Career Profile of

Er. E. Sreedharan
Chairman & Managing Director,
Kokan Railway Corporation Ltd

Recipient of S.B. Joshi Memorial Award for Bridge & Structural Engineering for the year 1995, cited by Alumni Association of College of Engineering, Pune

Date of Birth:

- 12^{th} June, 1932

Educational Qualification and Training:

- BE (Civil), Govt. College of Engg, Kakinada, Kerala in April 1953

Professional Experience and Achievements:

- Held a number of positions as Assistant Engineer, Executive Engineer, Divisional Engineer and Deputy Chief Engineer on the Southern and South Eastern Railways.
- In-charge of new line constructions such as Quilon-Ernakulam metre gauge line, Mangalore-Hassan railway line, a number of doubling projects, bridge and tunnel projects and also maintenance of permanent ways in Palghat, Hubli and Vijaywada Divisions.
- Restored the Pamban Railway Bridge in 46 days, 125 spans of which were washed away in a tidal wave in December 1963.
- As Dy. Chief Engineer, in-charge of investigation, planning and design of the first ever Metro in the country, viz. at Calcutta from 1970 to 1975.
- Worked as Divisional Supdt., Mysore Division, Southern Railway and as Additional Chief Engineer (Track), Southern Railway from 1976 to 1979.
- As Chief Engineer (Construction), Eastern Railway in March 1979, in-charge of all the major Railway Construction Projects on that Railway.
- Worked as Chief Engineer (Construction), Southern Railway, in-charge of all maojot projects on that Railway from 1981 to 1985.
- In February1986, as Chief Administrative Office (Construction), Central Railway, in charge of all the major construction activities and Metropolitan Transport Project on that Railway.
- In June 1980, in-charge of organizing the preliminary works for the prestigious Konkan Railway and subsequently, as Chairman and

Managing Director of the Konkan Railway Corporation Ltd in October 1990.

Honors, Awards, Patents

- Railway Minister's Award for Pamban Railway Bridge

Publications

- Published many technical articles and papers.

Affiliation with Professional Bodies:

- Fellow of number of professional bodies

Details of Contact:

Managing Director
Delhi Metro Rail Corporation Ltd.
NBCC Place, Pragati Vihar, Bhishma Pitamah Marg
New Delhi - 110 003, India
Ph: 011-24365395 Fax: 011-24365135
Email: mdmetro@hotmail.com

1 BRIDGES OF KONKAN RAILWAY CHARACTERISTIC FEATURES

E. Sreedharan
Chairman, Konkan Railway Corpn Ltd

1.1 Introduction and Brief Profile of Konkan Railway Project

Konkan Railway is the biggest railway construction project undertaken to the Indian subcontinent in the present century. This is a 760 km loan broad gauge (1676 mm) single track line along the west coat of the country connecting Bombay and Mangalore, 382 kms of this line lie in Maharashtra State, 105 kms in Goa State and the remaining 373 kms in Karnataka State, as shown in *Fig. 1.1*. With the completion of this line, an important gap in the railway map of the country along the west coast gets filled, thereby reducing the haulage distance and transit time between the western and northern part of the country with the southern areas significantly as given in Table 1.1. The completion of this project will usher an era of tremendous socio-economic development of he entire Konkan region, which is presently backward. Major investments in petroleum, power and steel sector are already under way in this area, taking advantage of this important railway line.

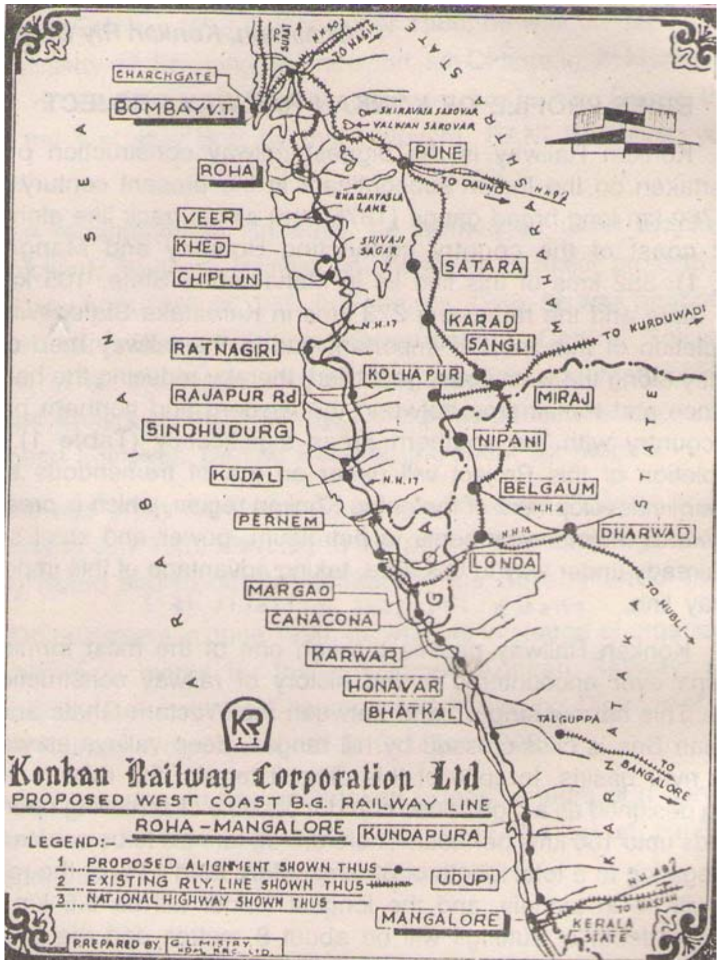

Fig 1.1 Map of Konkan Railway

TABLE –1.1

Reduction in Distances

	Distance as per present route in kms	Distance as per new route in kms	Savings in distance in Kms
Mangalore-Bombay	2041	914	1127
Mangalore-Ahmedabad	2653	1358	1295
Mangalore-Delhi	3033	2249	784
Cochin-Bombay	1849	1336	513

Konkan Railway passes through one of the most formidable terrains encountered in the history of railway construction in India. This narrow strip of land between the Western Ghats and the Arabian Sea is criss-crossed by hill ranges, deep valleys as well as wide river basins. In spite of this difficult terrain, the railway line is being designed as a high speed corridor capable of achieving operating speeds upto 160 kms per hour. There are 93 tunnels to be constructed, aggregating to a total length of 83 kms. More than 11% of the railway line will be in tunnels and the longest tunnel will be 6.5 km. The average depth of cuttings will be about 8 meters and the average height of embankments, 7 meters. Salient features of the project are as given in Table 1.2.

Table – 1.2

Salient Features Of The Konkan Railway Project

A) TRACK	
1. Gauge	- Broad Gauge (1676 mm)
2. Ruling Gradient	- 1 in 150 (Compensated) (0.67%)
3. Rails	- 52 kg 90 UTS (Welded Rails)
4. Sleepers	- PSC mono block sleepers
5. Route length	- 760 km
6 No. of Curves	- 320
B) BRIDGES	
1. No. of major bridges	-171 (Lineal Waterway 20.50 kms)
No. of minor bridges	- 1759 (Lineal Waterway 5.73 kms)
No. of Road crossings	- 288 (Road over bridge/ road under bridge)
Total	- 2087
2. Longest Span	
For Concrete bridges	- 53.5m (PSC Box Girder)
For Steel Bridges	- 124.2 m (Open Web Steel through Girder)
3. Longest Bridge	- Bridge across Sharavati River in Honavar (2065.8 m)
4. Tallest Viaduct	- Panval Nadi Viaduct, 65m high
5. First Bridge to be launched by incremental launching method	- Panval Nadi Viaduct (420m long) PSC box girder
C) TUNNELS	
1. Total no. of tunnels	- 92 (total length – 83.60 kms)
2. No. of tunnels longer	- 9 (length – 33.56 kms)
3. Longest tunnel	- Karbude Tunnel (6.50 km)
D) EARTH WORK	
1. Maximum height of Embankment	- 25 m
2. Deepest cutting	- 28 m
3. Total earthwork involved	- 87.67 million
E) STATIONS	
1. Total no. of stations	- 53

F) MATERIALS

1. Total qty of cement required	- 2,90,000 tons
2. Total qty of steel required	- 68,000 tons
3. Total qty of HTS	- 3,160 tons
4. Total qty of structural steel	- 14,000 tons
5. Rails	- 87,000 tons
6. PSC Sleepers	- 12,87,000 nos.

The Project is expected to be completed within a period of $5^{1/2}$ years. This will be the first major railway project of this dimension, magnitude and technical challenges getting completed in such a short time, any time anywhere in the world.

1.2 B.O.T. Concept

The Project is being executed under a very bold and innovative financing scheme on the Build, Operate and Transfer (BOT) concept. The estimated present day cost of the Project is Rs.2030 crores and including an expected financing cost of Rs.450 crores, the total outlay required will be Rs.2480 crores. Out of this, Rs.600 crores will come as equity contribution from the Indian Railways and the four participating State Governments of Maharashtra, Goa, Karnataka and Kerala. The balance will be raised from the market mainly through the instrument of tax-free bonds. After the project is completed, “Konkan Railway Corporation will continue to operate this line and it is possible to liquidate the entire loan within a period of 10 years out of surplus revenues.

1.3 Konkan Railway Bridges

Konkan Railway Project will go down in history as one having the maximum length of tunneling and maximum number of bridges. The Project involves design and construction of 171 major bridges and 1759 minor bridges. The total linear waterway of major bridges alone is 20.5 km. In Railway parlance, any bridge of a single span of more than 12.3 meters or of multiple spans of more than 20 meters is considered a major bridge. All bridges of spans less than this are treated as minor bridges. Many of the minor bridges, though minor from considerations of waterway, are indeed major in terms of cost. They have very long barrel lengths and expensive foundations. The total cost of bridging in the whole project is more than Rs.400 crores. In recent memory, there has been no railway or road project undertaken in our country involving such heavy bridging.

Locations of these bridges presented highly variable site conditions. Therefore, every such bridge needed detailed site investigations to determine the configuration of the waterway, detailed soil investigations, design and formulation of construction techniques. The immensity of the work load will be evident when we consider the fact that all these bridges were required to be completed in a period of 3 to 3-1/2 years. The terrain conditions were such, most of these bridge locations did not have easy access and collection of details by itself was stupendous task, let alone the logistic problems during the construction stage. No previous data with regard to the catchment area, intensity of rainfall, flood levels corresponding waterways on road bridges down stream, etc were readily available. On top of that, quite a few bridges, particularly in the Maharashtra area were located in the Seismic

Zone No. IV and had to be designed to withstand earthquake forces. Many of the major bridges were also located on steep hill slopes, which were not geologically stable.

Right in the beginning, the project team realized the fact that completion of these bridges well in time is the real key to the timely completion of earthwork for the railway formations. A multi-pronged strategy was therefore evolved to collect the field details, evolve conceptual plans, preparation of detailed designs and drawings and for the final execution.

The longest bridge on the project is across R.Sharavati near Honavar in Karnatake State having a length of about 2.1 km and the tallest viaduct is across Panval nadi near Ratnagiri with a pier height of about 64 meters.

Apart from the bridges needed to cross the waterways, the corporation had to construct a number of road-over bridges and road-under bridges to varying requirements to road traffic starting from a pedestrian path to the standards of a four-lane national highway. The endeavour of the Corporation was to eliminate level crossings on all important roads to avoid inconvenience to road-over and road-under bridges are as many as 288. The Corporation has also taken a conscious decision not to allow any unmanned level crossings on this line.

1.4 Design Parameters

The bridges are designed for Modified Broad Gauge Loading (MBG 1987) of Indian Railways which provides for running of 25 tonne axle-load trains and corresponding braking forces and tractive effort. Apart from the loads normally specified in he codes, bridge structures have been designed to withstand derailment loads and seismic effects, the later specifically in areas falling in Seismic Zone No.IV as per IS 1498.

In accordance with the social objectives of the Corporation, all major bridges on this project are provided with pedestrian pathways to enable local people to cross the waterways without exposing themselves to the dangers of running trains. Major bridges are also provided with approach slabs-this is being done for the first time in our country-so that trains will have a smooth transition from a yielding earth formation to a non-yielding concrete deck. Pedestrian pathways are provided with galvanized steel hand rails for pedestrian safety.

1.5 Investigations, Designs and Drawings

1.5.1 Zoning

The whole project length was divided into 7 zones, each under the charge of a Chief Engineer. These were sub-divided into lengths of 25 to 30 km under the charge of a Deputy Chief Engineer (Superintending Engineer). Investigations and collection of data were the responsibilities of the Dy. Chief Engineers and the Chief Engineers. The collected data were sent to the Corporate office, which had the responsibility for finalizing the designs and drawings of all major bridges. Field Chief Engineers were authorized to finalize the general arrangement drawings for minor bridges but designs for foundation, sub-structure and decks had to be obtained from the Corporate Office.

1.5.2 Standardization

At the very start, a decision was taken to standardize the spans and only in very exceptional cases non-standard spans were allowed. The spans standardized are 1.2 and 1.8 meter dia. Hume pipes, 2.5, 3.5, 5.0, 6.0, 7.5 and 10 meter RCC slabs, 12 ,15, and 20 meter prestressed concrete 'I' girder and 20, 30 and 53.5 meter PSC box girders. Similarly, designs of piers and abutments for varying heights were also standardized. In the case of piers and abutments, mass concrete was limited to a height of 5 meters and above that only RCC was adopted. Generally, above 6 meters in height, abutments were submerged or spill through. Piers above 16 meters in height were invariably RCC hollow type with rectangular or octagonal shape. By standardizing the designs of spans, considerable design and drawing works could be saved. To facilitate quick communication of data and drawings between the Field Chief Engineers and the Corporate Office, fax machines and computer net working were freely resorted to.

It is indeed to the credit of the Corporation, once the contactors came on to the field, the work never suffered for want of an approved drawing.

For foundations, use of large diameter RCC board and cast in-situ piles were standardized. Wherever open or earth foundations were justified, these were also standardized depending upon the permissible soil pressure. Only at nine locations in the Zuari and Mandovi bridges, well foundations were adopted.

In the whole project, only 3 steel girder spans have been used, one for the Mandovi Bridge and two for the Zuari Bridge. These steel girders were of 120 meter each over navigational spans.

1.6 Quality Assurance

Attention to Quality & Durability of bridge structures received very special importance from the beginning of the project. Following were the important measures taken:

a) Treatment of reinforcement by CECRI – Karaikudi process in bridge superstructures to inhibit corrosion. Setting up of laboratories for testing of chemicals used in Karaikudi process and training of supervisors by CECRI scientists.

b) Care in storage of HTS strands.

c) Insistence on stressing of strands & grouting of ducts within 7 days of insertion of strands.

d) Stringent quality control in formwork fabrication & erection, concrete-mixing, placing, compaction, curing, stressing & grouting.

e) Adequate cover over reinforcement.

f) Frequent testing of water, aggregates, admixtures & cement concrete.

g) Very rigid specifications of permeability of concrete and measures to test permeability at site.

h) Control over temperature of grout mix.

i) Tests on neoprene bearings.

j) Special Quality Assurance Teams of external consultants to monitor on Quality Assurance aspects and deficiencies, if any.

Implementation of these measures have resulted in high quality standards as can be seen from only to rejections in some 2000 girders.

PSC box girders and 'I' girders were cast in one pour well laid out casting yards, to ensure quality and durability. Testing laboratories were set up at each of the bridge sites having all the facilities including permeability tests as per DIN standards. For PSC 'I' girders, the cast in-situ portion of concrete is limited to diaphragms and a small strip of slab between the girders for pre-tensioned PSC girders, as shown in *Fig 1.2* and only diaphragms for post-tensioned PSC girders, as shown in *Fig 1.3***.** For 20 meter spans, PSC pre-tensioned 'I' girders have been adopted in a big way.

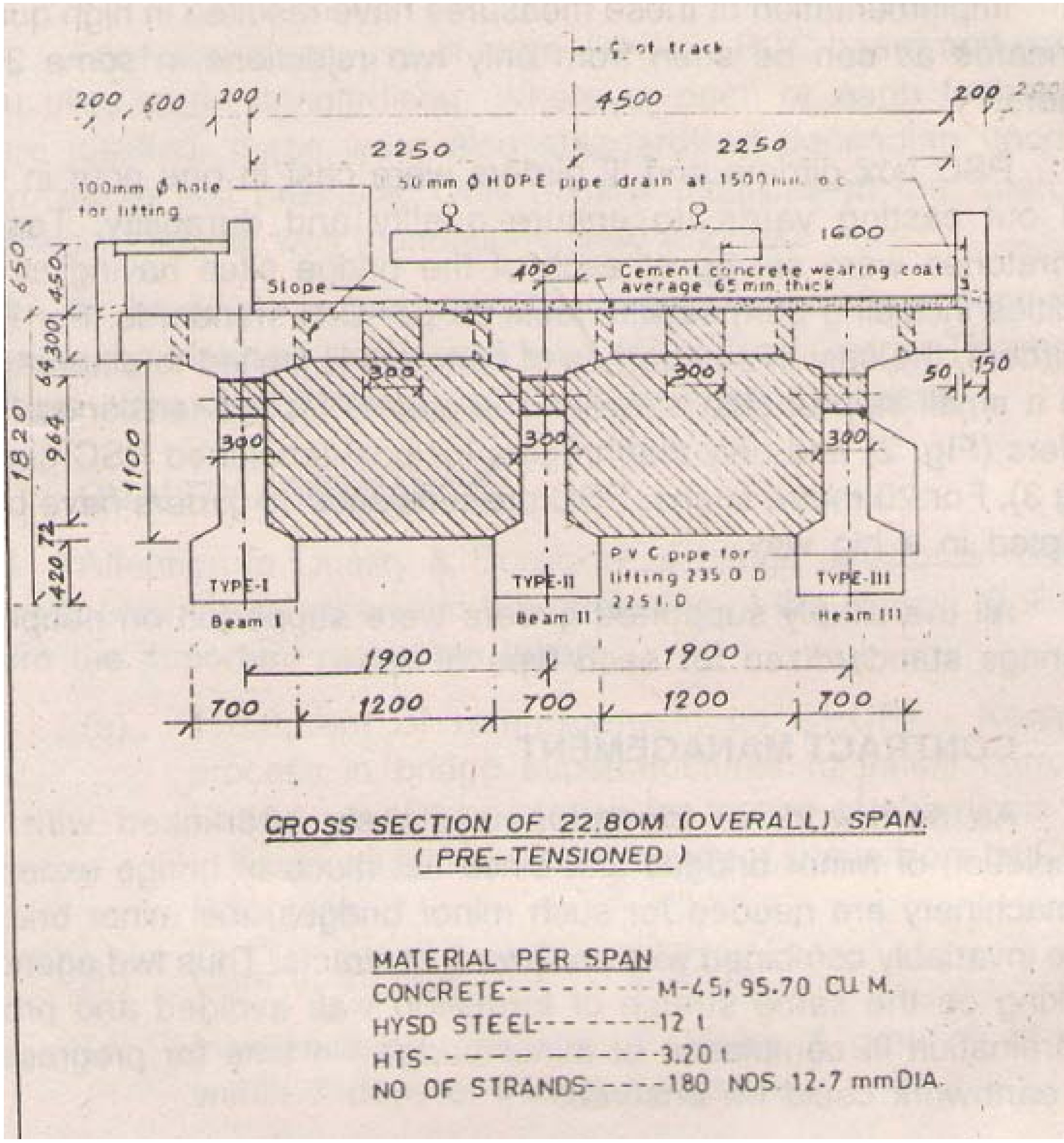

Fig 1.2 22.80m (Overall) Span PSC Girder (Pre-Tensioned)

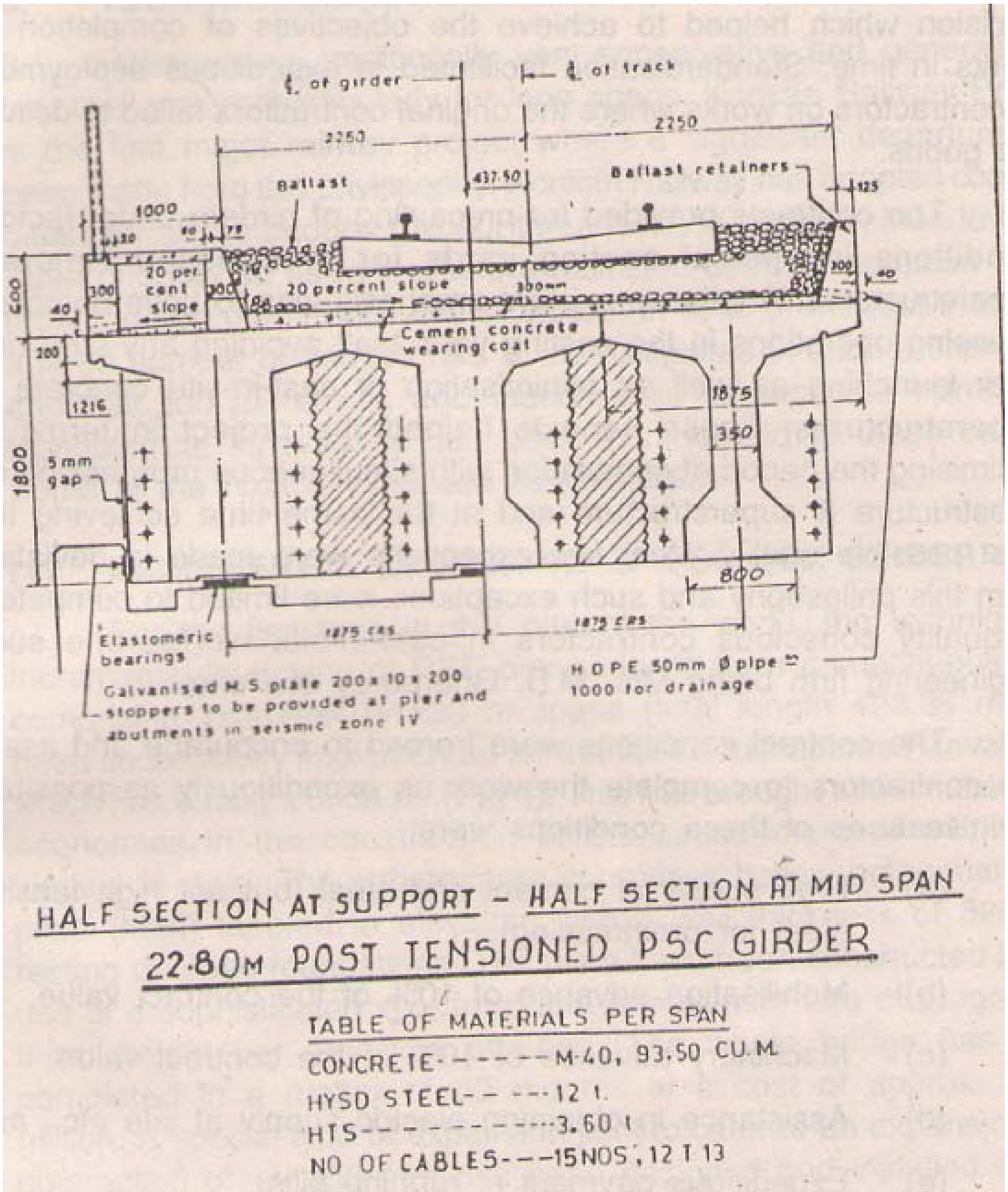

Fig 1.3 22.80m (Overall) Span PSC Girder (Post-Tensioned)

All the simply supported girders were supported on neoprene bearings standardized for each type of span.

1.7 Contract Management

As earthwork in formation is closely interlinked with the completion of minor bridges and since not much of bridge expertise or machinery are needed for such minor bridges, the minor bridges were invariably combined with earthwork contracts. Thus two agencies working on the same stretch of formation was avoided and proper co-ordination in completion of minor bridges in time for progressing the earthwork could be ensured.

For major bridges, contractors were pre-qualified in three categories, viz; bridge works upto Rs. 5 crores, Rs. 5 crores to Rs. 10 crores and above Rs.10 srores. A strict scrutiny on the credentials of the contractors and their track records were done while fitting them into the different categories. Limited tenders were then invited from these pre-qualified contractors only. Thus, inexperienced and undependable contractors were eliminated from participating in these tenders. While inviting tenders, large size contracts were generally avoided. For important bridges such as across rivers Halladi, Sharavati, Kalindi, Zuari, Mandovi, Panval Nadi, Shasri, Vasisthi, Savitri, individual contracts were awarded whereas for other major bridges they were clubbed in individual packages with contract values upto Rs.5 crores.

The later was done in order to have in built flexibility in the execution of works and to avoid keeping all the eggs in the same basket. Standardization of designs and invitation of tenders based on these designs (i.e. avoiding contactors' designs) was another important decision which helped to achieve the objectives of completion of works in time. Standardization facilitated in expeditious deployment of contractors on works where the original contractors failed to deliver the goods.

The contracts provided for precasting of girders under factory conditions in special casting yards for prestressed concrete superstructures. Another important emphasis was to have complete stressing operations in the casting yard itself avoiding any stressing after launching as well as minimization of cast-in-situ concrete in superstructures. These aspects helped the project in terms of optimizing the period of completion with simultaneous progressing on substructure & superstructure and at the same time achieving the best possible quality. Very few exceptions were made in deviating from this philosophy and such exceptions were limited to competent & quality conscious contractors in cast-in-situ works, one such engineering firm being M/s. M.B. Gharpuray of Pune.

The contract conditions were framed to encourage and assist the contractors of complete the work as expeditiously as possible. Main features of these conditions were:

(a) Free supply of cement and steel (but not high tensile steel for prestressing)
(b) Mobilisation advance of 10% of the contract value
(c) Machinery advance of 10% of the contract value
(d) Assistance in obtaining electric supply at site, etc
(e) Expeditious payment of running bills.

In all contracts, provision for testing of piles, girders or testing of a whole span was kept to be operated at the discretion of the Corporation.

It is not an exaggeration to state that successful completion of all the bridges on the project within the specified time was mainly due to the Corporation choosing the correct contractors for the appropriate type of work. The quality of construction has been hailed by one and all in the engineering profession.

1.8 Technological Innovations

Railways are traditionally very conservative and generally go for steel girders, particularly for long spans. Konkan Railway Project is the first major railway project where a significant departure has been made from this philosophy. Konkan Railway has adopted concrete decks for all the bridges (except three isolated spans in Mandovi and Zuari bridges) so as to facilitate a ballasted deck for adoption of the most modern permanent way structure. In spite of the fact that such a large number of bridges had to be completed in such a short time and that too in remote and inaccessible locations, a number of technological innovations had been incorporated in these bridges. Some of the notable ones are listed below:-

1.8.1 Incremental Launching of PSC Box Girder

For the first time in this part of the world, the technique of incremental launching of PSC box girder to form a continuous deck comprising 1x30+9x40+1x30 m spans (total length 423.25m) has been successfully implemented for the tall viaduct across Panval Nadi, as shown in *Fig 1.4*, has a height of 64m. This has brought about substantial economies in the construction of the substructure of this tallest viaduct in Asia. The substructure comprises hollow octagonal RCC piers (M35) tapered in elevation with a wall thickness of 325mm resting on open foundations. The piers have been constructed by the use of a sophisticated slip-form and a maximum rate of progress of 9m height per day was attained. The whole bridge has been completed in a matter of 30 months at a cost of approx. Rs.95 million.

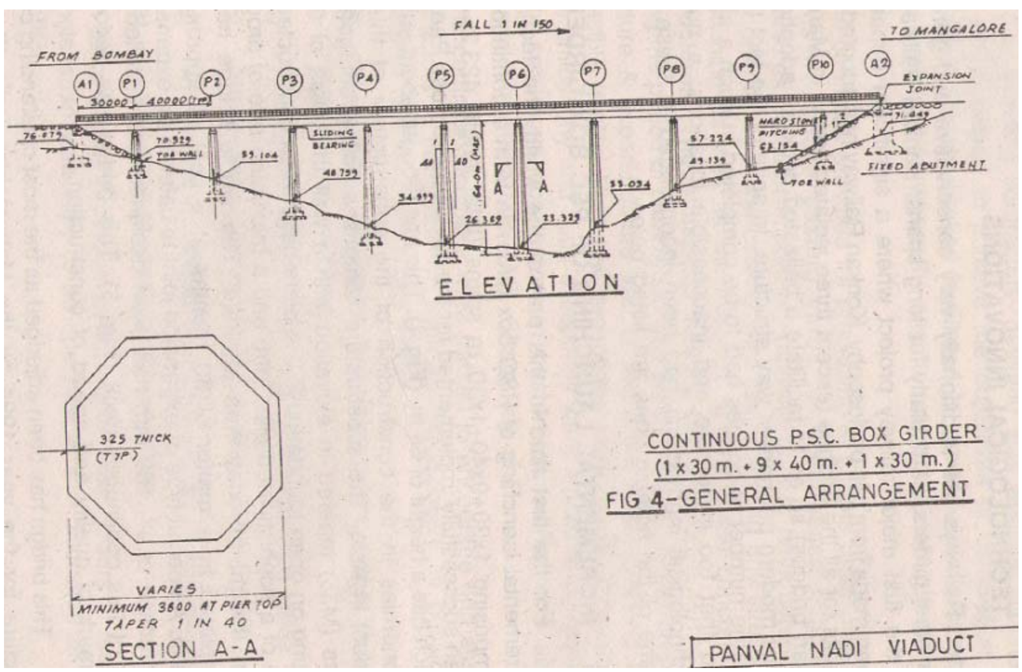

Fig. 1.4 Panval Nadi Viaduct

A special type of expansion joint, as shown in F*ig 1.5,* to cater to an expansion and contraction of +/- 150mm has been designed and installed at one end of this continuous deck. This bridge has become the hallmark of quality and speed of construction.

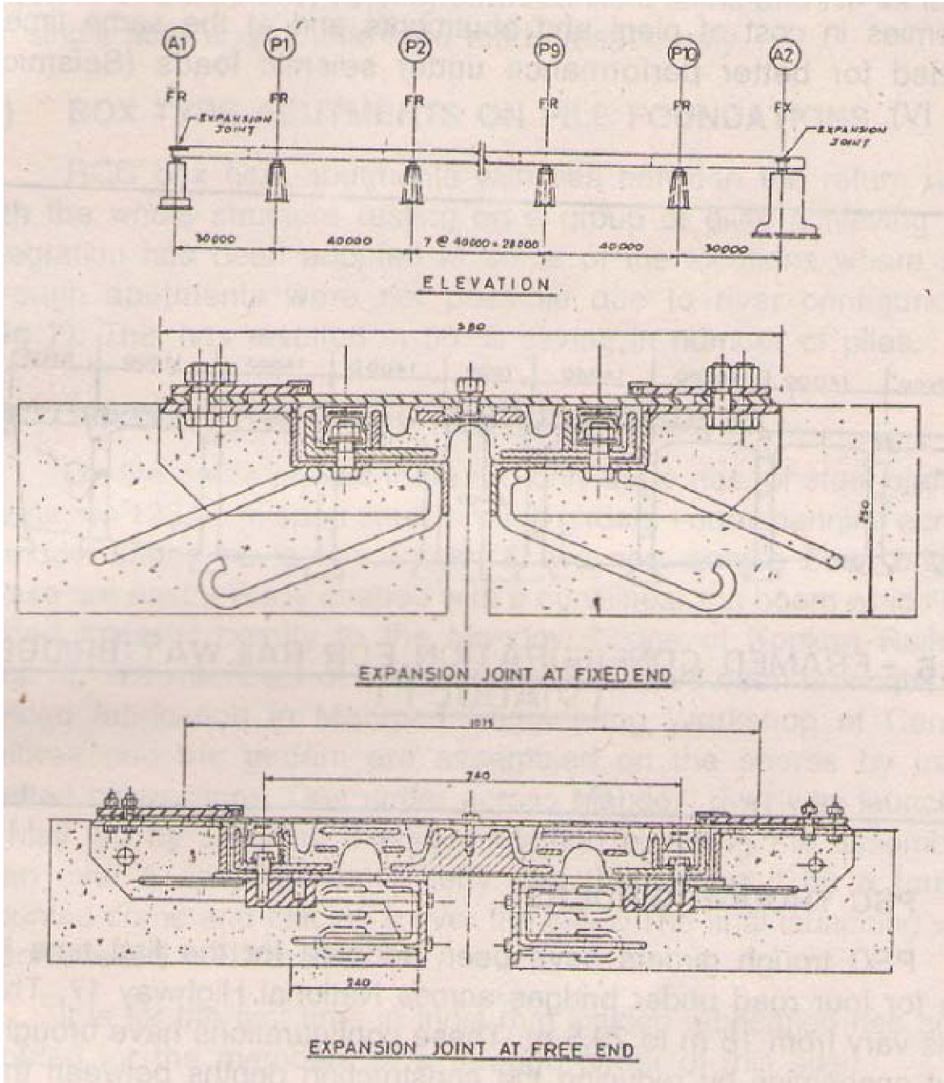

Fig 1.5 Special Expansion Joint At Panval Nadi Viaduct

This bridge has been adjudged as the most outstanding concrete structure for the year 1994 by the Maharashtra India Chapter of American Concrete Institute.

1.8.2 RCC Framed Configurations for Tall Viaducts

RCC framed configurations have been adopted with multiple spans of 10m and 14m with pier heights of upto 16m. The piers rest on open foundations taken to rock, as shown in *Fig. 1.6***.** This has resulted in economies in cost of piers and abutments and at the same time provided for better performance under seismic loads (Seismic Zone IV).

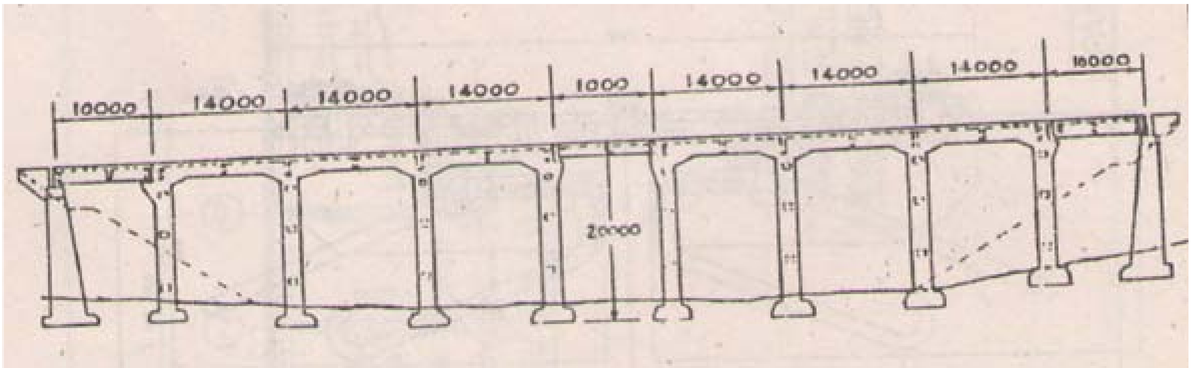

Fig 1.6 Framed Configuration For Railway Bridge (Viaduct)

1.8.3 PSC Through Girders

PSC through girders have been adopted for the first time in India for four road under bridges across National Highway 17. The spans vary from 18m to 29.5m. These configurations have brought about economies by reducing the construction depths between the soffit and the rail level consequently leading to substantial reductions in the height of approach embankments.

1.8.4 Funicular Shapes in RCC

Funicular shapes in RCC have been adopted for spans upto 12.5 m for road-under bridges crossing the tracks at high embankment location. Parabolic c.c arches have also been adopted for spans upto 6m.

1.8.5 RCC Framed Road-Over Bridges

Where ROBs are located in railway cuttings a novel framed configuration has been adopted which makes it possible to put up the structure at a total cost varying between Rs 9 lakhs and Rs 15 lakhs for single lane and double lane roads respectively.

1.8.6 Box Type Abutments On Pile Foundations

RCC box type abutments with ties between the return walls with the whole structure resting on a group of piles, as shown in *Fig 1.**7**,* achieving 3-D integration has been adopted at some of the locations where spill through abutments were not possible due to river configuration**.** This has resulted in 50% saving in number of piles.

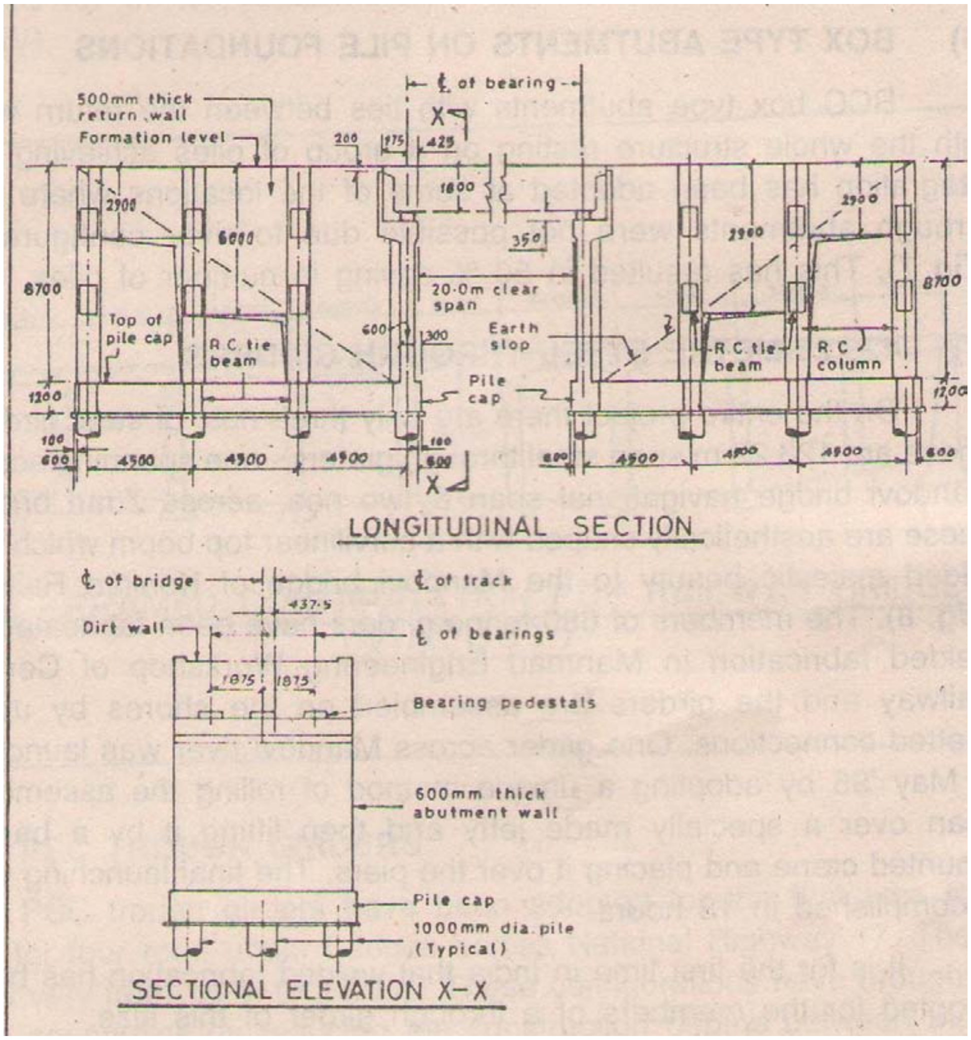

Fig 1.7 Integrated Abutment With Box Return on Piles

1.8.7 123.25 Meter Steel Through Girders

On the entire project there are only three nos. of steel girders. These are 123.25m spans steel through girders – one spanning across Mandovi bridge navigational span & two nos. across Zuari bridge, as shown in *Fig 1.8*. These are aesthetically shaped with a curvilinear top boom which has added majestic beauty to the Mandovi bridge of Konkan Railway**.** The members of 680 tonne girders have been fabricated by welded fabrication in Manmad Engineering Workshop of Central Railway and the girders are assembled on the shores by using riveted connections. One girder across Mandovi river was launched in May '95 by adopting a unique method of rolling the assembled span over a specially made jetty and then lifting it by a barge-mounted crane and placing it over the piers. The final launching was accomplished in 18 hours.

It is for the first time in India that welded fabrication has been adopted for the members of a through girder of this size.

These steel girders have been provided with a special type of pot bearings instead of the conventional steel rocker and roller bearings. This is the first time such bearings have been adopted for long steel girder spans in India.

A special design has been adopted in these girders for laying the track which enables elasticity in the track as well as noise reduction.

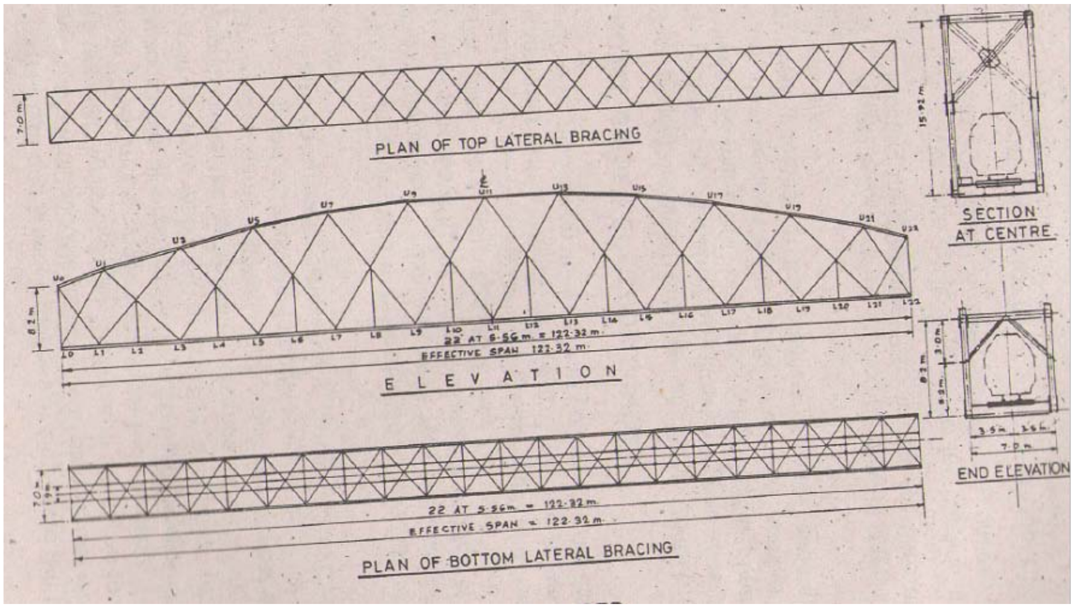

Fig. 1.8 Open Web Through Steel Girder For Zuari and Mandovi –I River

1.8.8 RCC Well Foundations

The Zuari and Mandovi bridges in Goa State are the only two bridges where well foundations have been proposed at nine locations. These are RCC wells of 8 and 10.76 meter dia. taken to a maximum depth (-) 28 meter under compressed air working. To speed up excavations inside the compressed chambers, high velocity jets feeding Toyo pumps were used for excavation and muck removal. The operations inside the compressed chamber were being monitored through video cameras installed in the pressure chamber and workers inside were given instructions through telephones. This is the first time sell sinking operations have been carried out in this fashion in our country.

At two locations where the wells had to be taken to very deep levels, a combination of piles and wells, as shown in *Fig 1.9*, was used to speed up the construction process. In this case, 8 numbers of 1.5 meter large dia. piles were first installed below the well curb level and thereafter the well was sunk to the required depth and the piles and wells integrated with a proper well plug. This type of well-cum-pile combination is also being tried in this country for the first time.

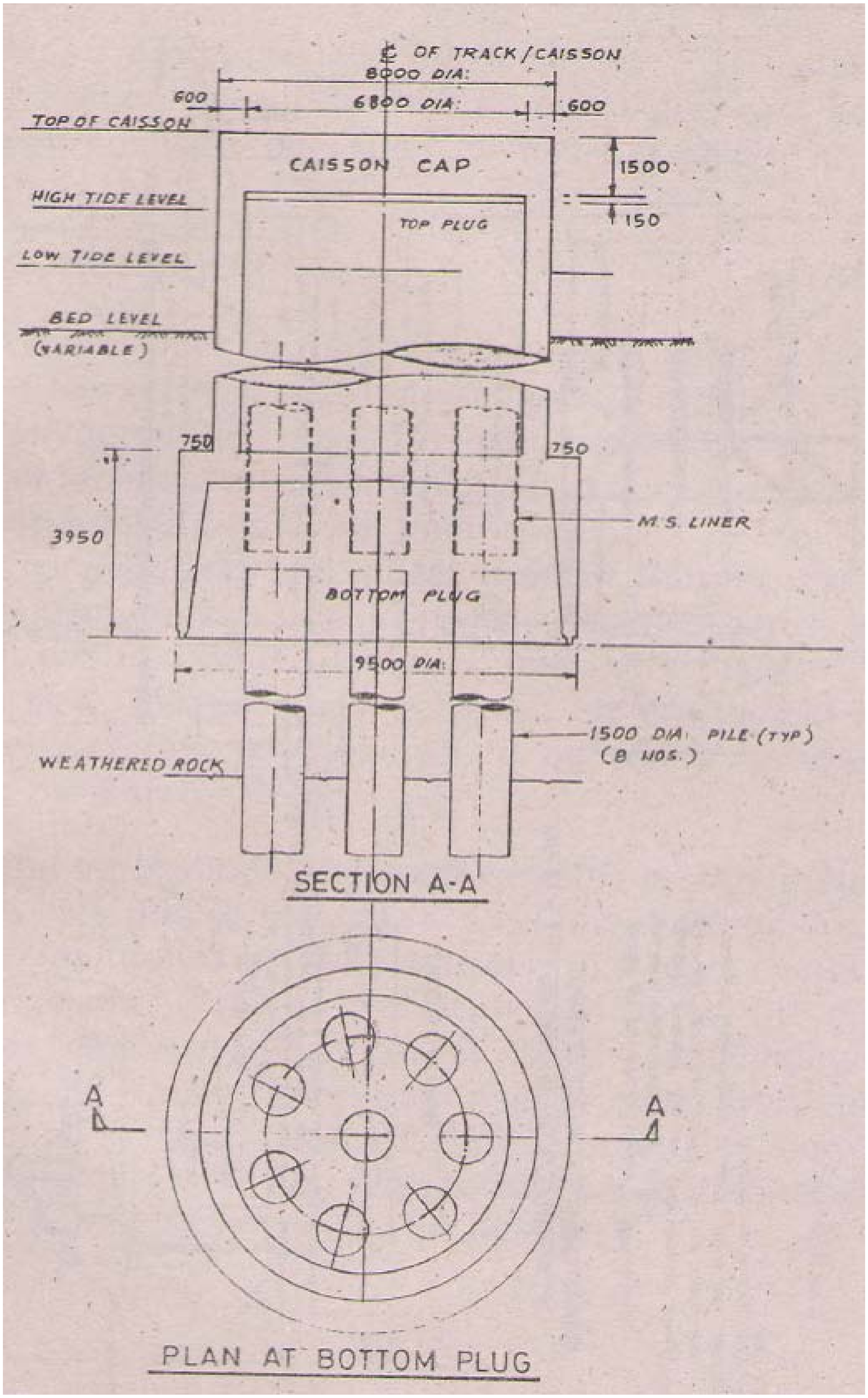

Fig 1.9 Combination of Piles & Caisson, Bridge Across River Zuari

1.8.9 Novel Girder Erection Scheme

The project involved erection of nearly 2000 prestressed concrete girders. The 30 meter PSC girders weighed as much as 320 tonnes, the 53.75 meter PSC box girder weighed 800 tonnes and the 120 meter steel girder weighed 680 tonnes. A number of novel methods were adopted for the erection of these girders. Notable among them are:-

(a) A specially designed floating barge with lifting towers for erecting the 30 meter PSC girders for Sharavati bridge.
(b) A similar type of floating crane for erecting the 53.75 meter PSC girder for Zuari and Mandovi bridges, as shown in *Fig. 1.10*
(c) A specially designed floating barge with four lifting towers erected on the same for picking up the fully fabricated 120 meter spans steel girders weighing 68 tonnes from a launching jetty and placing on top of the piers.
(d) Incremental launching method used for he first time in India across the Panvel via duct, as explained earlier.

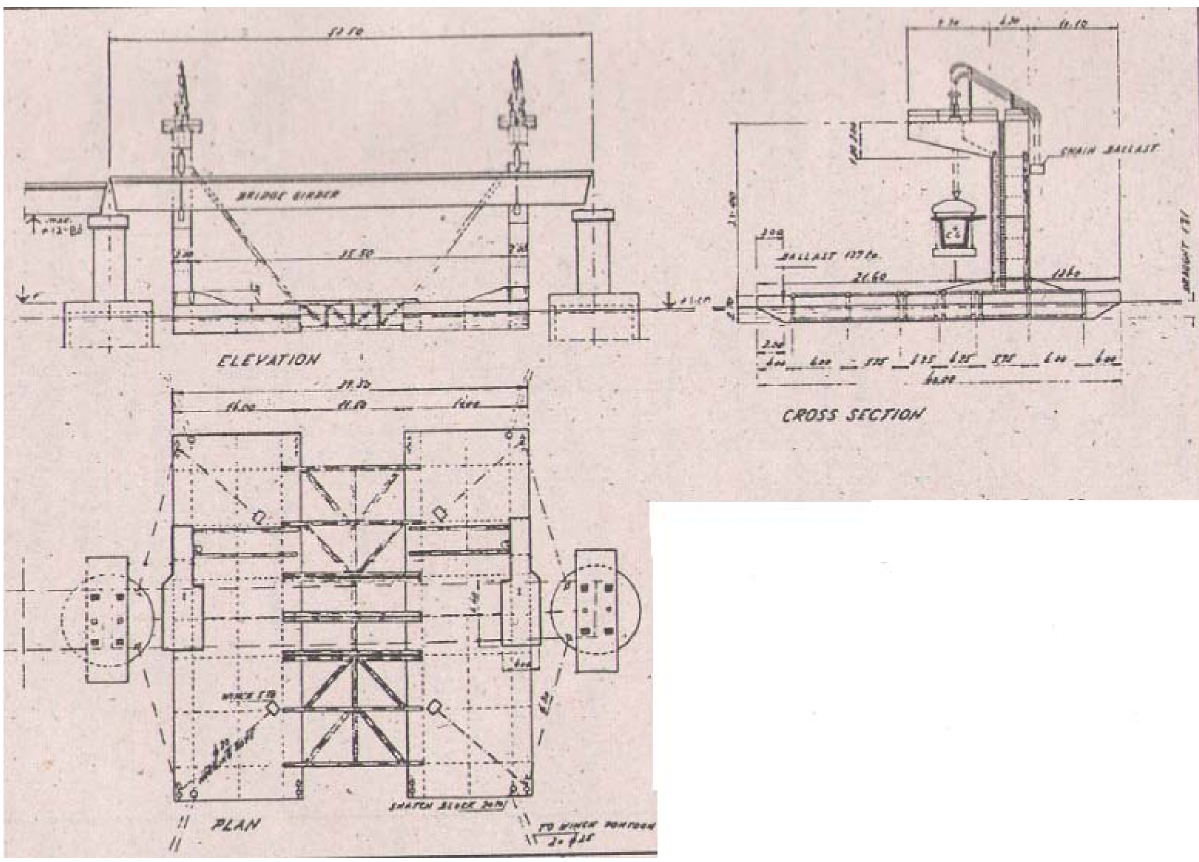

Fig 1.10 Lifting Arrangement For PSC Girder of Railway Bridge, Zuari - Mandovi

1.8.10 Mass production

Mass production of pretensioned PSC girders in a portable casting through assembled out of pre-case segments. This trough, as shown in *Fig 1.11*, could produce one 20 meter 'I' girder in a 72 hr cycle.

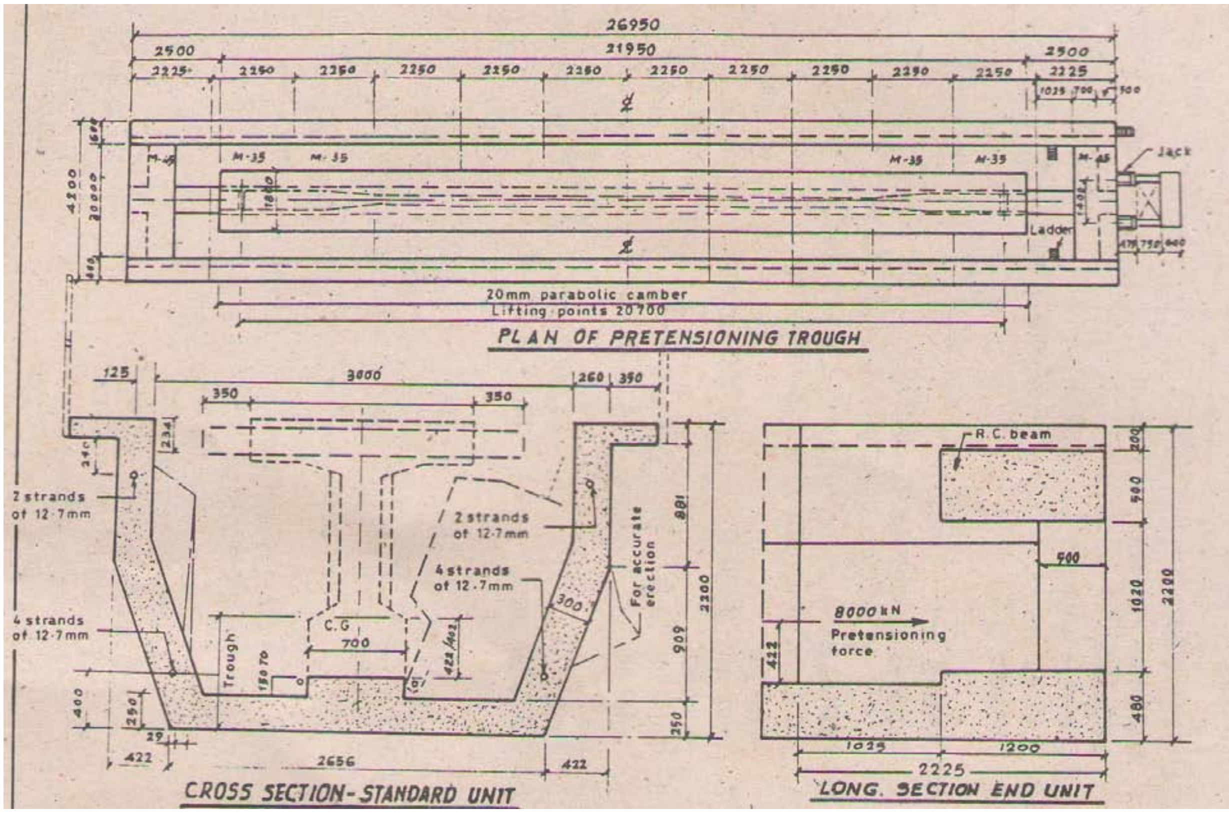

Fig 1.11 Trough Unit For Pretensioned Girder

1.9 Conclusion

The author has touched mainly the bridges constructed on the Konkan Railway Project. Other aspects of the project such as tunneling, permanent way, tele-communication, etc where number of technological innovations and front-line technologies have been adopted have not been covered. The project is now nearing completions. 200km of Konkan Railway are already under train operation. The Veer Khed section which is 52 km in length will be opened for passenger services next Monday on 25th inst. The progress achieved on the project is 92% and whole project is expected to be ready for passenger services by March, 1996.

The innovations and achievements on this project have been possible due to several factors, important amongst them being

- Clear definitions of objectives
- Team spirit between various agencies involved in execution of works
- High level of standardization in bridge design
- Modern communications facilities
- Immediate response to site problems
- Avoidance of the proverbial Red tape in decision making processes and lastly
- Total dedication to the staff, officers and contractors working on the project.