Design and construction of flyovers/ urban viaducts : Recent trends

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In the recent past, a number of flyovers and urban viaducts have been constructed in the metropolitan and other cities. In the next five years, the expenditure on the construction of bridges and flyovers is expected to touch about Rs 2000 billion. The paper focuses attention on various design and construction aspects of bridges and flyovers and highlights how the project cost and construction time can be reduced and quality improved.

In the past, some flyovers were constructed in different urban locations in India. Mumbai had less than 10 flyovers until recently. In Chennai, the Gemini flyover was built in the early seventies. In Delhi, flyover construction was triggered by the Asian Games. Of late a number of flyovers have been constructed all over India. Mumbai, Delhi, Chennai, Kolkata, Hyderabad and Bangalore account for more than 150 flyovers. The mass rapid rail transit system (MRTS) in Chennai envisages about 37 km of elevated viaduct. Delhi Metro Rail Corporation (DMRC) has planned elevated viaducts for a part of the 200 plus km network. The first phase length is 62 km out of which 38 km are elevated. Calcutta Metro Rail has started construction of about 5 km of elevated viaducts. Flyovers are under construction in all major cities. The Konkan Railway Corporation Limited (KRCL) has constructed a very large number of road over bridges (ROB) and underpasses (288 nos).

The investment totals more than about Rs 300 billion. In addition, during the next five years the expenditure on construction of bridges and flyovers is expected to touch about Rs 2000 billion. In the context of such huge investment, it is necessary to analyse the various aspects of planning, design, detailing and construction of flyovers. The paper focuses attention on these various aspects with a view to reduce the project costs as well as the construction time while maintaining the quality.

Concepts

During the formative stages, concepts such as decision making, conceptual design, design agency, buildability, benchmarking, soil investigation, type of contract, prequalification, project management agency, standardisation, new construction materials should be frozen. While it is universally recognised that flyovers are necessary for decongesting traffic through critical roads, the decision to build the flyover particularly in India has been fraught with obstacles from various sections of the public as well as the government agencies.

All the available options for a particular location are considered before deciding on the flyovers. Current and future traffic growth pattern, location of the bus stops, environmental impact etc. should be considered. Thereafter, a detailed traffic survey and future projection of traffic is conducted in order to determine the number of lanes in each direction. The planned layout of the flyover is carefully chosen to avoid disturbance to traffic and maximise the decongestion potential.

Indian loading standards and permissible stresses

The Indian Roads Congress (IRC) standards are appropriate to highway bridges. IRC loadings are conservative, not realised during the service life. Urban flyovers generally cater to cars, LCVs and buses. Heavier vehicles may use roads at ground level. IRC 70R/ Class AA loadings are not appropriate for flyovers, but often adopted. The IRC codes stipulate low permissible stresses, ignoring developments in high strength concrete and higher grades of reinforcement steel.

IRC codes specify minimum thickness for webs, deck slabs, pier walls etc which leads to avoidable increase in quantities, whereas these should be derived from design. In the past, hundreds of bridges have been built with web thickness of 150

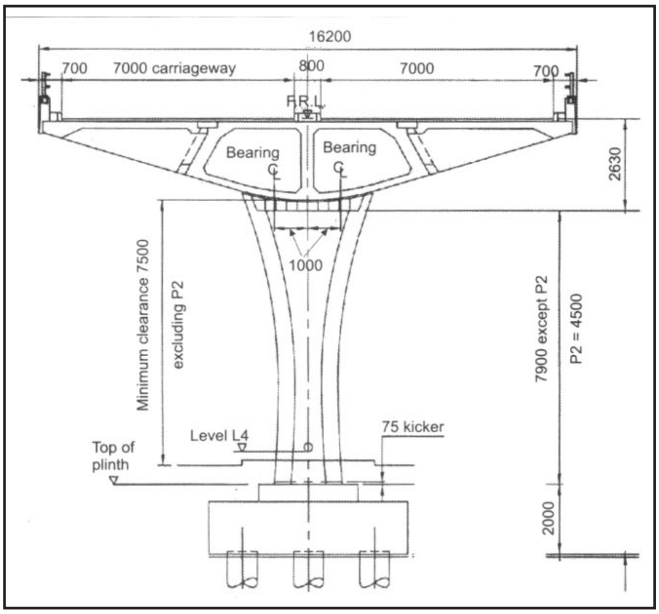


Figure 1. Cross section of J.J. Hospital flyover

mm and are in satisfactory service for more than 40 years whereas the thickness now is more than 250 mm. In the United States, a large number of flyovers are being built with web thickness of around 150 mm. There are no separate IRC codes for pretensioned flyovers. IRC: 18 (Post-tensioned concrete) is imposed for design of pretensioned girder bridges. This leads to further increase in the cost of construction.

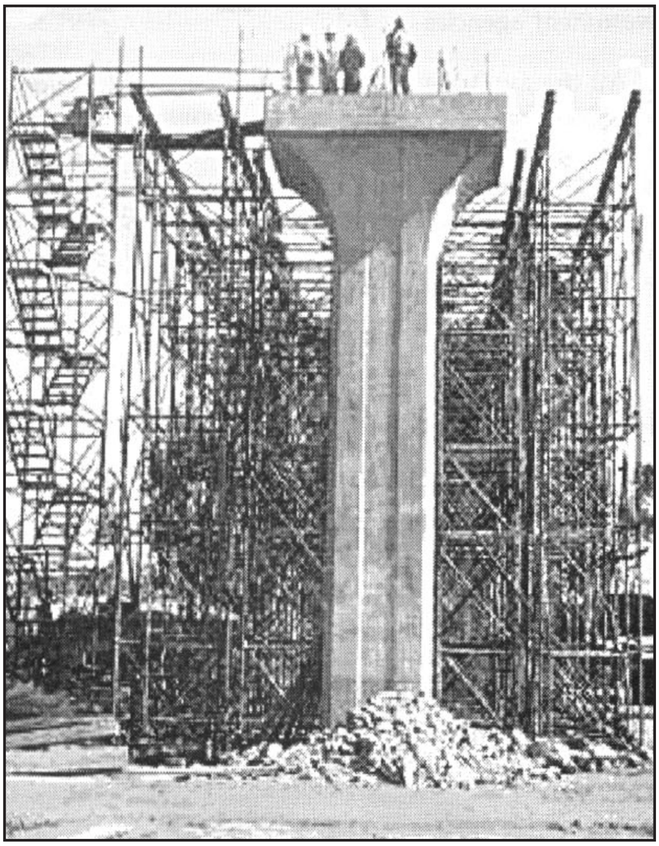


Figure 2. Construction of pier in progess for DMRC

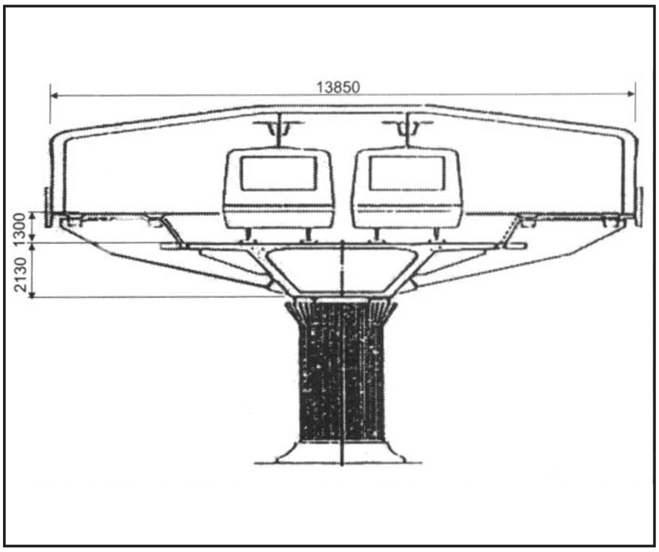


Figure 3. A cross-section of a typical single circular pier

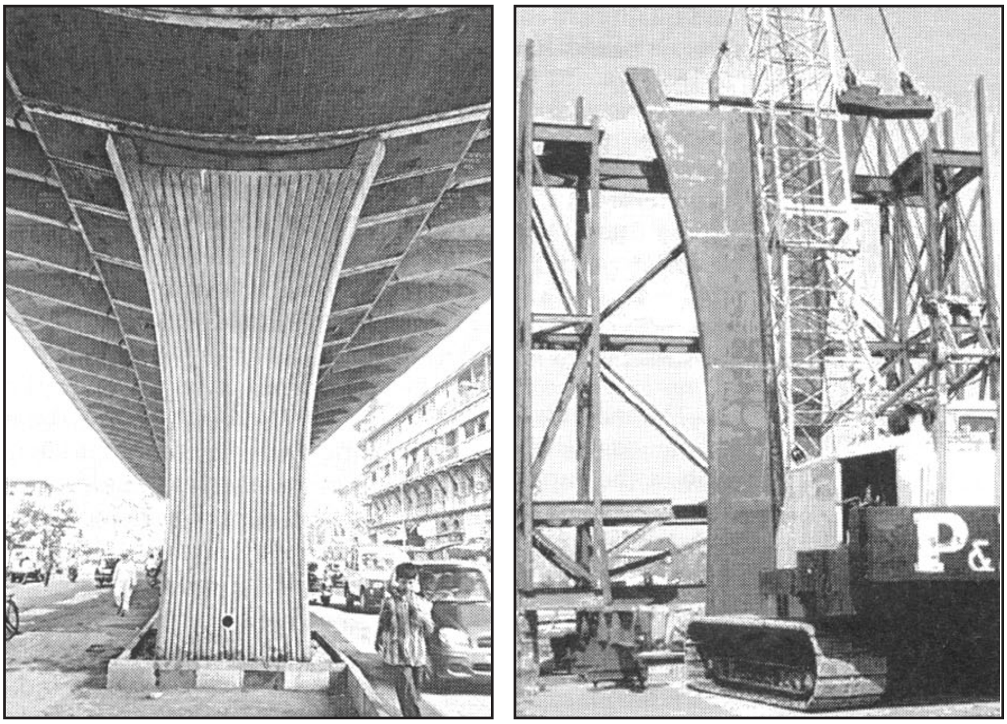
Pile foundations

When piles are fully designed and detailed as per the Standard Codes, there should be no further conditions on the minimum number of piles. Flyovers have been constructed elsewhere with pier resting on a single pile or on two piles. Examples include flyovers in Malaysia and Jamuna Bridge in Bangladesh. However, in India, three or four piles per foundation is insisted upon which is not justified. Raker piles should be used only when absolutely necessary. The bottom of pile cap should be above water level to facilitate construction and obtain better quality concrete.

The initial test piles should be carried out before the contract is awarded, because piling operation is generally on critical path and valuable time is lost in carrying out pile load test. The number of routine pile load tests should be judiciously selected and not blindly copied from requirements for buildings. The chance of failure of routine load tests should be minimised by providing a higher factor of safety for the initial test piles. Dynamic tests take up far less time, but should be first calibrated against static tests on both initial and working piles.

Environmental issues such as effect of pollution and influence of ground vibration shall be carefully examined for possible damage to neighbouring areas in an urban area. In such cases, bored piles should be specified instead of driven piles.

JJ Hospital flyover in Mumbai is founded on piles with the allowable bearing capacity for hard rock of 700 t/m^2 as against much lower values permitted elsewhere in Mumbai, Figure 1. Piles generally transfer the loads both by friction and by end bearing. This aspect should be recognised in the design. Socketing of piles into hard rock may be justified in specific cases and should not be universalised. The depth of socketing, if required, should be judiciously chosen. Even the rotary piling rigs cannot drill through hard rock. Unduly harsh specifications in this respect lead to delays in construction and increased cost.



(a) (b)

Figure 6. JJ flyover *(a)* Aesthetically elegant pier *(b)* Precast pier

Piers

Urban flyovers are built over precious land. Hence the space occupied by the pier should be kept to the minimum, Figure 2. Ideally circular piers of 1 m to 2 m diameter in high strength concrete should be adequate for up to six lanes of traffic, Figure 3. In the case of JJ Hospital flyover in Mumbai, the grade of concrete for the piers as well as superstructure is 75 Mpa, Figure 4(a). This is also aimed at providing a more durable concrete structure and eliminates the need for any type of coating to reinforcement and/or concrete surfaces.

The pier configuration can also be carefully chosen to eliminate pier caps. This reduces construction time. The full height of the pier is concreted in one lift to avoid construction joints and also reduce construction time; this was the practice followed in the construction of DMRC elevated viaduct. The vertical sides of formwork is removed in 6-8 hours after concreting. It is possible to precast the piers off-site, transport and erect them causing minimum disturbance to the existing traffic at site, as was done for some piers for JJ hospital flyover, Figure 4(b).

Superstructure

Most of the urban flyovers are built on heavily congested roads. Therefore in-situ work is reduced to the minimum. Beams, segments etc. are precast off-site, transported and erected during night. Precast pretensioned beams are extensively used for spans upto 45 m.

The superstructure of Chennai flyovers, Figure 5, consisted of precast post-tensioned 'I' beams with continuity established after erection. The entire design of the flyover was completed in a short period and almost all drawings good for construction were provided to contractors immediately after the work was awarded. The post-tensioned cables were stressed to about 50 percent of the final requirements in order to evacuate the casting yard. First stage prestressing was done within 24 hours of concreting. With four casting beds, four beams were precast every day. The piers are of circular cross section, flared as pier caps. The beams are erected on temporary trestles and integrated by cross diaphragm cast insitu; this arrangement utilises the transverse strength of the pier to the maximum. Indian flyovers use beams with conservative L/D ratio of 15-25 (expensive).

In the USA, pretensioned beams of large spans to 45 m are in vogue with slender L/D ratio of 25 to 35. Temporary steel diaphragms are fixed during erection. Once the deck slab is completed such diaphragms are removed and reused for subsequent erections.

Span range

The span range directly results from the site conditions. The span length influences the selection of cross sections and also the erection method of 20 m beam are easily erected using a single 50 t crane.

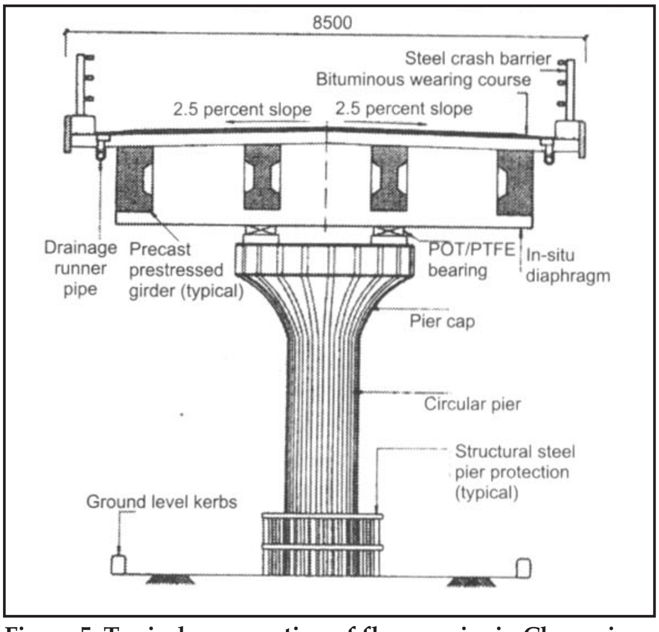
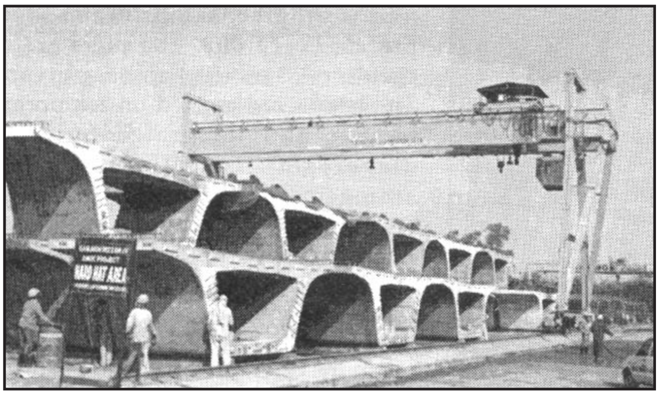


Figure 5. Typical cross section of flyover pier in Chennai



(a)

(b)

Figure 6. ***(a)*** **Typical precast deck components** ***(b)*** **Easy transportation of precast segment**

Cast-in-situ construction may be used economically for:

1. structures built over land, with good ground conditions
2. structures relatively close to the ground
3. work which is of modest dimensions
4. no major obstacles to be crossed
5. suitable for span by span construction.

The preferred method is to apply the full prestress to the span as soon as the concrete has attained the necessary strength. In the Indian context, it is possible to do so within 48 to 72 hours after concreting. The concrete strength at the time of prestressing should be pragmatically specified based on design calculations for the dead loads to be carried. The present practice of specifying 80 percent of 28 days strength is a wasteful practice and has no value addition. The number of stages of prestressing and grouting shall be reduced to the minimum, preferably not more than two.

The advantage of precast components, Figure 6(a), is ease of transportation and erection, Figure 6(b). Their use can substantially reduce construction time enabling superstructure to be built at rate of up to 3000 m2 per month. Shortened construction time and elimination of false work often result in low construction cost. The two most common precast components used in flyovers are beams and segments. Precast segments are normally economical only for long bridges due to the high cost of casting and erection equipment. The joints between segments are not normally crossed by reinforcement steel. Economy and quality are enhanced by the use of external prestressing. Precast beams have been used economically for spans upto 60 m.

In order to improve the riding quality and economics, continuous decking for several spans without expansion joints is preferred. The bridge across river Yamuna in Delhi (Delhi Noida Bridge Project) has deck continuous over the entire length between 2 abutments (13 spans of 42 m). In the case of flyovers in India, deck continuity has been practised with expansion joints spaced about 100-150 m and this could easily be stretched to full length of flyovers.

The individual spans should be transformed into a full continuous system by using diaphragms and continuous deck slab at the supports. By eliminating bearings under each individual girder, the width and thickness of the pier can be substantially reduced. The deck slab formwork for the gaps between the beams is made of thin precast planks with suitable shear connectors. This forms permanent shuttering and the strength of plank is taken into account in the design of the decking. It reduces the construction cost and time. In India this is not practised, though there are exceptions such as Akkar Bridge, Sikkim, the World Bank Bridge projects in Nepal, Almatti Spillway Bridge in Karnataka, MRTS viaduct, Chennai etc.

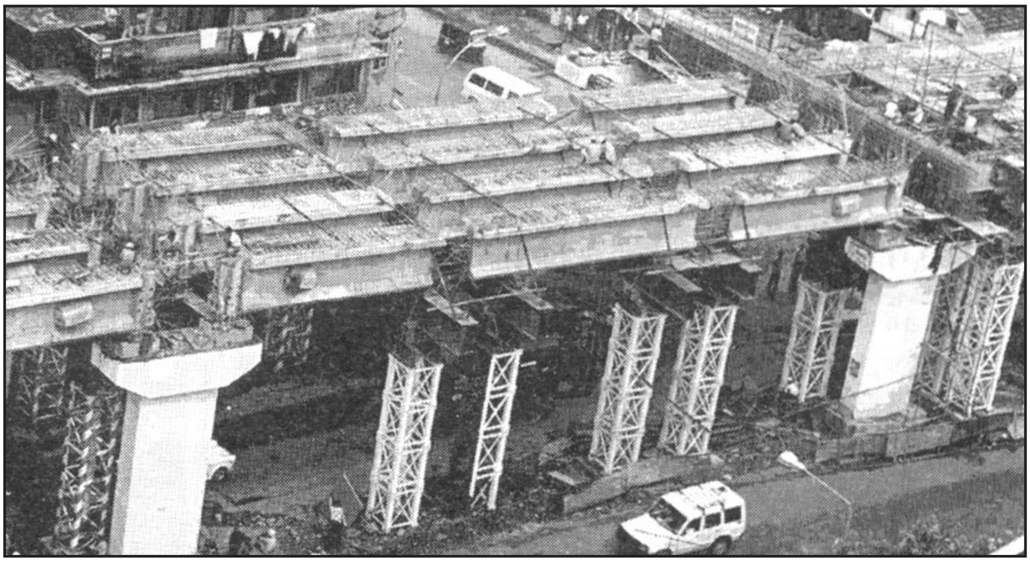


Figure 7. Flyover at Sion circle, Mumbai under construction

In the developed countries, integral bridges are being realised with abutments integral with deck. Continuity of deck results in a more economical profile with reduction in the cross section, thickness and dead weight of the superstructure. It is possible to eliminate the wearing coat altogether with the use of high performance concrete, as practised in the USA.

For obligatory spans (about 40 m) in-situ box girders are provided on grounds of aesthetics, involving disturbance/ closure of traffic for at least two months. Instead 'I' girders may be provided. The obligatory spans for Chennai flyovers consist of precast `I' girders to enable construction without disturbing traffic. For the obligatory spans of the Sion Flyover in Mumbai, the pretensioned beams are precast in three segments, and erected on temporary columns without dislocating the traffic. The prestressing tendons are then threaded through the preformed ducts and post-tensioned, as shown in Figure 7.

The construction on launching gantries can be considered for large spans. These are expensive items of equipment and their economic feasibility should be assessed. This can be considered only for long flyovers with many spans preferably of equal lengths. Their costs should be redeemed on the flyovers for which they have been designed and it should not be assumed that they may be of use on another project without the need of very expensive modifications. The author is aware of situations where such expensive launching girders were manufactured in anticipation of their continuous use for a number of projects. In reality they were used once in five years. It has not been possible to amortise the capital cost in a reasonable period of time.

Once in place, the launching girder or gantry should enable rate of construction of one span per three days. This has been achieved on a number of projects. During the construction of the 3.2-km long bridge at Dehri-on-Sone, involving 93 spans, a pair of launching gantries was able to transport and erect two spans (10 girders) every day.

Beam cross section

Many different types of cross sections have been used for precast beams. Precast 'I' beams placed at 0.6 m to 4 m centres; with in-situ concrete deck slab is common. The formwork for this slab usually consists of fibre reinforced panels or even concrete slab which is integrated into the deck. In India, flyovers are now predominantly constructed in reinforced or prestressed concrete, barring exceptions in Delhi, Calcutta. Standardisation has not yet been seriously attempted. The deck is made of either pretensioned or post-tensioned 'I' beams and deck slab or box girders. The piers are over-sized using low or medium grade concrete. Box girder decking is adopted indiscriminately, on grounds of aesthetics, irrespective of constructability problems. Where headroom is limited, a solid/voided slab or 'I' beam and deck slab should be the answer.

In India, for a typical 30 m span, it was usual to provide four 'I' beams for a 7.5 m carriageway. This was subsequently reduced to three beams and also two beams by many designers in order to realise the minimum quantities of concrete and/or steel. This does not necessarily result in overall economy and ease of construction. A number of bridges have been constructed for spans up to 50 m with two 'I' beams. Though optimised for quantities, this case has resulted in a number of problems. A heavier launching truss (200 tonnes) is required. The deck slab construction is quite expensive because of larger spans between the two beams. On occasions it was difficult to contain all the reinforcements within the optimised cross sections with consequent problems of difficulties in placement and compaction of concrete.

Figure 8. Panoramic view of the JJ flyover, Mumbai

In contrast, a 14 × 30 m span bridge deck was constructed in prestressed concrete over a short period of six months. In order to reduce general mobilisation, time and cost, it was decided to limit the weight of each precast girder to about 20 tonnes. This was realised by using eight girder configurations instead of three or four girders per span. Because of the reduced weight of girders, local arrangements were rigged for hoisting beam on to the deck. All the 'I' beams were precast, transported on rail tracks adjacent to the bridge and erected by using derrick. In retrospect, a review of quantities of concrete, reinforcement and prestressing steel actually used per span indicated that they were not more than what would have been the case with three beam combination.

High strength concrete

High strength concrete up to 80 MPa is now permitted in IS 456 : 2000. The Euro Code allows strengths up to 115 Mpa. In India,

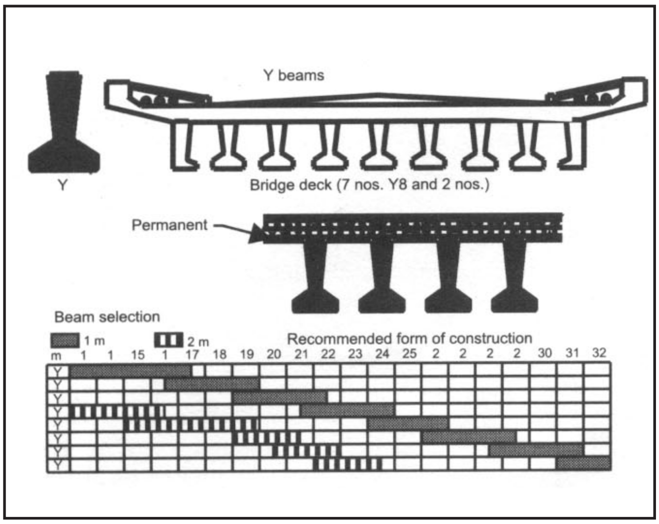


Figure 9. Standard Y beams recommended by PCA, UK

the JJ flyover has been constructed with 75 Mpa concrete, Figure 8. The Federal Highway Administration (FHWA), USA had investigated the feasibility of optimising cross sections for the high strength concrete. The same is relevant to India even for normal concrete. The use of concrete strengths of up to 85 MPa cube strength allows longer span lengths and more economical structures for existing beam sections. To effectively utilise higher strength concrete additional prestressing force must be applied in the form of smaller strand spacing, larger strand size, and higher strength strand or post-tensioning. The bulb-tee should continue to be considered as US National Standard for spans from 24 m to 61 m.

In India, compressive strength of 40-50 MPa is for pretensioned beams. However, strengths at release have often controlled concrete mix design so that the actual strengths at 28 days are often higher, but not utilised in the design, thus adding to the project costs. In one of the flyover projects under execution, characteristic compressive strength is 50 MPa and specified strength at release is 40 Mpa.

The mix was designed for the specified strength at release. Consequently the actual 28 days characteristic strength realised is excess of 65 MPa. This increases the cost without utilising the actual realised strength of 65 MPa plus.

The use of higher strength concrete enables a given section to be designed for a longer span length. The increase is greater when additional prestressed force is applied to the cross section. Otherwise, it is limited to the increase in allowable tensile strength at mid span. A shallow section with a high strength concrete can be more cost effective than a deeper section with normal strength concrete.

Effect of strand spacing and size

For concrete strength of 80 MPa, decrease in strand spacing from 50 mm to 38 mm enabled the maximum span length to increase by about 12 percent. The use of 15 mm strand instead of 13 mm is beneficial at higher concrete strength, increasing the maximum span length by about 10 percent. FHWA recommends the use of concrete with characteristic compressive strengths of 70-85 MPa (cube strength). Many precast factories are already producing beams of this strength.

The following approaches in order of efficiency are recommended by FHWA.

1. Use of 17.8 mm strand at 51 mm centres
2. Use of 13 mm strand at 38 mm centres
3. Use of 15 mm strand at 51 mm centres
4. Use Grade 300 strand in place of Grade 270
5. Increase bottom flange thickness by 51 mm to allow an additional layer of strands.

Beam spacing wider than 2.3 m may not be economical as the advantage of fewer girders is of-set by additional cost of decks spanning a large distance.

Integral bridges

Integral bridges are used widely in the USA, Canada, UK, Malaysia, etc and some are under construction in India. These are bridges with full/partial continuity at piers with abutment and possibly also pier heads built integrally with bridge deck. Expansion joints are totally eliminated. If pier heads are integral, bearings also dispensed with entirely. In many countries, the standards stipulate that all bridges up to 70 m length should be designed as integral bridges.

Figure 10. View of a typical precast pretensioned beam

The piers are designed to be flexible, with compliance foundations, to enable thermal movement of concrete without substantial resistance. The integral abutments are small (in order to limit the weight) which must move with the deck and to avoid excessive passive reactions during thermal expansion of the deck. However, the fill behind the abutment has sufficient passive resistance to deal with longitudinal, braking and traction forces.

Standardisation

The Ministry of Road Transport and Highways (MORTH) have attempted to set up standard drawings for spans up to 40 m, in reinforced and prestressed concrete. These are not being widely used, as they are not economical. The Konkan Railway Corporation (KRCL) adopted standardised precast pretensioned beams for flyovers. Where suitable founding strata were available at a depth of 3-8 m below grounds, open foundations were adopted with relatively shorter spans (20-30 m).

For Delhi Noida Bridge approaches, three flyovers with individual spans of 12, 16, 24 m were constructed with precast pretensioned 'I' beams. The cross section was standardised, with same dimensions for all the three spans. Only the number of pretensioned strands per beam was increased progressively for 12, 16 and 24 m spans. Only one set of formwork was used to produce beams of three different lengths.

Precast pretensioned beams have been standardised in the UK by the Prestressed Concrete Association (PCA) in consultation with the Ministry of Transport, UK Factory produced beams are accepted as bought out items for bridges, avoiding expensive individual designs for the deck. The manufacturers provide data concerning span range, crosssection of the beams, section properties, depth, area, self weight, reinforcement and HT strand details. In the case of 'Y' beams (most popular for spans in the range of 12 m to 31 m), the bottom flange dimensions are frozen whereas the depth can vary from 700 - 1400 mm, Figure 9. In the U.S, standard factory produced beam sections as per AASHO / PCI norms are adopted.

In the absence of standardisation in India, chaotic conditions prevail. No two designs, even by the same organisation, are identical. Formwork has to be manufactured for each flyover increasing the cost. The equipment in the precasting yard is not standardised, leading to duplication of work. Even the handling gantry has different spans and load capacities in different sites. The concrete characteristic strength as well as strength at transfer of prestress varies widely, for no apparent reason. Efforts are duplicated in designing the mix repeatedly even for flyovers in the same region.

In the UK, all pretensioned factories produce beams with characteristic strength of 60 MPa and transfer strength of 40 MPa. Even in the case of Maharashtra State Road Development Coporation (MSRDC) flyovers, more than a dozen deck cross sections were adopted in the same city. With such diversity, centralised factory production is rare. Each of the dozen or more contractors has put up precasting yards of varying designs at the respective flyovers site.

Expensive steam curing has been adopted in the precasting yards. In most parts of India, the ambient temperatures are high and steam curing can be eliminated without increasing time cycle. For construction of seven flyovers in Delhi, the author had insisted on standardised precast pretensioned beams of about 20 m spans. Except during winter, beams were produced on 24 hours cycle without steam curing Figure 10. The concrete mix was designed for high early strength and the strands de tensioned after 16-18 hours. In contrast, many others work on three days cycle, with steam curing.

Length of flyovers

Many factors are involved in deciding the length of flyovers, including headroom to the soffit of the deck, the approach gradients, the strength of concrete, the design speed and the length of reinforced earth approach. By a judicious choice, based on ground realities, it is possible to substantially reduce the length of stilt portion of the flyover.

Cost of flyovers

Flyover cost in India is substantially higher compared to developed countries. This is probably due to conservative specifications, absence of standardisation frequent changes in decision making, uneconomic concrete mixes, and discontinuing design- build contract. Alternative designs by the bidders results in savings up to 10 percent and rationalising codes and updated specifications will reduce cost by about 20 percent.

Benchmarking

There has been no organised attempt at benchmarking for design and construction time or economics. The construction time is generally arbitrarily fixed. In contrast, benchmarking in other developing/developed countries reduces construction time and cost. The author, as an UNDP expert in Teharan (Iran), witnessed the completion of a flyover in exactly 30 days, thanks to benchmarking – seven days for pile foundations using rotary rigs. The precast RC piers and prefabricated steel girders were installed at night time and concrete deck slab cast in-situ.

The MSRDC flyovers in Mumbai benchmarked time of 12 to 17 months, with a stiff bonus/penalty clause and realised those four to six months ahead of schedule. Choice of materials of construction including structural steel was left to the prospective bidders; international codes such as BS/DIN/ ASTM etc were permitted. These inbuilt flexibilities had resulted in a fast track construction at a reduced cost.

Buildability

The following aspects should be examined for easy buildability.

1. Type of foundations: Open foundations are appropriate for shallow depths. With modern rotary

piling rigs, very high speeds of pile installation are possible. One or two foundations can be realised per rig in a day.

2. Detailing of reinforcement to facilitate easy placement of concrete and effective compaction. Congested reinforcement should be avoided by the use of higher grades of reinforcement, bundling bars, avoiding laps, using mechanical couplers etc. Mock-up of critical components should be carried out in advance to examine buildability.

3. Bridge geometry should be kept simple, avoiding unnecessary curves, skews, variations in superelevation and splays.

4. Working below water table is hazardous and expensive. The top of the foundation bases should therefore be kept above the water table.

Method of construction and methods statement

A viable method of construction should be an integral part of any design. The designer's assumed construction method and sequence should always be presented in the drawings. The designer should state any special constraints, which the design would impose on alternative methods of construction. In order to be right the first time during construction, the owner, the consultant and the contractor should understand the meaning of various documents and arrive at a common approach. This will result in timely construction of right quality, avoiding the infructuous expenditure and additional time for correcting mistakes.

These are best realised by the preparation and use of Methods Statement by the contractor, scrutinised by the consultant /owner. Once approved, the Methods Statement should have the same sanctity as the contract documents. Methods Statement is intended to describe in detail the sequence and manner of construction. Existence of an agreed method statement reduces tension and conflicts between the inspectors and the construction personnel. Early approvals are also realised, thus reducing the construction delays.

Project management

Traditionally, the engineers appointed by owners have been managing the projects. Employment of independent project management consultants (PMC) based on expertise in flyovers by MSRDC facilitated fast track construction. The PMC assisted the owners in soil investigation, preparation of tender documents, pre-qualifying the bidders, evaluation of tender documents, etc. After the award of the work, the PMC proof checked and recommended approval of contractor's designs, supervised the project, ensured quality assurance and certified the payments. Designs were scrutinised and approved in weeks and bills certified in days.

Types of contract and alternative designs

In India, most of the road bridges and flyovers built until 1985 were based on the alternative design by contractors. Innovations in bridge/flyover construction in India were brought out only by alternative design. This includes:

1. the first reinforced concrete bridge
2. the first prestressed concrete railway and road bridges
3. the first prestressed concrete cantilever/segmental construction
4. the first externally prestressed concrete viaduct
5. the first cable-stayed bridge
6. the first cable stayed flyover
7. the first pretensioned deck for flyovers.

The primary advantages of the alternative designs include:

1. innovation in design and construction
2. greater risk allocation to the contractor
3. an inbuilt desire to economise on cost in order to secure the project.
4. the prospective bidders' past experiences effectively utilised.
5. the effective utilisation of contractor's equipment.

Some employers feel that alternative design involves conflicts and delays in approvals of designs leading to delays in delays in construction. This depends entirely on the mindset of the proof checking authorities. Even after change over to designs by consultants in the recent past, delays in approval and construction have continued depending upon the personnel involved. The Indian Railways use item-rate contracts, with own designs or by consultants.

Europe follows the alternative design concept for bridges and flyovers. UK employs consultants for designs. In the USA, the contract is awarded based on the owners/Consultants design with a value engineering clause. The contractor then proposes cost effective, alternative design. The employer scrutinises and accepts same. The savings are shared equally between the employer and the contractor. A number of bridges and flyovers have been realised during the last decade with savings of about 10 percent or more. Value engineering is obligatory for all US projects costing US $ 10 million or more.

Quality of tender documents

In India, there are more than 100 different general conditions of Contract, leading to confusion, conflicts, cost and time overruns. The use of FIDIC Conditions of Contract, drafted by the federation of various international consultancy bodies, including India, is preferred. The FIDIC Conditions are universally adopted for majority of international projects. In India also, they have been in force for all internationally funded projects.

The Technical specifications should be precise. A classic case of conflict concerns the specifications for concrete. IS: 456 specify standard requirements for materials and workmanship. In practice, many tender documents refer to IS: 456 and in addition specify confusing and contradictory requirements. Many owners/consultants specify arbitrarily higher values for minimum cement content and wasteful method of mix design leading to increase in cost and decrease in quality of concrete.

Prequalification of bidders and pre-bid activities

Flyovers are highly specialised items and prospective bidders should be carefully prequalified, based on standard criteria. The number of prequalified bidders for each project is limited to five, to give opportunities to technically qualified and sound bidders and at the same time provide a reasonable level of competition.

However, in India there are cases of 40 to 50 prequalified bidders. The prebid meeting is a must and all genuine problems of the prospective bidders should be given serious consideration and amendments issued.

Quality assurance

Due to the speed of construction and pressure on supervisory personnel in fast track construction, unintended quality deficiencies may occur. Adoption of ISO:9000 minimises quality deficiencies. The design and construction organisations should get ISO:9000 certification or should at least follow all the ISO:9000 requirements in practice. The author's organisation had recently successfully completed construction of a 2.645-km long prestessed concrete bridge across the river Godavari in a period of 2 years at a competitive price. A good deal of success was due to the project management consultants and contractors holding ISO certification.

Reinforcement detailing

The detailing should use a minimum number of diameters of bars. It is always a good practice to standardise the diameter of the reinforcement to be used. This should be done after taking into account the easy availability of the respective diameters from the prime producers. Some diameters of TMT bars are either not being manufactured at all or not readily available, are best avoided in the designs. For one of the flyovers under construction, the pile cap design and detailing included four different diameters (8, 10, 20, 25 mm). This could have actually been reduced to two diameters (10 and 25 mm).

The specification should only give reference to IS Codes. Phrases such as "Cold rolled, TMT, CRS" etc are not appropriate. Complicated shapes and multiple leg stirrups should be avoided as they increase the cost of construction. The designer should always provide the bar bending schedules to the construction team who will scrutinise and comment on the same if required, to facilitate construction.

Mineral admixtures

IS 456:2000 permits blending of mineral admixtures — fly ash, GGBS, etc — to produce blended cements or in the concrete batching plant. Concrete is sourced from RMC plants or automated batching plant at site. The mineral admixtures can easily be incorporated in the site mixed concrete without difficulty. The minimum cement content specified in the codes is really meant to be "minimum cementitious materials content". Thus when a minimum content of say 400 kg/m^3 of concrete is specified it means sum total of cement plus mineral admixtures.

Future research requirements

The future research requirements are:

1. transfer and development lengths in pretensioned beams
2. deflection, lateral stability and dynamic characteristics
3. prestress loss
4. post-tensioning in stages
5. combination of pretensioning and post-tensioning.
6. designed strength age (56/90 days rather than 28 days).

Conclusions

Fast track construction has become the emergent trend the world over. In India, the concept of fast track construction is catching up. With huge investments planned during the next five years, it is inevitable that fast track construction will become the norm. This requires complete change in the mindset of all concerned.

1. General Conditions of Contract need to be standardised.

2. Codes and specifications should be updated judiciously used.

3. All flyover construction should be machine oriented.

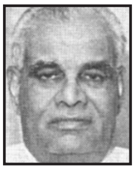
4. The PMC concept should be extensively used.

5. Value engineering should be practised.

6. New construction materials should be used.

7. Alternative designs should be encouraged.

8. Reducing headroom and design speed and using high performance concrete will substantially reduce the flyover lengths.



Mr S.A. Reddi has a wide and rich experience of over fifty years in various types of concrete constructions in India and abroad. The projects handled by him include prestressed concrete bridges, major railway bridges; specialised concrete production and placement techniques for sub-Sahara temperature conditions, etc. Currently, he is the Deputy Managing Director, Gammon India Ltd. He is a strong advocate of good construction practices. Mr Reddi is actively involved in the activities of many professional bodies and technical committees. He has been instrumental in bringing out many modifications in IS 456. He was a UNDP consultant in Iran, Vice Chairman of the Indian National Group of International Association for Bridge and Structural Engineering (IABSE). He was also the President of the Indian Concrete Institute during 1993-95.

(Source: ICJ July 2003, Vol. 77, No. 7, pp. 1175-1183)