Short-to-medium span bridges - Need for standardisation of precast elements

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The paper lays emphasis on the urgent need for development of standard designs to encourage the growth of prefabrication in India, in response to the increased needs for improvements in quality and performance in bridge construction industry. The paper also presents an overview of prefabrication in other countries where mass produced precast beams are commonly used in bridges.

There have been numerous pioneering innovations in the field of bridge engineering over the last four decades in India. Prestressed concrete, which first came into practice about 40 years ago, is now the most common form of construction material for bridges. The present trend in India is to adopt prestressed concrete for spans of about 20 m and above. Reinforced concrete is generally used for short and medium span bridges upto 25 m span.

Use of structural concrete for short and medium span bridges is coming under closer scrutiny today as design engineers, contractors and owners strive to optimise, and achieve speedier construction along with long-term durability.

With the demand for rapid infrastructural growth in India, the construction industry would require a multiple choice in the selection of bridge components. The designer will be left with no other choice than to extrapolate the existing system to meet this demand. The precast concrete industry which is presently in its infancy in India, is ideally placed to accommodate these higher demands.

The objective of this paper is to highlight the need of developing standard designs adopting precast elements in order to encourage the precasting industry to grow from infancy. The paper also highlights in detail the salient design and construction aspects of precast elements adopted in other countries and compares with the present practice in India.

Present practice in India

In India, concrete is the most common material of construction for bridges, flyovers, and cross-drainage structures.

The main form of construction for spans of 3 m to 10 m is cast-in-situ reinforced concrete (RC) slab. For spans beyond 10 m, upto 25 m, RC - T beam and slab system using cast-in-situ construction is generally adopted. In urban flyovers, cast-insitu concrete voided slab is a common structural form.

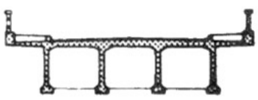
For spans above 25 m, prestressed concrete (PSC) T beam with in-situ RC slab type of construction is widely used, while for bridges and flyovers with longer spans, PSC box girders are the common forms.

The various structural arrangements and construction technologies generally adopted are shown in Table 1. It can be seen that in India, the precast elements are seldom used in bridge construction, in contrast to the global trend. This is mainly because of the policy of selecting the lowest bidder which has often not proved to be the most economical solution.

There have been limited progress in standardisation of analysis and design initiated by the Ministry of Surface Transport (MOST) (Roads Wing) for a few types of spans[11]. The MOST standard designs are, however, developed essentially for cast-in-situ construction.

Though development of MOST standards have resulted in saving in design time and also ensured improved quality of design / detailing, the quality of construction at site in majority of the cases are found to be poor. The reasons for poor quality of construction could be many, such as use of poor quality of shuttering, poor mixing and placing of concrete, poor quality of supervision work at site, etc., especially for bridges located in remote areas.

Table 1. Typical cross-sectional arrangement

Type of superstructure	Span range	Typical application	Method of construction	Remarks
 RC slab bridge	3.0 m - 10.0 m	Right/skew slabs for slab culverts, minor bridges for railways/ highway in urban areas, hilly roads, underpasses, etc.	Cast-in-situ on staging, scaffolding.	In-situ construction is invariably used. The construction being labour intensive, is economical in India. MOST standard drawings are available for highway slab bridges. It is diffiicult to control the quality of construction in these bridges since mostly the work is entrusted to local contractors with little/no exposure to quality works
 RC/PSC voided deck	13.0 m - 25.0 m (For RC voided deck)	Minor/major bridges, flyovers, curved bridges, skew crossings, underpasses.	Cast-in-situ on staging, scaffolding.	The structural arrangement is aesthetically pleasing. Usually adopted for urban flyover projects, situations where consideration of headroom is important.
	20.0 m - 35.0 m (For PSC voided deck)	Minor bridges, flyovers, curved bridges, skew crossings, interchanges, grade separators.	Cast-in-situ on staging, scaffolding.	
 RC/PSC T-beam and RC deck	10.0 m - 24.0 m (For RC T-beam and deck)	Minor/major bridges over streams, canals, rivers, ROB's, underpasses.	Cast-in-situ on staging, in most of the cases. In exceptional cases where casting on staging is difficult, prec.ast T-beam with RC deck is done.	The system is widely used for bridges in remote areas. The structural arrangement is aesthetically not very pleasing. Moreover it is difficult to control the quality of construction in these bridges since mostly the work is entrusted to local contractors with little/no exposure to quality works.
	25.0 m - 40.0 m (For PSC T-beam and deck)	Major highway/ railway bridges, flyovers, underpasses, ROB's, bridges over deep gorges.	PSC girder is either precast in casting yard or cast-insitu. Deck slab is cast on staging erected from girder.	The system is widely used for bridges over major rivers, deep gorges, flyovers.
 RC/PSC box girder	20.0 m - 40.0 m For RC box girder)	Major highway/ railway bridges, flyovers, underpasses, ROB's, bridges over deep gorges.	Cast-in-situ on staging, scaffolding.	The box girder is generally used for major bridges over rivers, flyovers. The structural form is aesthetically pleasing in appearance.
	25.0 m - 60.0 m (For PSC box girder)	Major highway/ railway bridges, flyovers, underpasses, ROB's, bridges over deep gorges.	Cast-in-situ on staging or over centering truss. Alternatively precast in casting yard and launched in position using floating barges.	Most widely used structural form for majorbridges and flyovers. In most of the situations cast-in-situ construction is followed. However, in recent times precast girders had been successfully adopted in few bridges.

There have been significant changes in the government policies and objectives as regards upgradation of transport network, in the past decade or so. The concept of achieving economy through acceptance of lowest bid and minimum use of construction material, has given way to a broader approach which includes:

1. Durability and serviceability
2. Quality
3. Life cycle cost

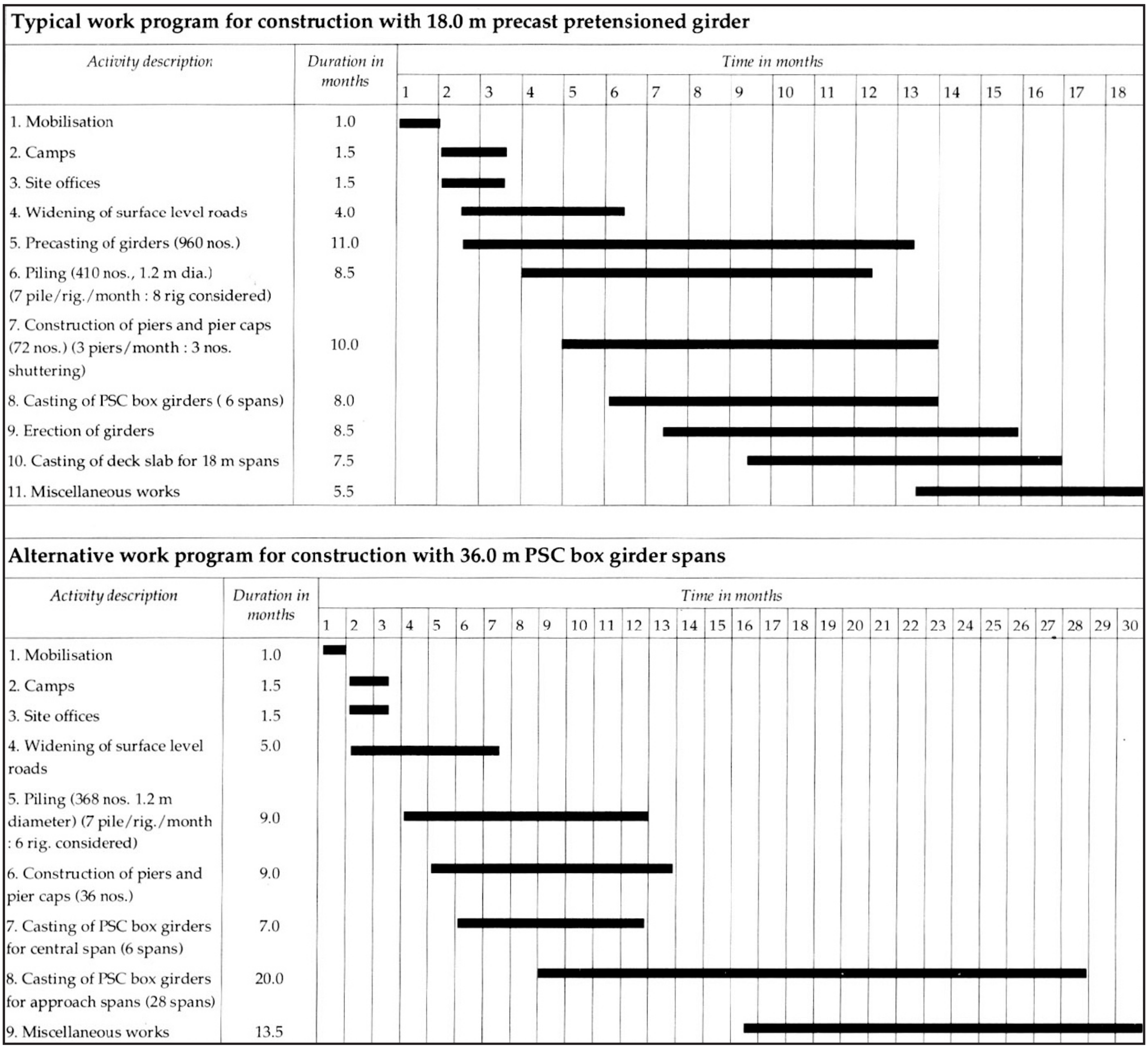


Figure 1. Work programme for flyover project in Delhi at a busy intersection

4. Ease of operation and maintenance

5. Visual impact of the structural form (Aesthatics)

6. Environmental impact

These trends have highlighted aspects such as standardisation, prefabrication etc. in the execution of bridge projects.

Recent applications of prefabricated girders

An innovative technique using precast pretensioned girder has recently been adopted for four flyover projects in Delhi[2, 3]. Precast, pretensioned factory produced I-girders of 18.0m span have been successfully used in these flyovers. The centralised factory for mass production of girders is located at the outskirts of Delhi and is geared to produce about 100 girders a month. The adoption of precast pretensioned girders for these flyovers has resulted in considerable saving in cost and time of construction. It has also resulted in improved quality of construction with minimum hindrance to traffic during construction work. Structural scheme using precast pretensioned I-girders has also been adopted for a flyover project in Jammu (presently under construction).

Similar innovative superstructure schemes using precast pretensioned girders were also adopted for some of the railway bridges along the Konkan Railway route. The original design by the Railway authorities was for standard spans of 22.8 m (on centres of pier) with precast post tensioned girders. The contractor came out with an alternative design adopting pretensioning system with steam curing for the same span. The

Table 2. Summary of important data for proposed expressway between Delhi and Ambala

No.	Particulars	Major bridges		Minor bridges	
1.	Existing number of bridges	16		41	
2.	Total length of existing bridges	1,132 m		697 m	
3.	Total estimated length	1,318 m		903 m	
4.	Estimated cost with cast-in-situ proposal	Rs 518.2 million		Rs 234.5 million	
5.	Average cost/sqm of carriageway covered width of carriageway = 23.6 m	Rs 16,660/-		Rs 11,000/-	
		Using 20.0 m precast girders superstructure	Using 30.0 m PSC voided slab PSC box superstructure	Using 15.0 in precast girders superstructure	Using 22.0 m PSC voided slab superstructure
6.	Approximate number of spans	66	44	60	41
7.	Approximate number of foundations	82	60	101	82

pretensioning trough was designed in such a way that it could be dismantled, transported to other sites of works and re-assembled (a mobile precasting factory).

Adoption of such innovative system incorporating prefabrication and construction has resulted in saving in overall cost and time and also led to improved quality of construction.

Need for standardisation

Standardisation of design for small and medium span bridges, which constitute nearly 90 percent of the total bridging on highways would confer enormous benefits as regards the time and cost factor. Standardisation of engineering design using factory produced precast elements for these structures will not only improve the quality of construction (and therefore utility of structure), but would also result in speedy construction and early completion of the projects.

The need for standardisation of design using prefabricated girders arises out of the growing realisation among the engineering fraternity for faster and environmentally-friendlier construction and demand for higher quality of workmanship. The high quality of precast elements, cost effectiveness of mass production in factory environment and unquestionable aesthetic quality of the concrete makes it the material of choice for short to medium span bridges.

The principal advantage of construction with prefabricated elements over other forms of construction are as follows :

1. Prefabrication minimises the construction activity required on site and enables a substantial simultaneous progress in the construction of the substructure and superstructure reducing the overall construction period considerably.

2. The use of precast elements reduces the requirement for formwork and supporting falsework at site. Multiple use of custom-made forms leads to economy and enables a high quality steel mould to be used. This leads to high quality of finish.

3. Quality control is likely to be more effective in a centralised unit rather than at site where concrete may have to be transported to considerable distance on roads and placed in structures which have been exposed to direct sunlight, drying winds and dust.

4. For construction on busy roads, the reduced construction activity at site due to precasting reduces the problems of traffic management during construction by a great deal.

The precast elements can be either of reinforced concrete or prestressed concrete. In case of prestressed elements, stressing can be achieved by either pretensioning or post tensioning, or a combination of the two.

As it stands today in India, there is currently no standardisation of precast bridge products within the industry. Another important point to be noted is that there are no specific guidelines/recommendations/ provisions for the design and construction of pre-fabricated girders in the present Indian Roads Congress (IRC) codes of practices. In fact, there is no IRC code for pretensioned structures. Therefore, in absence of any relevant codal guidance for design of factory-produced precast elements, one encounters difficulties in implementation of project using prefabricated units. This is considered to be one of the prime reasons for restricted application of precasting technique in bridge industry till date. A step forward in this regard was taken by formulating guidelines for precast, pretensioned girders by consensus for four flyover projects in Delhi.

Some of the short-comings of IRC codes in this respect are:

1. The IRC:18-1985 is applicable only for post-tensioned structures. There is no similar IRC code for pretensioned and prefabricated post-ten-sioned structures.

2. Some of the recommendations given in the IRC special publication-33 are more appropriate for cast-in-situ, post tensioned structures and requires review for

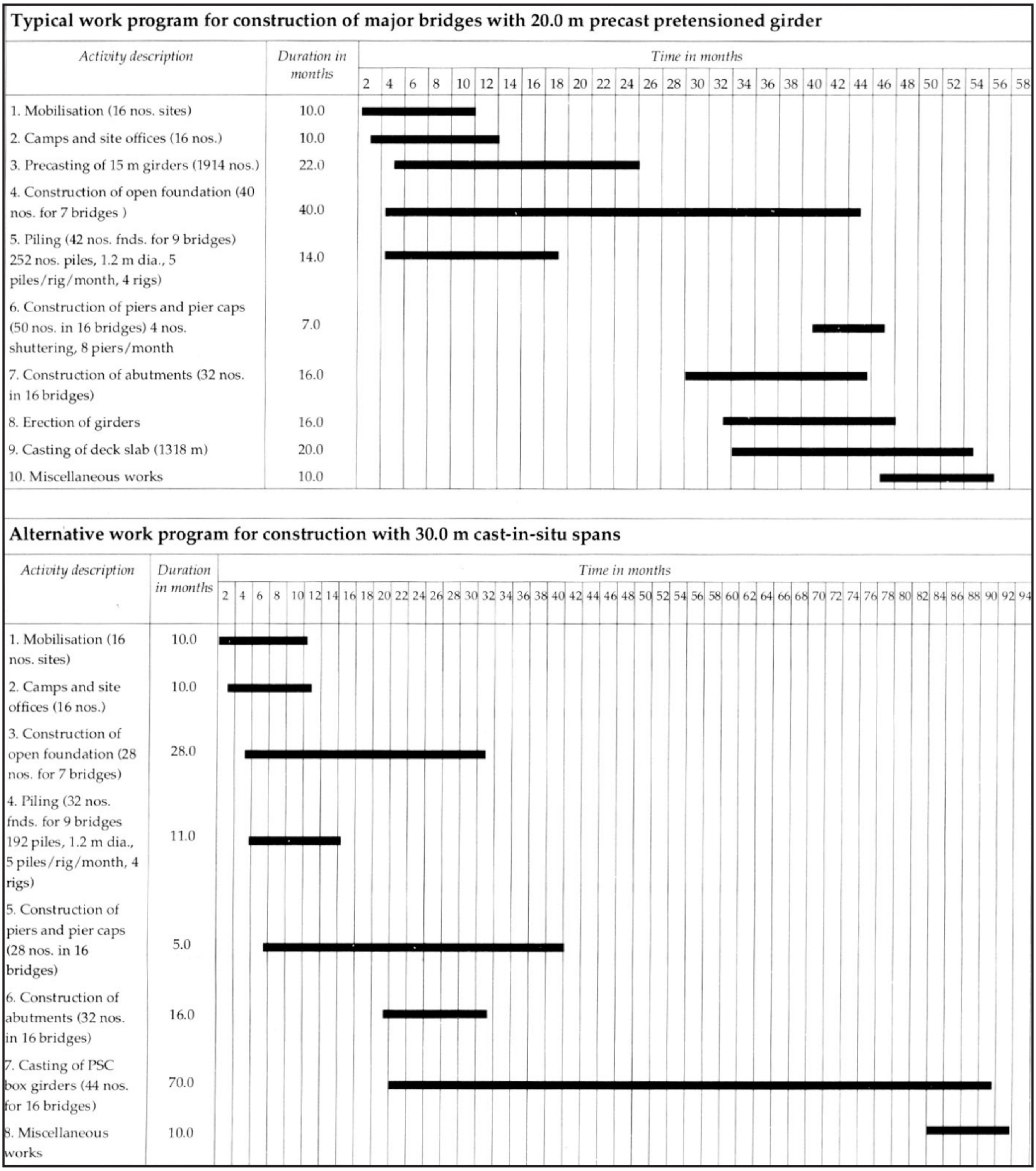


Figure 2. Expressway project between Delhi and Ambala

pretensioned and pre-fabricated structures.

These provisions are :

1. minimum web thickness of 200 mm plus duct diameter
2. minimum diameter of 10 mm for untensioned reinforcement and minimum clear cover of 50 mm to any reinforcement
3. minimum thickness of 200 mm for deck slab and minimum thickness of 150 mm for tip of cantilever slab etc.

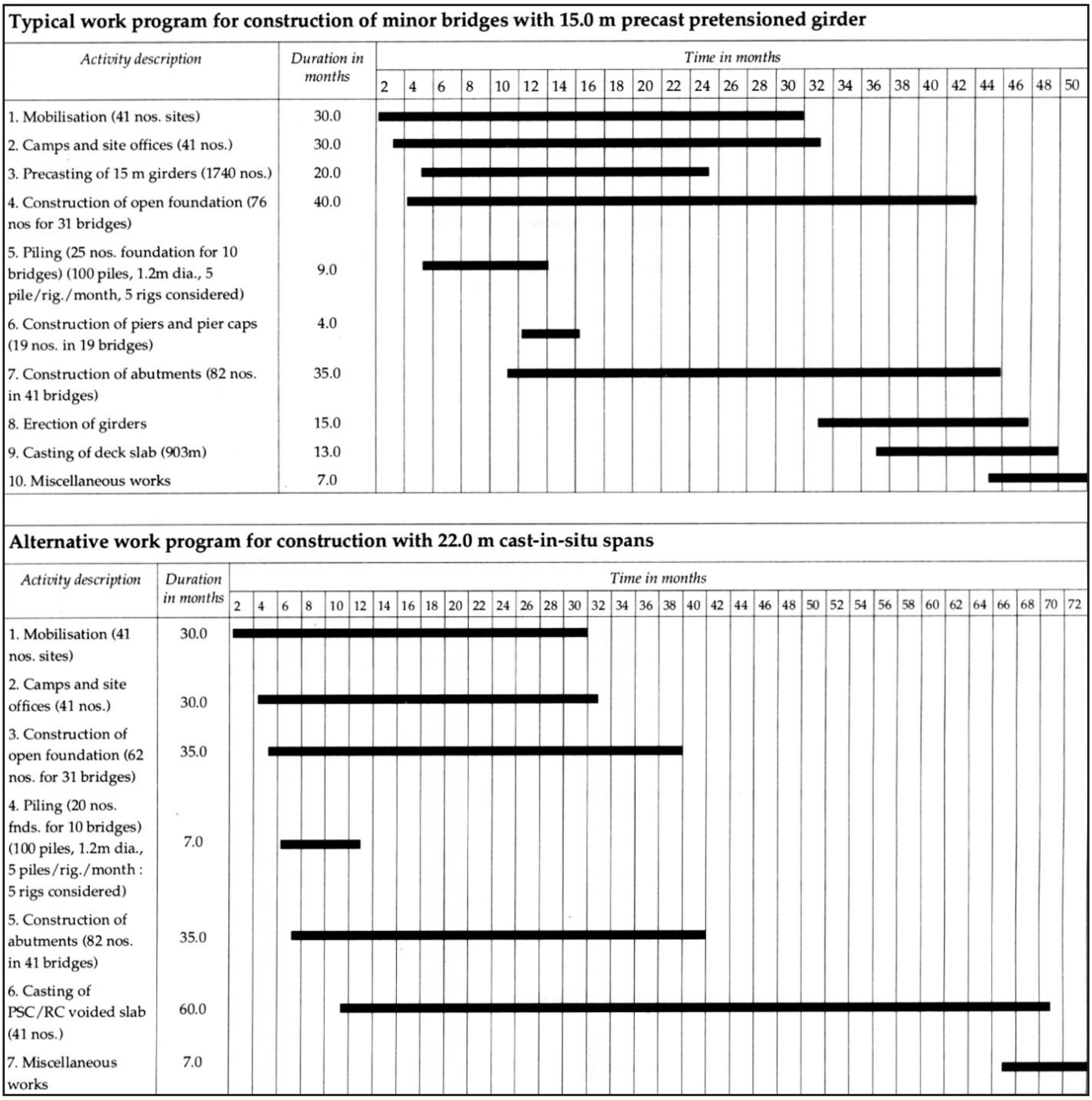


Figure 3. Expressway project between Delhi and Ambala

For precast, prefabricated structures, the above provisions need review from following consideration :

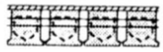
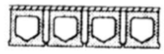
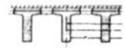
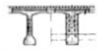
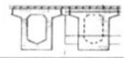
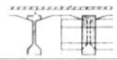
1. higher quality control which can be achieved in factory environment
2. for keeping the dimensions of prefabricated members as minimum as possible for ease of handling and transportation, keeping the durability and safety requirement into considerations.
3. for reduction in the time of construction period.

Hence, updating the IRC codes and other relevant documents would be a significant step taken towards increasing the awareness of application of precast element in the bridge projects and also towards the growth of prefabrication industry in the country.

Post-tensioning of precast units

An advantage of post tensioning system is that the prestressing cable ducts can within reasonable accuracy, be located at the optimum position to control the stress over the full length of the beam. It is usual to provide a draped profile for cables. The provision of duct for post tensioning may however necessitate an increase in web thickness to provide for the required shear

Table 3. Precast, prestressed concrete sections used for short to medium span bridges in Japan

Typical section		*Base width, mm*	*Depth, mm*	*Span rang, m*																				*Typical construction details*
				2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	
	Pretensioned solid box girder	700	325 to 400			■	■	■																
	Pretensioned voided box girder	700	425 to 800						■	■	■	■	■											
	Pretensioned T-girder	750	800 to 1060								■	■	■											
	Post tensioned T-girder	1500	1050 to 2150											■	■	■	■	■	■	■	■	■	■	
	Post tensioned box girder	1000 to 1600	800 to 1600													■	■	■	■	■	■	■	■	
	Post tensioned T-girder	650 to 1050	1560 to 2450											■	■	■	■	■	■	■	■	■	■	

resistance and to accommodate the cable.

Post tensioning however would not be advantageous for short and medium spans as the losses due to slip at anchorages would considerably reduce the effective prestress. Secondly, in post tensioned beam, it may be difficult to place concrete around relatively thin webs. The ducts will require to be grouted following stressing. Additional reinforcement would be needed at the ends of the beams to resist the bursting effects of the anchorages.

Pretensioning of precast units

Precast beams with straight pretensioned fully bonded tendons are very common and convenient for detailing and manufacture. When the prestress is applied, the initial theoretical tensile stresses at the top of the section are counteracted by the self weight sagging moment induced compressive stress at the same point. Undesirable stress at transfer may be reduced by debonding of tendons in a graduated manner towards the ends of the beam.

Precast pretensioned longitudinal beams for the bridge deck is the most commonly found bridge system in various developed countries[4]. The main advantages of pretensioning for short and medium span bridges over post-tensioning are:

1. Beams can be produced in a factory, hence production is independent of weather conditions.

2. Continuous production can be achieved.

3. There is statistical control of the quality of the materials (concrete, steel, etc.) and control of the means of fabrication; conformity to the drawing and dimensional tolerances.

4. Dimensions of the elements can be reduced resulting in economy and ease of transportation.

A comparative study was carried out using precast pretensioned girders vis-a-vis alternative cast-in-situ girders for two recent projects in Delhi region. The summary of the above study is presented here.

Project - 1 : Proposed flyover over busy intersection at Punjabi Bagh, Delhi

A comparative study of economics with spans of 18.0in precast pretensioned girders vis-a-vis 36.0m cast-in-situ PSC box girder for the approach viaduct of the flyover was worked out. The choice of 18.0m pretensioned girder was made with a view to make use of the existing centralised factory for production of girders situated at the outskirts of Delhi and owned by DT&TDC.

The comparative study was made considering the following factors only:

1. cost of construction

2. time required for construction.

Since the cost of construction was dependent upon the period of construction, the escalation in cost of the estimated period of construction was also accounted for. The indirect cost saving for 18.0m span alternative in terms of vehicle operating cost (VOC), due to speedier construction, due to lesser inconvenience to traffic during construction period and due to better quality of construction was difficult to quantify hence not considered for cost comparison.

The results of the comparative study indicates:

1. Period of construction with precast girder was estimated as 18 months while with 36.0m PSC box girder (cast-in-situ) it worked out as 30 months, Figure 1.

2. The cost of construction with 36.0m span was about 25 percent higher than with 18.0m spans.

Table 4. Precast, prestressed concrete sections used for short to medium span bridges in United Kingdom

Typical section	Base width, mm	Depth, mm	Span range, m (2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40)	Typical construction details
SBB	600	225 to 600		
Inverted T-beam	495	300 to 815		
M beam and UM	970	720 to 1300		
Y beam and Y edge beam	750	700 to 1400		
U beam	970	800 to 1600		
Standard box and edge	970	510 to 1510		
Wide box beam and edge	1257	510 to 1510		

Project - 2 : Proposed expressway project of about 160 km long between Delhi and Ambala.

One of the key factor in the evaluation of economic viability of this BOT project was time of construction and its cost effiectiveness. Therefore, the study comprised of comparison of time of construction and cost for the major and minor bridges using proposed precast pretensioned girders vis-a-vis cast-in-situ PSC/RC slab/girder. The said alignment is almost parallel to and located on the west side of NH-1 towards river Yamuna. The salient data such as number of major and minor bridges, length of the existing bridges and estimated length of proposed bridges etc. were prepared based on the inventory of bridges for State of Haryana. Some of the relevant information has been presented in Table 2. Following span types were considered for this comparative study.

For major bridges

20.0 m precast pretensioned girder vis-a-vis 30.0m cast-in-situ PSC voided slab/PSC box girder.

For minor bridges

15.0m precast pretensioned girders vis-a-vis 20.0m cast-in-situ PSC/RC voided slabs.

The study estimated the period of construction for major bridges with precast pretensioned girders to be 55 months whereas the same with cast-in-situ PSC voided slab/PSC box girder is works out to 92 months, Figure 2.

Similarly, the period of construction for minor bridges with precast girders is worked out to be 50 months in comparison to the same with cast-in-situ scheme 72 months, Figure 3.

The following inference may be drawn from the above analysis:

1. The cost of project would be affected considerably due to increase in the time of construction causing escalation of the cost of project and loss of revenue from toll income.

2. The economic feasibility of project would largely be dependent upon the above factor.

The growth of prefabrication industry in India would be all the more important considering the increasing trend in the execution of projects under BOT system brought about by the new economic reform policy.

Transportation and storage of precast elements

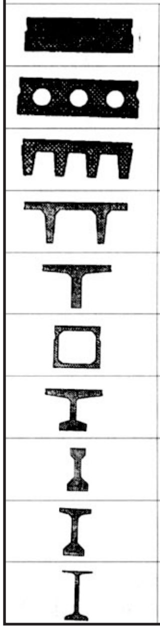
Apprehensions have been expressed in ceratin quarters regarding the problem of transporting large number of precast elements on Indian roads where turning radius is small and width inadequate. The authors feel that these apprehensions are exaggerated. In many big cities and metropolitan areas, it may be possible to overcome the transportation problem.

Apprehensions are also expressed regarding the problem of storing the large number of girders in a precasting factory. The authors are of the opinion that the precasting factory can always be designed to stack the desired number of girders. Moreover, the girders can also be stacked at site, depending upon the available space.

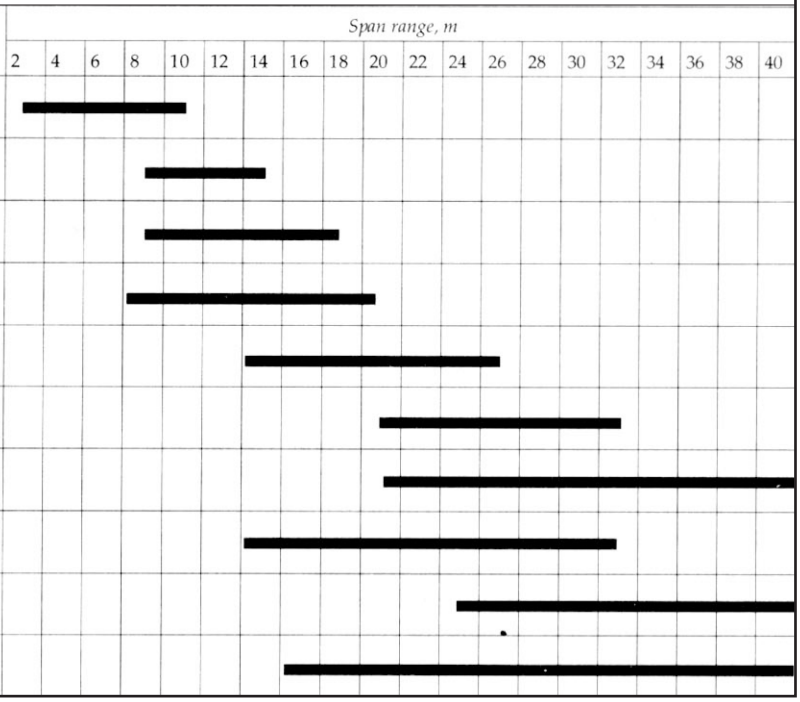
Practice in other countries

The salient features of design and construction using precast, prestressed concrete girders for bridges with spans ranging from 2 to 40 m in four countries, namely Japan, UK, USA and Sri Lanka, is presented here. Comparisons are made among Japanese, British, American and Sri Lankan systems related to such factors as span range and the corresponding width and depth range, the typical construction details, weight of precast members etc.

Table 5. Types of precast, pretensioned concrete beam sections used in United States



Typical section	Base width, mm	Depth, mm
Solid slab	910-2440	250-460
Voided slab	912-1220	380-530
Multi stem	1220	410-530
Double stem	1520-2440	410-580
Single stem	1220-1830	610-1220
Box girder	910-1220	960-1070
Deck bulb tee	1220-2130	740-1040
I-girder	460-660	910-1370
AASHTO/PCI bulb Tee	1070	1370-1830
Local standard I-girder	610-1520	710-2740



Japan

Cooperation between the precast concrete industry and Japanese transportation authorities has produced highly successful standardised bridge systems.For the past three decades, bridges with precast, pretensioned concrete girders spanning upto 21 m have accounted for more than 97 percent of the total number of prestressed concrete bridges constructed in Japan[6]. During the period between 1985 and 1989 alone, 6151 precast, pretensioned bridges were built.

Three types of standardised precast pretensioned concrete girders, namely pretensioned solid box girder, voided box girder and T-girders and three types of standardised precast, post tensioned girders, namely post tensioned T-girder, box girder and I-girder are used for highway bridges in Japan. The maximum length of the girder that can be moved from a precasting yard to any construction site is limited to 21.7 m by the transportation authorities. In view of this constraint, the span length of precast, pretensioned girder bridges is limited to 21 m. In unusual cases, larger girders have been utilised, with special permission from the transportation authorities. For the post- tensioned girders, the span length varies from 20 to 40m. These girders are precast at the bridge site obviating transportation.

Table 3 lists the various types of precast, prestressed concrete girders used for short to medium span bridges in Japan, giving details of span range, corresponding depth, width ranges and details of typical construction.

United Kingdom

Precast prestressed concrete beams are used for a majority of the new, widened, and rebuilt road bridges in the United Kingdom. Standardised off-site prefabrication, under controlled factory conditions offers optimum speed of construction at an economical cost. Over the years since World War II, these advantages have enabled precast beams to take over from the traditional masonry and in-situ concrete alternatives. The long term durability of precast concrete, with minimal maintenance, is considered superior to that of structural steel.

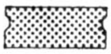
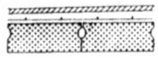
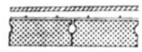
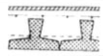
The range of precast prestressed bridge beams manufactured by a precast concrete manufacturer comprises seven types[7] - four with related edge beams, that can bridge upto 36-m using recommended type of construction. The range of beams has been developed in conformity with the Department of Transport, UK and British Rail. The bridge beam types, SBB and inverted T beam constructed with infill concrete span from 3 m to 17 in, whereas the types, M beam, Y beam and U beam constructed with in-situ deck slab span from 13 m to 34 m. The third type, that is, standard box and wide box beam span from 12 m to 36 m.

A brief summary of types of bridge beams with the span range and the corresponding range of base width and centre depth and typical construction details for the above seven types of bridge beams has been presented in Table 4.

United States

In the United States, precast prestressed concrete I girders were first used in bridge application in the early 1950's. Presently, they have become the most commonly-used girders in 21 m to 36 m span range. Several states in the United States have their own standardised shapes and methods of production. In 1956, the Federal Highway Administration

Table 6. Standard precast, pretensioned beams used in Sri Lanka

Typical section		*Base width, mm*	*Depth, mm*	*Span range, m*																				*Typical construction details*
				2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	
	Solid slab	610	178	■	■	■																		
	Solid slab	610	203 to 228			■	■																	
	M-beam	610	368				■	■	■															
	Inverted T-girder	457-610	610 to 648							■	■	■	■											--

(FHWA) adopted its own standards for precast concrete I girders. These shapes are now known as girders. Some states have continued to rely on the Federal Standards while other states have developed their own standards. This uncoordinated evolution has resulted in significant diversity in the girder shapes that are used from state-to-state throughout the nation. The Washington state bridge beams and AASHTO-PCI standard beams are such two standards used in the United States.

The Washington State bridge beams are used for composite structures, the cast-in-situ slab being added to the top of these sections in a manner similar to the AASHTO-PCI standard beams. The Washington State sections have thinner webs than the AASHTO-PCI beams, which are standard in many states.

The exhaustive survey on the performance of highway bridges in the United States,[12] indicates that since the introduction of precast prestressed beams in 1950, PSC bridges have captured almost 25 percent of the total bridge market.

Table 5 lists a few types of precast, pretensioned concrete beam sections used for short span bridges in the United States.

Sri Lanka

In Sri Lanka, pretensioned girders are in use since early sixties. Typical bridge beam and slab units are widely used for culverts, slabs, minor bridges.

Table 6 shows a few standard types of precast pretensioned and post-tensioned bridge beams used in Sri Lanka including the typical construction details for these types of bridge beams. The Road Development Authority of Sri Lanka has also developed standard designs adopting the pretensioned units[8].

A comparative data is presented in Table 7 showing salient features related to the practice of production of precast prestressed bridge beams in Japan, UK, USA and Sri Lanka.

Conclusions

The need for standardisation of designs of short and medium span bridges, using precast beams is highlighted in this paper. The paper also highlights the current practice in other developed/developing countries where use of mass produced precast beams are the most commonly found bridge systems. The following conclusions can be drawn.

1. Mass produced prefabricated girders area viable cost-effective alternative to conventional cast-insitu system in cases where,

   - higher speed of construction is important

   - casting on staging is difficult

   - in-situ construction with desired quality cannot be ensured.

2. The Government can play a significant role in directing the trend towards precast industry. The standardisation approach, as presented in the paper is required to be taken up at the National/State level by the Ministry of Surface Transport (MOST) and State PWD's respectively. Task forces (working groups under the general leadership of IRC/MOST may be formed with a mission to develop standard designs for various span ranges, taking into account the available resources and technology and the available transportation and erection facilities. The beam section thus developed must provide a cost-effective bridge system.

3. Formulation of appropriate codes and specifications or/and updating the present IRC codes to cater to the provision for precast and pretensioned structures would be a pre-requisite for its application as well as to help the growth of prefabrication industry.

4. Precast concrete girder system is the most widely used methods for constructing bridges in shortto-medium-span range, in various countries like Japan, UK, USA and Sri Lanka. Considerable research and study has gone into the selection of girder shape and optimisation of cost in these countries. The different girder shapes thus arrived at, duly takes account of the difference in available local materials, as well as technology available in different geographic regions.

5. The future in India is looking bright for quality and productivity improvements within the design and construction industry. Gone are the days when industry's inefficiencies could be ignored and buried in project

Table 7. Salient features of practices of production of precast girder in Japan, UK, USA and Sri Lanka				
Description	**Japan**	**U.K.**	**U.S.A.**	**Sri Lanka**
1Material Properties Concrete Strength Selection of concrete strength & type of girder & construction procedure adopted	A concrete compressive strength of 49 MPa (7100 PSI) is used for pretensioned girder since a high degree of quality control is maintained at the prestressing plant, whereas a lower strength of 39 MPa (5700 PSI) is used for post- tensioned girder because these girders are produced at the job site. A compressive strength of 59 MPa (8500 PSI) or more is employed for factory produced post tensioned box girders.	One of UK manufacturer's bridge beams are cast with concrete of minimum characteristic strength 5MPa. High strengths upto 75MPa are available to meet special requirements. All beams are suited to composite action with in-situ concrete.	All precast concrete bridges built in the United States haveconcrete strength in the 34 - 4 MPa (5000 - 6000 PSI) range. Cast-in-place deck strength is specified as 24 - 34 MPa (3500 - 5000 PSI).	The characteristic cube rength of concrete for the type of beams mentioned is 40 - 41.4 MPa (5800 - 6000 PSI).
b.Prestressing Strand The choice is influenced by economy and span length.	Prestressing steel used for pretensioned girders is either 15.2 or 12.7 mm (0.6 or 0.5 inches) diameter low relaxation strand with an ultimate strength of 1860 MPa (270 KS!). A multi-strand or multi-wire system with fpu of 1620 to 1720 MPa (235 to 250 KSI) is used for post tensioned girders. For posttensioned girders, the standard practice in Japan is to use 12.7mm (0.28 inch) diameter multi-wire systems for girders with span lengths upto 27m (89 ft) and 12-12.4 mm (0.49 inch) multi-strand systems for longer spans.	Prestressing strand used in a UK manufacturer's precast beam is either 12.5 min or 15.2 mm , class 2 relaxation standard at a maximum initial force of 123 kN or 174 kN, respectively. Alternatively, 12.7 mm or 15.2 mm drawn strand at a maximum initial force of 156 kN or 225 kN respectively, can be used.	12.7 mm (0.5 in diameter strand are used almost exclusively for pretensioned girders, and 15.2 mm (0.6 in) diameter strands are often employed in post-tensioning applications . Research is underway at several institutions in United States to develop formulas for development and transfer Lengths of 15.2 mm (0.6 in) diameter strands in pretensioned concrete applications.	Prestressing steel used for the precast prestressed concrete girders is 5 mm diameter high tensile strength steel wires with characteristic strength of 1570 N/mm^2 .
2. Design Concepts	Flexural design of prestrressed concrete girders is primarily based on the working stress method with the flexural strength checked, similar to the approach taken by the AASHTO specifications.	A UK manufacturer's Standard Bridge beams designs are based on British Standard codes of practice and the extensive discussions with the main client bodies within the industry, principally the Department of Transport, the major local and country authorities, and British Rail.	Flexural design of prestressed concrete girders is primarily based on the working stress method with the flexural strength checked as per AASHTO specification.	The design of the standard precast prestressed beams on SRILANKAN/BS specification.
3. Live Loads on Bridge girers	Two different types of live load, namely TI. and TT Loads, are used to determine the Live Load effect on all highway bridges in Japan	These Standard bridge beams desiged for 45 units of HB Loading from BS 5400 code.	The Live Load for standard precast prestressed beam is as per AASHTO specification.	These beams are designed for BS Live Loading.

costs. The Total Quality Management (TQM) culture is expected to permeate the design and construction industry.

References

1. _______Design of Precast Prestressed Bridge Girders Made Continuous, NCHRP' Report 322, Transportation Research Board, National Research Council, Washington D.C. Nov 1989.

2. Chakraborty, S.S. and Roy, B.C., Use of Precast elements in the construction of Delhi flyovers, 14th IABSE Congress Report, 1992.

3. VIJAY, P.B.. and others, Loni Road Flyover in Delhi - An innovative approach for urban flyover construction, IRC Journal, Vol. 53-3, October 1992.

4. _______Bridge Decks with Pretensioned Precast Beams, Technical Report, FIP publication, August 1978.

5. SASTRY, M.V., Some recent policy decision regarding execution of major bridge projects, IABSE seminar on Erection System, 1994.

6. TAKASI II YAMANE and others, Short to medium span precast prestressed concrete bridges in Japan, PC1 Journal, Vol. 39, No. 2, March - April 1994.

7. ________Bridge beams -Technical Bulletin for Precast Concrete, Costain Dow Mac, UK, Sept 1991.

8. _________Drawings from Road Development Authority, Ministry of Highways, Sri Lanka.

9. LIN, T.Y. and BURNS, NED, H., Design of Prestressed Concrete Structures.

10. BALWANT RAO, B., Developments in design and construction of small and medium size highway bridges, 11BE Journal, Vol X111; Feb 1994.

11. _______ Standard Plans for Slab Bridges developed by Ministry of Surface Transport, Government of India.

12. DUNKER, K.F., and RABAT, B.G., Performance of prestressed concrete highway bridges in the united states - The first 40 years, PCI Journal, Vol. 37, No. 3, May - June 1992, pp 48 - 64.

13. LYNN GEREN, K. and TADROS, MAI IER K., The NU precast prestressed concrete bridge 1 girder series, PCI Journal, Vol. 39, No. 3, May-June 1994, pp. 26 - 39.

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