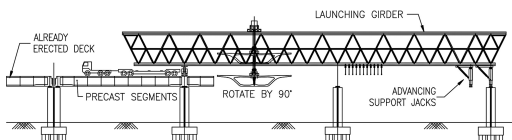


Figure 3. Launching of precast segments by overhead launching girder using span by span method.

ground level and these transfer points shall be located as close as possible to the casting yards. Figure 4 shows the arrangement for handling the precast segments across the traffic with the Transverse Gantry crane.

Preliminary site inspection and time cycle analysis indicates need for two separate casting yards. The first casting yard serving the segments from km 12.470 to km 9.500 shall be near km 11.350. The second casting yard serving the segments from km 15.360 to 12.470 and from km 15.440 to 17.735 may be located near km 16.350. The first casting yard, therefore, has to produce appx. 1000 segments and the second one appx. 2200 segments. The erection sequence for the deck in the entire 9.5 km length shall be chosen in such a manner that the two nos lay-by modules with wider and heavier segments can be erected at the end of erection of the normal deck segments once all the standard spans are completed. With the given sequence, one Overhead Launching Girder needs to be relocated one time during erection.

The segment shall be transported from the casting yard to gantry crane avoiding the use of main highway at the ground level through temporary access road to be built by the Concessionaire.

## 8 ERECTION OF FIRST SEGMENTAL SPAN

Since the Transverse Gantry Cranes cannot be used for the erection of first span, the precast segments shall be delivered on ground across the road to the central barricaded area by low bed trailers after the Overhead Launching Girder has been installed in the first span.

To minimize traffic disturbance (only for the first span), the delivery of segments may be carried out only during night time when traffic is low. At day time, the road shall be completely opened again to traffic.

## 9 ERECTION SCHEME FOR INTERCHANGE PORTION

The interchange superstructure comprises both precast and in-situ units. The structure is located at the entry

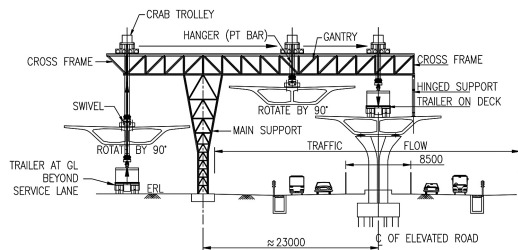


Figure 4. Transverse gantry crane for loading precast segments from casting yard on top of the erected bridge deck.

to the Electronic City where large volume of IT traffic passes everyday and as such, the construction scheme shall be so as to ensure no traffic disturbance/closure on the existing highway at GL.

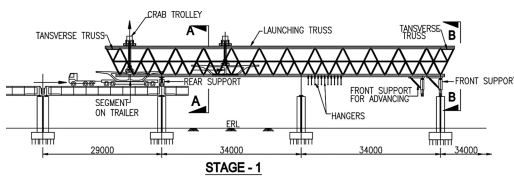
The PSC precast I – girders (for 25 m spans) shall be manufactured close to the erection site and erected on pier caps by mobile cranes. End diaphragms shall be cast-in-situ. Temporary structural steel supporting brackets with temporary bearings are planned to be used for supporting the end precast girders till the in-situ diaphragms are fully commissioned.

The PSC in-situ box girders shall be concreted on suitably designed temporary structural steel casting truss (nos of plate girders of shallow depth with cross beams to ensure maximum vertical moving clearance) spanning between the piers thereby avoiding closure of any span for moving traffic at GL.

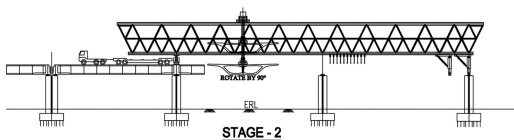
## 10 ERECTION SEQUENCE AND CYCLE TIME

Span by span erection of superstructure with precast segments has been adopted and the major steps of erection sequence are as follows:

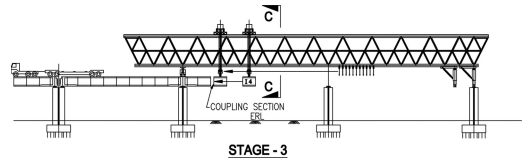
Detailed time-study analysis of all activities has been carried out and the target cycle time per span is 5 days (average). With the site mobilisation planned and earlier experience in similar projects, it is found achievable. Even, after the initial learning curve, it is expected to reduce the average cycle time to from 5 to 3 days per span. Cast-in-situ stitch has been incorporated in the precast segmental superstructure (@ approx. one per span) for compensating manufacturing tolerances, effects of creep and shrinkage. The thickness of in-situ stitch preferably should not exceed 200 mms and should be of richer grade than that of the precast segments.



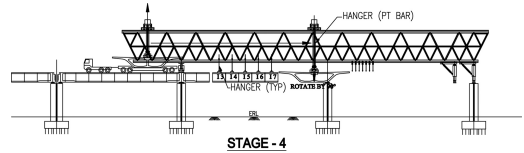
Lift segment from trailer by crab trolley, segment reaches by trailer on top of erected span and move segment in longitudinal direction.



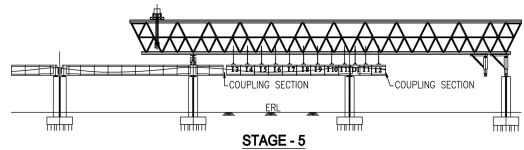
Lower the segment approximately to correct level and rotate segment by 90°.



Suspend the segment from launching truss by means of the hangers. Move segment back to coupling section leaving a gap of approximate 1 meter.

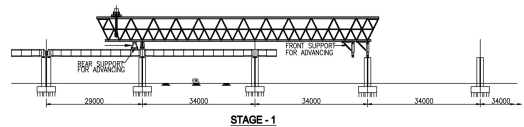


Launch all remaining segments according to step 1–3 until full span is suspended. Leave approximately 50 mm between the segments.

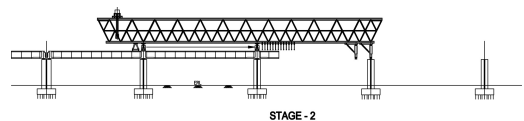


- Dry-match all segments, check line/levels, adjust hangers if required.
- Install and couple all PT tendons (unstressed).
- Apply epoxy glue and join first segment (13) to previous span, Install and stress temporary PT bars.
- Join all remaining segments one by one as described above.
- Stress PT tendons to approx. 2/3rd of final force.
- Lower span on to the bearings.
- Stress PT tendons to final force.

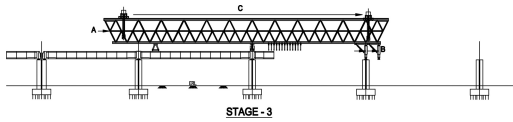
## 11 ADVANCING SEQUENCE OF LAUNCHING GIRDER



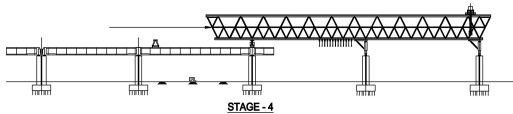
Install rear support for advancing



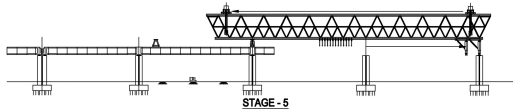
Release rear support and move it (along with hangers) to the next pier location.



- A : Advance launching girder by appx. 3.50 m
- B : Release front support and move it to tip of launching truss. Move front support for advancing to pier location.
- C : Move crab trolley into next span (to act as counter weight)



Advancing launching girder to correct position for the erection of the next span.



Move crab trolley to rear end of the launching truss. Move front support for advancing to front of launching truss.

## 12 LAY BYE SEGMENTS

Within the 9.5 km long elevated structure with 4-lane deck, two nos lay-by modules have been provided at approx. 1/3rd of full length. At these locations, the bridge deck gradually widens from 16.4 m to 23.6 m. These are provided for emergency needs e.g. accidents, break down of cars, surveillance etc. Provision has been made in the design to arrange quick removal of a portion of central crash barrier (at regular intervals) for emergency situations. A sophisticated Highway Traffic Management System (HTMS) shall be in place to handle such situations.

The lay-by spans shall be constructed with wider precast segments and with a different system of longitudinal PT to allow the erection sequence between the already erected superstructure.

## 13 PRECAST CRASH BARRIERS

For this project, the total length of precast/prefabricated crash barriers is appx. 22.00 kms which is to be manufactured in 7330 nos of precast units of average 3.0 m length. These units are designed to AASHTO standards as containment structures and are provided with liner

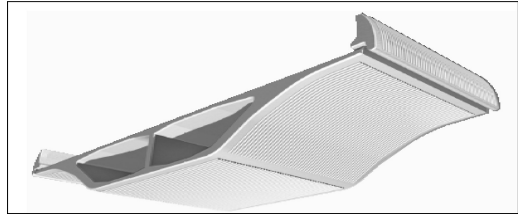


Figure 5. Perspective of liner Finished Outer Face of Crash Barrier and Bos Girder.

form finish in the moulds for good aesthetics. Figure 5 shows a perspective view of liner finished outer face of precast crash barrier and precast box girder.

Special care has been taken in their fixing details on the deck slab and on safety aspects while handling these units on edge of the bridge deck, below which traffic will be moving at ground level.

## 14 PIERS

The piers are being constructed in-situ with smooth flowing geometrics and with liner finish. The pier top flares out to house the POT/PTFE bearings. All piers shall be concreted in single pour even for the tallest pier of appx. 15 m height, where the elevated viaduct spans across another flyover. Three types of piers have been used viz., regular, anchor and expansion piers.

## 15 PILED FOUNDATIONS

The size of the pile caps has been decided based on the criteria of minimum disturbance in the existing road. All site work has been planned to be carried out within a central barricaded portion of 8.5 m width. All the piles are cast-in-situ bored type constructed with rotary hydraulic rigs with faster productivity. The capacities and termination levels at each location have been worked out based on results of extensive soil investigations carried out in the stretch by the design consultants.

## 16 SALIENT DATA

Total area of bridge deck	: 1,44,316 sqm
Total quantity of HT strands (0.6" dia)	: 3,930 MT
Total quantity of Fe 500 grade rebar	: 27,330 MT
Total quantity of concrete in superstructure (M50)	: 1,22,450 cum
Total project cost	: INR 4500 million

## 17 CONCLUSION

The experience in the above project has shown that precast segmental construction on a large scale is one of the most appropriate solution for big cities with high density of vehicular traffic. For such elevated expressways of long length, the adopted technology provides a number of advantages viz. fast track work, least disturbance to traffic during construction, better quality and also provides a cost-effective solution.

## 18 SALIENT FEATURES OF THE FLYOVER

- Overall length of elevated structure : 9.50 km (approx)
- Deck width : 4-lane divided carriageway (16.40 m)
- Type of superstructure : Precast Segmental (PSC)
- Type of post-tensioning : 1906/1206/406 system
- Type of piers : in-situ, single shaft
- Erection method of deck : Overhead Launching Girders (3 nos)
- Longest continuous module : 8 span Continuous (262 m)

- Type of joints in segments : Shear keys with epoxy glue
- Type of bearings : Pot/PTFE
- Type of expansion joints : Modular strip seal
- Provision for future external PT : exists
- Nos. of precast segments : 3200 (approx)
- Total nos. of spans : 250 (approx)
- Max. weight of one segment : 80 t (normal)
- Type of foundations : bored piles driven by Hydraulic rigs
- Concrete grade of precast segments : M50
- Concrete grade of normal piers : M50
- Concrete grade of anchor piers : M60
- Concrete grade of crash barriers : M40

## REFERENCES

- AASHTO Guide Specifications for “*Design & Construction of Segmental Concrete Bridges*”, Washington DC, USA, 1989.
- Podolny Walter & Jean M.Muller, “*Construction and Design of Prestressed Concrete Segmental Bridges*”, John Wiley & Sons, USA.