Career Profile of

Er. Shashikant D. Limaye
Officer on Special Duty, Pune Metro Project, PMC, Pune

Recipient of S.B. Joshi Memorial Award for Excellence in Bridge & Structural Engineering for the year 2013

Cited by Alumni Association of College of Engineering, Pune

Date of Birth:

- 4th August 1949

Educational Qualification and Training:

- Bachelor of Engineering (Civil) Pune University 1971
- M. Tech (Structural Engineering) I.I.T Bombay, Mumbai 1973
- Stood fifth in the order of merit in the **Engineering Services Examination** conducted by the UPSC in 1972 and joined the **coveted Indian Railways Service of Engineers** in December 1973.
- Certificate Course in French, University of Pune 1985

Professional Experience and Training:

- **Officer in Special Duty, Pune Metro Project, PMC, Pune**

- **Executive Director of STUP Consultants Pvt. Ltd. Mumbai**
  Overall direction to Design, Construction Engineering, DPR and PMC assignments encompassing Highways, Railways, Bridges etc. In this capacity, provided guidance to approximately 125 Engineers (Design/Supervision) / Persons at various levels including all senior levels.
  Direction and decisions with reference to Business Development. Reporting to CMD of the Company. In this capacity handled major design projects such as directing the teams (i) designing Eastern Freeway and Lalbaug Flyover at Mumbai, (ii) Cable Stayed ROB at Nagpur, (iii) Proof Checking of Mumbai Metro One 3 x 60m Steel Girder Bridge across Western Railway Track at Andheri, (iv) design of launching systems for segmental girder erection on Delhi Metro, (v) Panjarpol - Govandi Link Road in Mumbai, (vi) 1.2 km Long tunnel at Lavasa etc.

- **2001-2006 COO - Sir Owen Williams Innovestment Ltd., Mumbai**
  Sought Voluntary retirement from the Indian Railways in January 2001, after serving the organization for 27 years holding charge of various important posts. Thereafter, joined **as Chief Operating Officer of Railway Division of Sir Owen Williams Innovestment Ltd.** in Belapur, Navi Mumbai, India. As COO SOWiL Trans rail established the Railway Consultancy unit at Belapur, Navi Mumbai and evolved the same over five years to position it as one of the leading Railway Engineering Consultancy Firms in India. Provided Technical and Managerial Leadership to the Organization**.** Retired from SOWiL in September 2006.
  While with **Sir Owen Williams Innovestment Ltd** set up a new facility for Geometric Design of Railway Track (implementing softwares such as MX Rail, Hallade, ITD) with 10 Engineers. **This set up was involved in design of track geometry for the upgradation of Railway Line from London to Glasgow (WCRM project) to achieve the speed potential of 125/140 mph for tilting trains on this prestigious route.** This

work was highly appreciated for the accuracy & innovative solutions. During this tenure he also worked **as a Project Director** as a part of the **Project Management Consultancy** on the prestigious (i) Second Mahanadi Bridge Project (2 km long bridge on well foundations and 63 m span steel through girders) and (ii) construction of a new Railway Line between Keonjhar & Tomka (100 km) near Bhubaneswar in difficult terrain conditions for the Rail Vikas Nigam Ltd. This is ADB project and stands completed as of July'2008. **Designed ballastless track on curved alignment for Tunnels on Jammu Udhampur Project of Northern Railway which has been successfully implemented**. A number of tunnels were designed under his guidance on NFRly. **He led the Design team which designed/proof checked several Railway and Road bridges during this period. He also worked as a Bridge Expert on behalf of SOWIL-Frischmann Prabhu JV, on NHAI BOT Project of six laning of Kolhapur-Belgaon NH 4 (executed by M/s Punj Lloyd) in 2003-2005. He also served as Bridge Expert on a DPR assignment for 4 laning of Nagpur Akola section of NH 6 (MORTH Project.**

Evolved a novel design of 12 m wide FOB by using PSC Pretensioned Precast Hollow Slab Panel Deck which is successfully implemented at Ghatkopar and Dombivli Stations in Mumbai Suburban Area. This reduced the height of FOB by as much as 1 m resulting in elimination of 6 steps.

- **1973-2001 – Indian Railways Service of Engineers (IRSE)**

From December 1998 to January 2001 worked in the key post of Divisional **Railway Manager of Ajmer Division** of the Western Railway. In this capacity he **managed** the entire gamut of Railway working encompassing all the disciplines of Railways (such as Traffic, Mechanical, Engineering, Signal & Telecom, Electrical, Commercial, Accounts, Medical etc.) of the Ajmer division with an earning of Rs. 7500 million per annum (1999 price level) with approx**. 15,000 employees** on its rolls.

This assignment involved management of all the departments of Railways in order to ensure smooth running of the system over nearly **1500 route km**. The division had more than 150 trains every day and important tourist and industrial centers of Ajmer, Udaipur, Mt. Abu, Gandhidham, Kandla and Bhuj were in its jurisdiction. Major ports at Mundra and Kandla were also in its jurisdiction. During his tenure the Division won several Efficiency Shields of Western Railway.

During the year 1998 held the charge of the post of **Chief Track Engineer** (**Track Machines**) on the South Eastern Railway at Calcutta. In that capacity managed a large fleet of On-Track machines meant for maintenance and relaying of track effectively and improved their productivity by as much as 50%. The machine holding comprised Tie Tamping machines (CSM's), Ballast Cleaning machines, Track Relaying Trains, P & C Replacing Cranes etc. with overall investment of Rs. 1200 million (1996 price level). **This was made possible by bringing about perceptible attitudinal changes in the staff and motivating and training them to achieve excellence in their respective working areas.** These HRD inputs brought about the large scale increase in productivity of this machinery,

Major contribution in the field of Civil / Structural Engineering / Project Management / Project Monitoring came during 7½ years stint with the Konkan Railway Corpn. Ltd (KRCL). Involved with the **Konkan Railway Project** since its very beginning in 1990 till 1994 as **Chief Engineer (Designs)** and thereafter as **Chief Engineer (Co-ordination**) till the date of commissioning of the entire line in January 1998. He was closely associated in vital **planning, designing & implementation activities of the Konkan Railway Project.** The Konkan Railway Project – a mega-project of Indian Railways comprising construction of 760 km Broad Gauge Railway Line traversing the rugged countryside of Indian west coast connecting Mumbai to Mangalore., With an estimated cost of Rs. 24000 million, it involved construction of 179 major bridges (21.5 km), 92 tunnels (83.6 km), and 90 million m^3 earthwork.

Conceptualization, designing and awarding contracts for the works of major bridges was carried out under his guidance. The bridge structures with their aesthetics merging in the beautiful surroundings of the West coast terrain and efficient use of concrete as a material of construction have received appreciation from India as well as abroad. The surprise to many is the use of high level of standardization without giving up on aesthetics. Despite the relatively short time frame many innovative concepts were introduced. Premier amongst them was use of incremental launching technique for PSC box girder at the tallest viaduct for the first time in Indian Subcontinent. Adoption of RCC framed structures for viaducts, PSC U girders (first time in India), funicular arches, RCC hollow piers were some of the other techniques which were introduced in a big way. All these technologies led to perceptible economies in construction of bridges.

Design, Fabrication, assembly & launching of 124.2 m steel through girders across navigational channels of Zuari & Mandovi river in Goa in a matter of 20 months was a record. The launching of these mammoth girders measuring 124.2 m long x 8 m wide x 16 m tall by barge mounted cranes was a unique operation accomplished under his direct guidance and supervision.

Development and implementation of a completely new design of main line ballast-less track (laid over 24 Km inside tunnels) and development of new type of adjustable toe load elastic fastening system for track on Steel Through girders across Mandovi and Zuari bridges in Goa were some of the unique accomplishments.

Designing of tunnels – particularly in soft soil and also giving technical solutions to several problems encountered during construction of tunnels, cuttings, embankments & bridges is another area in which a measure of speed & efficiency was accomplished. Evolution of design of precast segmental lining for shield driven tunnel at Honavar.

He was associated with finalizing schemes for ventilation of long tunnels on Konkan Railway. Approximately 130 km of track works were completed between Ratnagiri & Karwar under his direct guidance in a record period.

Undertook three study tours abroad during this tenure and **presented technical papers at FIP symposium on post – tensioned girders in London – Sept'96.**

- Before joining KRCL from February 1989 to August 1990 worked as Sr. Divisional Engineer on Western Railway at Mumbai Central holding the charge of busy Bombay suburban section of Churchgate-Virar for 1-1/2 years.

- From 1983 (October) to 1989 **worked in the capacity of Professor (Bridges) in the prestigious Indian Railways Institute of Civil Engineering (IRICEN) at Pune.** During this tenure he also held appointment as **Dy. National Project Director (DNPD) on UNDP Project IND 85-061** – for Development of Indian Railways Institute of Bridge Engineering, Pune. In that capacity worked as **Team Leader of 12 officers of Indian Railways** who were trained in USA for one year/six months.

  Received special training in USA on Modern Bridge Technology for one year (1985-86) – University of Maryland, CALTRANS, Florida -DOT, SANTA-FE, Parsons-Brickerhoff, Freeman & Fox (UK). Designed & conducted specialized bridge engineering courses for the benefit of Indian Rly. Engineers and Engineers from construction Industry at IRICEN in association with M/s Parsons Brickerhoff and M/s DRC Consultants of USA. During his tenure at IRICEN also conducted courses on Design of Rly. Curves, Track Stresses, Elastic Fastenings, Design and Manufacture of Prestressed Concrete sleepers, Long Welded Rails.

- From 1975 to 1983 worked in Western Railway as Asstt Engineer, Divisional Engineer, Executive Engineer, Sr. Divisional Engineer – mainly on Rajdhani Route between Vadodara and Mathura. Important works of yard remodelling at Agra Fort and doubling over a length of 40 km between Nagda & Kota were carried out under his supervision and direction in the capacity of Executive Engineer. He was responsible for maintenance of track over major lengths of the prestigious high speed route of the Western Railway.

Training & study Tours:

A) Abroad:

- August 1985 to May 1986 (9 Months): Special Training in Advanced Bridge Technology at Univ. of Maryland, College Park, USA under a UNDP Fellowship.

- June 1986 to August 1986 (3 months): USA & UK – Practical professional training in Modern Bridge Technology anta-Fe Railroad, CALTRANS, FLORIDA-DOT, TY LIN Intl. , Parsons- Brinckerhoff, Freeman & FOX – UK.

- February 1992(one week): JAPAN – Tunnel Ventilation safety - with JARTS & JRCC. Visit to a longest railway tunnel Seikan across Tsugaru straits connecting Honshu and Hokkaido islands.

- September 1994 (one week): UK, France, Germany - Channel Tunnel – Ballastless Track, Safety , Tunnel Control TGV construction near Paris, Normandy Bridge, ICE of DB, BWG Pts & Crossing Plant

- November 1995 (one month): SWEEDRAIL– Underwent training programme in 'Advance Track Technology' in Sweden under a World Bank Scheme.

- September 1996: Presentation of Technical Paper in FIP Symposium on Post Tensioned Concrete Structures held at London.

- 2001 to 2002 : Four study tours to OWR Birmingham, UK to get acquainted with methodologies for Track Alignment design for increasing speed of trains on London Glasgow route of British Rail (WCRM Project)

- 2010: Tour to Australia to study Concrete Sleeper Manufacturing Process at Waga Waga Plant

B) Important Training Courses in India:

- 1973-75: Foundation course at **Lal Bahadur Shastri Academy of National Administration.**
  Foundation and Induction Course at Railway **Staff College** – Vadodara
  Foundation and Induction Course at **IRICEN – Pune**
- 1980: Special course on Cost Benefit Analysis of Projects at National. **Institute of Economic Growth – New Delhi**
- 1982: Advance Management Course at **BHU**
- 1984: Special course on Training of Trainers in use of Audiovisual aids at **NITIE – Powai, Mumbai**.
- 1989: Senior Management Course at **Railway Staff College – Vadodara**.
- 1999: Advanced Management Course for Divisional Railway Managers at **Railways Staff College – Vadodara**.

Publications:

- **Wind Forces on Tall Buildings - Evaluation to Design**, A technical paper in association with Prof. C. K. Ramesh of Department of Civil Engineering, Indian Institute of Technology, Bombay and was presented at National Tall Building Conference held under the auspices of IABSE - Asian Group & IRC at New Delhi in January, 1973.
- **Computer Programme for Arch Bridge Analysis** - Program written in association with Shri V.K. Vaish, the then Dy. Director (Civil Engineering) Railway Board, published by Efficiency Bureau, Ministry of Railways, 77/EB/404 in January, 1978.
- **Inspection of Masonry Arch Bridges** - Seminar on Inspection & Maintenance of Bridges at Calcutta in 1987.
- **Prestressed Concrete for Railway Bridges** - All India Seminar on Railway Engineering in India - Corporate View in 2001 AD organised by Institute of Engineers (India) at Calcutta in November 1988
- **An Innovative Approach for a cost-effective solution for RCC Culvert of 10m span for Railway loading** - presented at the International Seminar on Bridge Sub-structures held under the auspices of IIBE at Bombay in 1992.
- **Konkan Railway Project - Technical Innovations & Achievements** - presented at seminar on 'Innovative Building Products/Techniques' by IE (India) at Cochin on 13-14 August 1993.
- **Tunnelling on Konkan Railway - A Challenge**: co-authored, with Shri A. K. Somanathan, Dir (Tech) /KRCL - presented at Tunnelling India '94 held under the auspices of Central Board of Irrigation & Power at Pune 23-25 February 1994.
- **Major Bridges on Konkan Railway - Approach to design and Standardisation**, published by Indian Concrete Journal: December 1993.
- **Viaducts on Konkan Railway - Standardising Substructure Design** : ICJ December 1993 Issue.
- **Panval Nadi Viaduct - Salient Design Features**, ICJ December 1993 Issue.
- **Tunnels on Konkan Railway - Standardising Cross Sections,** ICJ February 1994 Issue.
- **Design of circular lining for shield-driven tunnel,** ICJ Feb-94 Issue.
- **Vertical sand drains for Railway embankment on marine clay**, ICJ February 1994 Issue.
- **Innovative approach to design, planning and construction of RCC and PSC Bridge Structures,** Vol.10, No.1 Jan-Mar 1995, Bulletin of Maharashtra India Chapter of ACI.
- **Planning and management of major bridge works on the Konkan Railway Project** - National Seminar on Planning & Management of Bridges & Flyovers: 17 - 18 May 1996, New Delhi - P 207.
- **Standardisation of post-tensioned girders on the Konkan Railway Project** - FIP Symposium 1996, London on Post tensioned concrete structures, P 112
- **Incremental launching of prestressed concrete box girder at Panval Nadi Viaduct on Konkan Rly Project** , Presented at FIP Symposium 1996 London on Post tensioned concrete structures, P 1022
- **Konkan Railway Project, Tunnelling: Important Aspects** - Structural Engineering Convention 1997 - Feb 12 - 14, 1997 at I.I.T. Madras.
- **Geotechnical problems in soft soil tunnelling on Konkan Railway** - a special presentation during Indian Geotechnical Conference-97 at Baroda on 19th Dec '97
- **Excellence in transportation systems in India - Achievements on Konkan Rly Project**: Keynote address at 12th Indian Engineering Congress held by Institution of Engineers (India) at Nagpur on 12th Jan '98.
- **Construction of Zuari and Mandovi Bridges on Konkan Rly. Project, India**, Proceedings of XIIIth FIP Congress on Challenges for Concrete in the next Millennium - Amsterdam-Netherlands 23-29 May 1998, pp 363-368.
- **Jammu-Udhampur Rail Link** ICI - Special Issue: Vol 76, May 2002, No 6, Guest edited the special issue.
- **Integral Bridges on Konkan Railway,** ICJ Vol 79, September 2005, No 9 – Co-authored with Dr V. V. Nori, S C Gupta, M K Gupta, and V. L. Dodeja.

- **Planning, Design and Construction of Metros for Indian Cities** presented at FIB Days 2008 Conference at Bangalore

Honors & Awards:

- **GM's award** for work done in Restoration of breaches on Kota Division of Western Railway – 1980
- **ACI Maharashtra India Chapter Award** for 'Most Outstanding Concrete Structure in India – 1994' for Panval Nadi Viaduct on Konkan Rly Project in Sept. 1995, awarded to KRCL.
- **S.B. Joshi Smriti Paritoshik by Institution of Engineers (India**) in appreciation of contribution in **spreading Engineering knowledge** - January 1996.
- **Distinguished Alumnus Award of IIT Bombay** for the professional contribution made in structural design and construction of Bridges, Tunnels and Track on the Konkan Railway Project **– March 2000** (thus far this award has been rarely conferred on a Civil Engineer)

Affiliation with Professional Bodies:

- Member of Institution of Engineers (India)
- MCSI
- Fellow member of Indian Institute of Bridge Engineers
- Member of Indian Road Committee
- Member of American Concrete Institute, India
- Joint Secretary of Indian Institute of Bridge Engineers (India)

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19 My Tryst with Bridge Engineering

Mr. Shashikant D. Limaye
Officer on Special Duty, Pune Metro Project, PMC, Pune

19.1 Introduction

Civil Engineering is a fascinating profession. Particularly, Bridge Engineering, a niche area of civil engineering, provides the Engineer with the highest satisfaction of witnessing physical realization of creative ideas. Development of conceptual design of bridges followed by detailed design including overcoming of numerous problems which arise during execution of bridge projects requires a strong background not only of Structural Engineering but also several other sub-disciplines of civil engineering such as structural dynamics, earthquake engineering, soil mechanics, foundation engineering, hydrology etc. Unless the academic knowledge of a structural engineer is supplemented by field experience and observations at the sites of various types of bridge projects, such an engineer is bound to suffer from lack of confidence in implementation of newer concepts within the framework of four cardinal principals of bridge design viz. Safety, Durability, Economics and Aesthetics.

As an engineer, thanks largely to the Indian Railways; the author has been fortunate in getting opportunities in an optimal sequence in design office, field work, teaching, study tours to sites of projects in India and abroad and interaction with renowned experts in bridge engineering. This was followed by a unique opportunity to lead implementation of several modern concepts in bridge engineering, tunnel engineering and track design in the prestigious Konkan Railway Project and thereafter in several projects while working in senior positions with reputed consultancy organizations.

The paper brings out some of the concepts in Bridge Engineering which were successfully implemented during the author’s career spanning over nearly 40 years. The paper is drafted with the idea of invoking the young generation of intelligent and tech savvy engineers to break the barriers and try ‘out of the box ideas’ during their careers.

19.2 Western Railway 1975 - 1983

19.2.1 Following were some of the works with which the author was associated as AEN/Designs in the Construction office of Western Railway at Ahmedabad (1975 - 1976)

19.2.1.1 Replacement of Sabarmati Railway Bridge at Ahmedabad along the same alignment as existing bridge without interrupting traffic – 20 x 60’ Steel Plate Girders three track bridge where new concepts such as 0.9 m diameter RC bored pile foundations were adopted in a highly scourable bed of Sabarmati river *(Fig. 19.1).* Another feature was piers comprising three RC columns, each column supporting one track girder. It was the first attempt to use a new structural form with highly mouldable concrete as the material of construction.

Fig. 19.1 Sabarmati Railway Bridge at Ahmedabad

19.2.1.2 Testing of Masonry Arch bridges on MG section between Viramgam and Okha to ascertain their strength to carry BG loading and also evolve measures to strengthen the Arch Bridges wherever considered necessary.

19.2.1.3 Damanganga Bridge 14 x 60’ span on Rajdhani Route between Valsad and Bhilad got completely washed away in July 1976. The scheme to support the temporary Calendar Hamilton Steel girder spans with RC pile foundation trestles proved its merits in the second floods by avoiding any distress to the temporarily restored bridge.

19.2.1.4 Adoption of single circular RC piers on well foundations with conical RC pier caps for replacement of Br 945 near Mehsana which got severely damaged in floods of July 1976.

19.2.1.5 Concept of inclined wing walls while widening the bridges in connection with Viramgam Okha Gauge Conversion Project (VOP).

19.2.2 During 1977 and 1983 while working in the maintenance and construction divisions of Western Railway as Divisional Engineer, Executive Engineer, Sr. Divisional Engineer following were some of the bridge projects which were executed under the author’s guidance.

19.2.2.1 Replacement and strengthening of cross girders of Strachy Road cum Rail steel through Girder Bridge (comprising 200’ steel girders spans) at Agra (between Agra and Agra East Bank) under traffic conditions.

19.2.2.2 New Darah Viaduct along a curve with steel composite girders as a part of doubling project between Nagda and Kota.

19.2.2.3 Replacement of Steel Bearings by neoprene bearings under 60’ span PSC girders of Hadap & Panam bridges between Godhra and Dahod on Rajdhani route. This operation required as many as 20 traffic blocks of 8 hours duration each on one of the two lines of this critical section of Rajdhani Route. The ends of PSC I girders of these bridges had developed cracks due to nonfunctioning of the steel bearings as a result of to corrosion leading to a speed restriction of 40 kmph on these bridges for nearly two decades. After the retrofitting the speed was relaxed to 80 kmph.

19.3 IRICEN – Pune 1983-88

The author was fortunate to work as Professor (Bridges) in the Indian Railways Institute of Civil Engineering, Pune, a premier Railway Institute, which trains the Civil Engineering officers of Indian Railways and also organizes several advanced courses, seminars and workshops for the benefit of senior officers on topics related to Track and Bridge Technology. With the background of 10 years of field experience in Design, Maintenance and Construction with reference to Railways; this tenure provided a unique opportunity (i) to update the technical knowledge, (ii) hone the skills of presentation and (iii) conduct study tours to several work sites on Indian Railways. The interaction with the intelligent groups of trainee officers of Indian Railways Service of Engineers during the training courses went a long way in sharpening the skills in design and maintenance of track and bridges. Training of one year in USA & UK as a Fellow under UNDP Project for Development of Bridge Faculty at IRICEN lent an opportunity to learn the state of the art design and construction techniques in modern bridge engineering. Syllabi developed with the assistance of renowned international experts in the relevant field of bridge engineering as a part of this project was a rich experience. Some of the bridge construction/fabrication sites visited as a part of study tours in India and abroad were:

- Aroor- Kumbalam Railway Bridge – first segmental construction with 30 m PSC Box girder spans in Southern Railway.
- Thane Creek Railway Bridge with 53.5 m PSC Box Girders casted in single pour and launched by floating cranes
- Vasai Creek Railway Bridge with 45.7 m span PSC Box girders launched by barges by making use of tidal variation.
- Sunshine Skyway Cable Stayed Bridge in Florida-USA with 96' wide Concrete Box Segments lifted from the sea level to the height of 75'.
- Steel Box Girder fabrication shops at Harrisburg Pennsylvania – USA
- Baltimore elevated Metro system
- Lynn Cove viaduct with precast PSC hollow piers in USA
- Metro Mover at Miami – Florida
- LRT at Sacramento – California
- Century Expressway at Los Angeles with trough type PSC girders carrying Railway Tracks of Santa-Fe Railroad.
- Golden Gate Bridge – San Fransisco.
- Swinging steel through girder span of Railway Bridge at Kiukuk across Mississippi River.
- Large scale concrete girder precasting plants in Virginia and Kansas City.
- Swinging Cable Stayed Bridge at Kingston upon Hull in UK

This tenure in IRICEN and the training under the UNDP Project instilled a measure of confidence which was largely responsible for the several concepts in modern bridge engineering which could be successfully implemented by teams of engineers which worked with the author in the prestigious Konkan Railway Project and subsequently during his stints with the reputed Consultancy Organizations.

19.4 Konkan Railway Project – a Cradle of Innovations

19.4.1 Bridges

- All bridges with concrete girders and ballasted deck to ensure uniformity of track structure.
- High level of standardization in bridge designs and non adoption of Design and Build contract concept, which contributed in a big way in achieving desired speed of construction and afforded flexibility.

- All bridges with precast girders to ensure quality and speed of construction by making it possible to progress on substructure and superstructure simultaneously.

- Use of PSC pre-tensioned / post-tensioned precast Tee girders on a number of bridges, minimizing cast in situ concrete in bridge superstructure. This became a common practice in highway bridges and flyovers which followed this project.

- Majority (99.9%) of deep foundations of bridges with 1m, 1.2m, 1.5 RC bored and cast-in-situ piles. This paved the way for adoption of pile foundation for highway bridges/ flyovers in India bringing about a paradigm shift in the construction scenario and has gone a long way in enhancing the speed of construction.

Adoption of Hollow RC piers (rectangular & circular) with wall thicknesses of 450 mm for viaducts with heights greater than 16m *(Fig. 19.2 & Fig. 19.3).* This made it possible to achieve substantial economies in consumption of concrete and reinforcing steel and at the same time reduced the mass of substructure leading to significant reduction in seismic forces. In line with the international practice these tall piers were not provided with intermediate diaphragms, and this made it possible to construct them with slip forming technique. Their excellent performance over past over 18 years is testimony to the success of this concept.

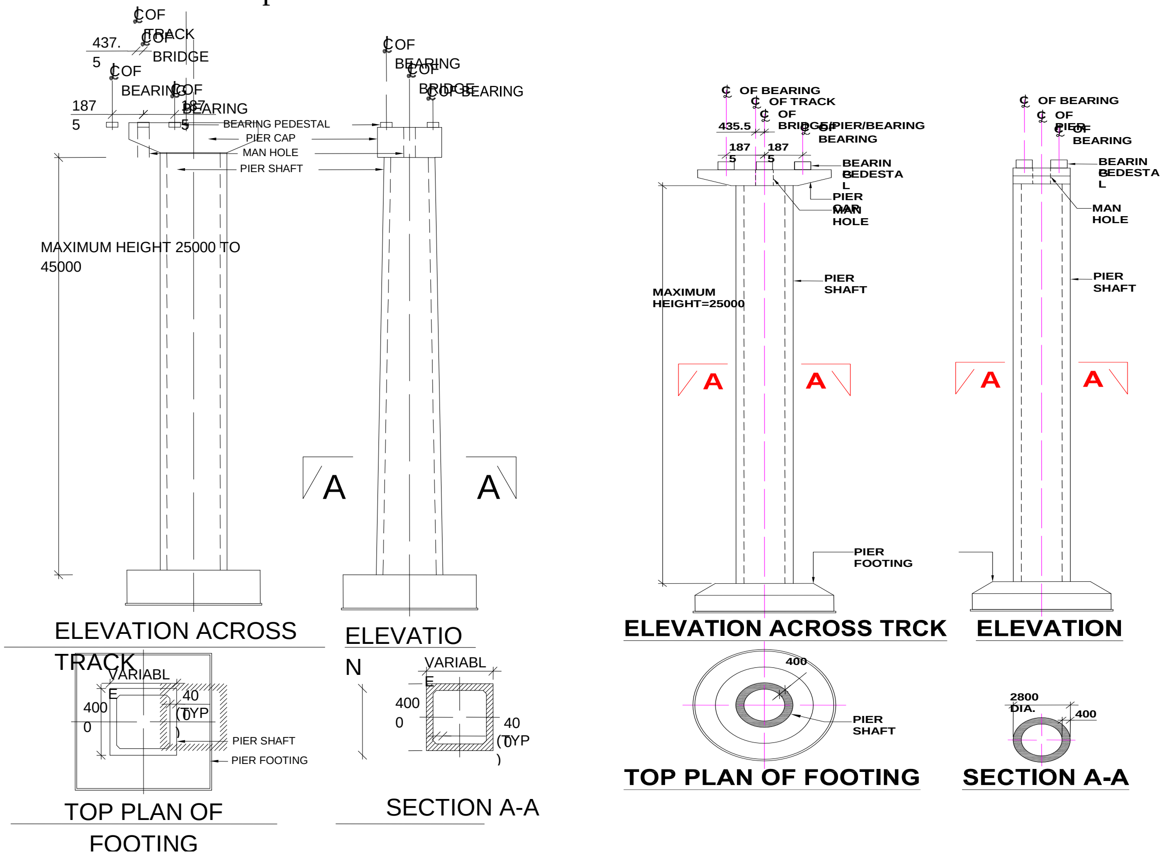

Fig. 19.2 Geometrics Hollow Rectangular and Hollow Circular RC Piers

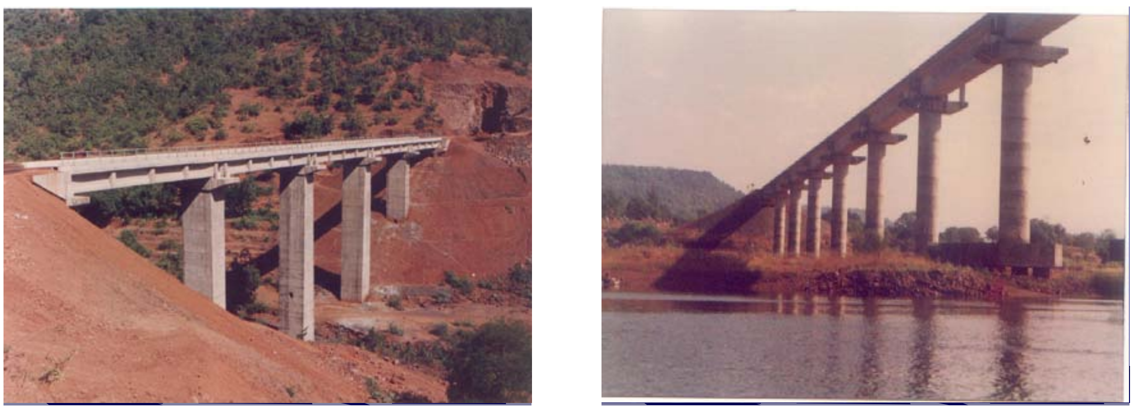

Fig. 19.3 View of Hollow Rectangular and Hollow Circular RC Pier

- Abutments of bridges required careful thought while designing bridges due to the need

(i) to span across long valleys with very small waterways needing shorter lengths of viaducts which entailed taller abutments wherein spill through abutments founded on open/pile foundations were adopted upto heights of 16 m *(Fig. 19.4).*

(ii) to locate abutments for bridges across creeks with flat beds featuring thick marine clay deposits overlying hard rock strata needed a different structural scheme. RC 3 D framed structures founded on plies were designed for such locations, which brought about large scale reduction in number of piles supporting the abutment structures *(Fig. 19.5 & Fig. 19.6).*

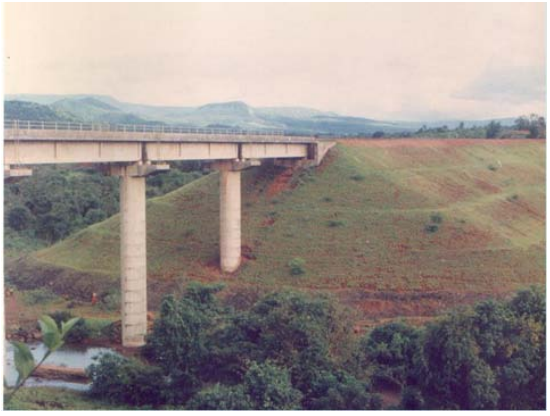

Fig. 19.4 Spill through Abutment

Fig. 19.5 3D RC Abutment

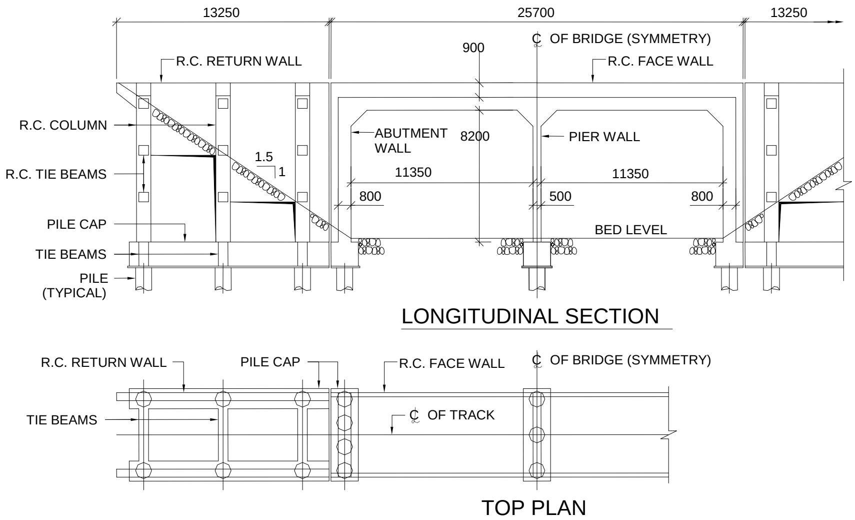

Fig. 19.6 3 D Framed Structure for Abutment

- Adoption of RCC framed configuration for viaducts up to 16 m height with implementation of the concept of flexible piers *(Fig. 19.7 & Fig. 19.9)*. This resulted in minimum concrete quantity as a sequel to the advantage of transfer of major component of longitudinal forces arising out of tractive effort & breaking forces of trains to rigid abutments resting on hard rock.

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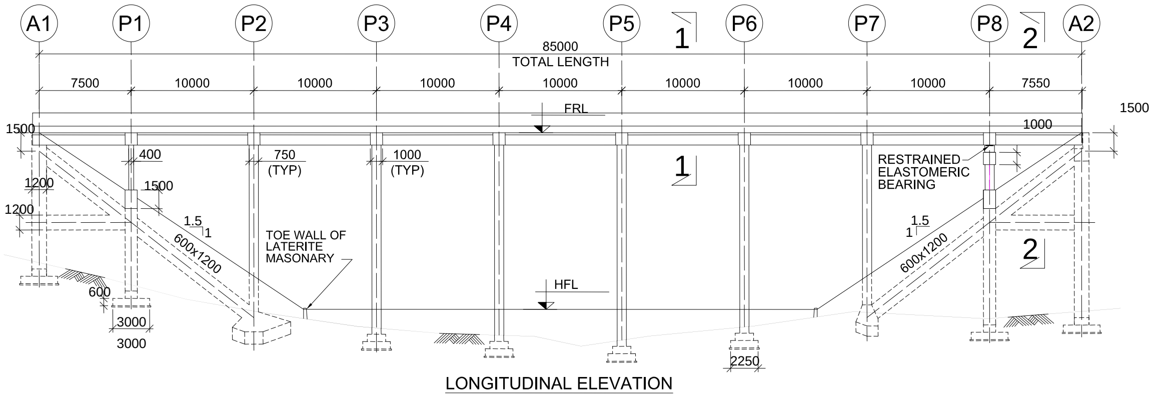

Fig. 19.7 Concept of Framed Viaduct

Fig. 19.8 Nandivli RC Arch Bridge

Fig. 19.9 RC Framed Viaduct

- Open Spandrel Arch 36 m span at Nandivli is a unique structure in which advantage was taken of hard rock foundation strata to span a small valley by this form *(Fig. 19.8).*

- Use of PSC-U girders 20m/33m span or Road under Bridges in order to achieve requisite clearance above Roads which resulted in minimum embankment heights on approaches which in turn minimized land acquisition in urban areas *(Fig.19.10).* This concept was introduced for the very first time in India. Today the Delhi Metro and Mumbai Metro have adopted this configuration of girders in a big way.

Fig. 19.10 PSC U Girder for a RUB

Fig. 19.11 Parabolic CC Arch

- Adoption of parabolic CC arches (M 25 concrete) for culverts under high embankments (> 10m) with spans of 3m, 4m, 5m and 6m spans with and arch thicknesses of 50cm, 60cm and 70cm *(Fig. 19.11).* These structures brought about substantial saving in consumption of concrete and reinforcing steel vis-à-vis conventional RC slab/RC Box culverts as the barrel length of these culverts varied from 30m to 70m due to high embankments. Their excellent performance once again proves that the age old concepts of structural forms are as effective today as in the past.

- There were upwards of 250 Grade Separators along Konkan Railway alignment as a result of the strategy to minimize level crossings. Apart from normal configurations, where the railway line passed through cuttings across existing roads a novel RC framed configuration was adopted at several locations.

- **Panval Nadi Viaduct**:

  This is the tallest viaduct with a height of 62m. A novel scheme of a continuous span PSC Box girder with a deck length of 423.5m (1x30m+9x40m+1x30m) supported on hollow octagonal tapered RC piers with wall thickness of 325mm were adopted creating the most optimal structural configuration *(Fig. 19.12 & Fig. 19.13)*. The continuous PSC box girder of this bridge was constructed by incremental launching technique for the very first time in India. The continuous deck is fixed at one abutment which is short and stiff. Major component of longitudinal force arising out of traction & braking of trains gets transferred to this abutment, thus relieving the tall piers of this force and in turn making them economic. The reduction in mass of piers results in substantial reduction in the seismic forces. This structure has won many accolades for its concept, quality and speed of construction. However, most importantly, it is the most economic configuration at the given site.

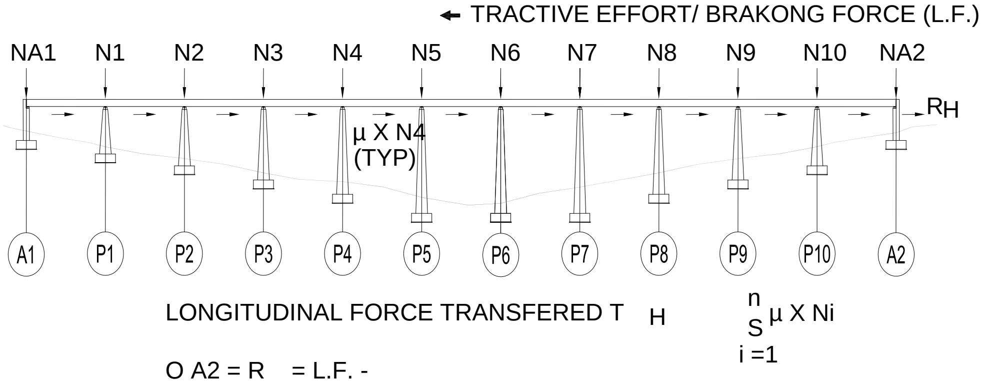

Fig. 19.12 Panval Viaduct – Structural Concept

Fig. 19.13 Panval Nadi Viaduct

- **Zuari Bridge (Goa)**

A 1.4 km long bridge across navigational channel of Zuari River. Adoption of a mix of spans along the land approach, marine approach and navigational spans; in order to achieve optimal cost without giving up on functionality is a unique feature of this bridge *(Fig. 19.14)*. The bridge comprises two spans of 124.2m steel through girder across the navigational channel preceded by 52.5m PSC Box girders and 20m PSC pretensioned Tee girders along both its flanks. The steel girders are a unique design with arch configuration. It was for the first time that the members of the open web girders were fabricated by welding. These 124.2m x 16 m height x 8 m width steel girders weighing 700 tonnes were launched by a floating crane in a unique operation *(Fig. 19.15)*. Only seven piers on this bridge were founded on RC Wells (constructed by Caisson floating). One of these wells is a Pile cum Well with the well resting on top of piles, the piles being integrated with the well through the bottom plug concrete.

Fig. 19.14 Zuari Bridge – Goa

Fig. 19.15 Zuari Bridge – Launching

19.4.2 Tunnels

Construction of 74 tunnels with an aggregate length of 85 km, with the longest being 6.5 km, was a mammoth task hitherto not attempted in India for vehicular tunnels. These tunnels passed through all types of strata varying from Hard Granite to water charged Lithomargic Clay. By using appropriate mix of technology comprising at one end electro hydraulic drilling jumbos to Shield tunneling method at the other end. Vehicular tunnels longer than 2.2 km were attempted for the first time in India and needed special facilities such as forced ventilation, communication from within the tunnel, pollution and visibility monitoring systems etc. These tunneling works including the novel ventilation systems were implemented and completed in time. This lead to tremendous confidence building amongst engineers in India and paved the way for planning of long tunnels on Mumbai Pune Expressway and several other tunnels along numerous Highway projects. It gave a measure of confidence to the teams attempting large scale underground construction of Delhi Metro.

The design of tunnel support systems by the Konkan Railway's Design team was a mammoth task which could only be accomplished by a large level of standardization. One of the unique tunnel support design was at the Tunnel constructed by Shield Tunneling technique (a previous incarnation of modern TBMs) at Honavar. Tunnel support comprised of RC tunnel segments connected by bolts forming a 7.2 m dia circular section *(Fig. 19.16)*. These types of linings have now become a very common feature of tunnels being constructed by TBMs for Metros in India. Horse Shoe Tunnel *(Fig.19.17)* was also used in the project**.**

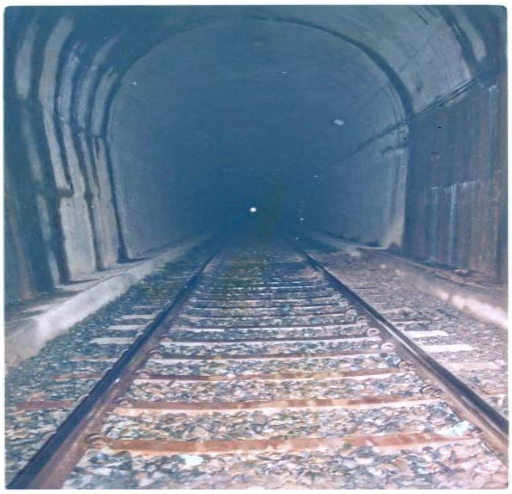

Fig. 19.16 Shield Tunnel at Honavar

Fig.19. 17 Horse Shoe Tunnel

19.4.3 Track

To attempt geometry of track in terms of flat curvatures, adequate lengths of transition curves and easier gradients in the difficult terrain conditions was a challenge and the same was addressed successfully by increasing tunnel lengths, and cutting across rivers, creeks and valleys with skew bridges in order to keep the alignment as straight as possible. The entire length of the track including turnouts has been laid on Concrete sleepers and converted into Long Welded/ Continuous welded rails. The welded track has been continued across all the bridges and has performed exceedingly well over the years. Turnout were provided with thick web switches imported from Germany but to Konkan Railway Design. These have shown unparallel performance with hardly any wear after 15 years in service. All these modern inputs bring in at least 10 % fuel saving in hauling of trains and Konkan Railway will be reaping the benefits of the same in perpetuity. Long tunnels in Konkan Railway are provided with Ballastless track which was designed in-house by KRCL design team and was successfully implemented after a meticulous prototype testing under dynamic testing rigs at RDSO *(Fig. 19.18)*. The cost of this track system was only 1/3rd of internationally used systems of ballastless track. This system has largely eliminated track maintenance operations in long tunnels

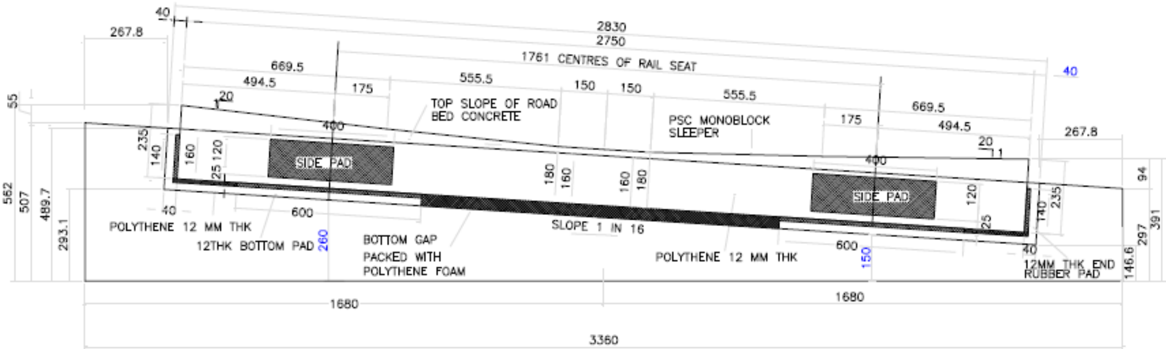

Fig. 19.18 Ballast - less Track in Long Tunnels

19.5 Problems and Solutions

In the project of the magnitude of Konkan Railway technical problems and distresses did occur on few occasions. These could be overcome only due to the problem solving approach rather than focusing on fault finding. Two of the interesting problems were (i) tilting of one of the 18 m height pier at Shastri Bridge near Sangameshwar and (ii) repeated failure of embankment at Sancaole creek near Cortalim in Goa.

19.5.1 Shastri Bridge

Shastri Bridge comprising 12 spans of 30.5 m PSC Box Girders is located on the downstream of the confluence of Shastri and Gad rivers between Sangmeshwar and Ukshi stations of Konkan Railway. The substructure comprises spill through abutments at both ends resting on 1.2 m dia bored and cast in situ piles socketed in hard rock. Piers extend upto a maximum height of 25 m from top of pile cap to top of pier cap and are configured as 2.8 m outer dia hollow RC circular section with the bottom 5 m of solid circular section. Each of the PSC Box girders weighs 330 tonnes and carries a single Broad Gauge railway track. The PSC box girders were precast and launched in position. After completion of the substructure the last PSC Box girder was launched between pier P 11 and abutment A 2 in May 1995. In July 1995 minor cracks were noticed on the pile cap of P 11. The top of the pier cap of P 11 had deflected towards P10 as revealed by shear deformations of Elastomeric bearing pads under the girders at P 11. Shear deformation of the elastomeric bearings on top of Pier P 11 were observed to be of the order of 50 mm. P 11 rises to a height of 18 m from the pile cap (4.8 m x 4.8 m x 1.2 m deep) supported on 4 nos. 1.2 m dia. RC bored and cast in situ piles taken through 6.5 m of reddish laterite soil, followed by 3 m of soft rock and thereafter socketed in hard basalt rock.

Steel liner plate of the piles was continued up to hard rock. The reason for distress was due to piles being subjected to excessive lateral pressure exerted due to tendency of laterite soil overlying the rock to slide over the rock interface. This lateral force was proposed to be isolated from the piles by sinking a Concrete cofferdam encompassing the pile cap and the piles up to the hard rock strata *(Fig. 19.19)*. A concrete pedestal was raised encasing the piles up to the bottom of pile cap. The latter provided an additional support directly under the pile cap of P11. It was astonishing to note that the pier sprang back to its vertical position after sinking the cofferdam to a depth of 6 m which confirmed all the initial premises about the cause of the distress. The repairs in terms of epoxy grouting of cracks in pile cap and raising of concrete pedestal inside the cofferdam were completed and the bridge was commissioned.

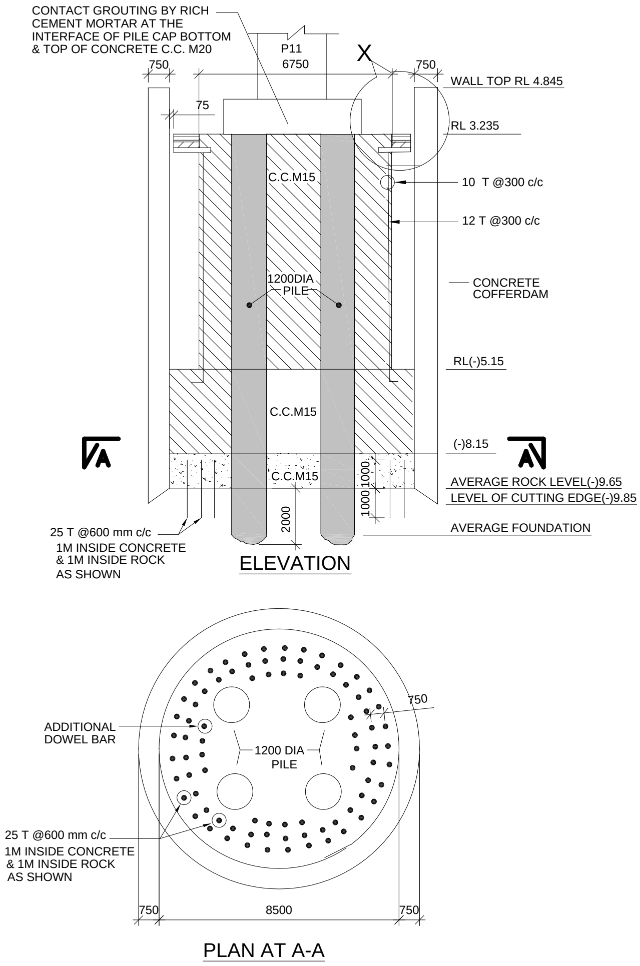

Fig. 19.19 Shastri Bridge – Remedial Measures

19.5.2 Sancaole Creek

The stretch between Zuari Bridge and Verna Tunnel presented very soft ground conditions with SPT N values varying between 1 and 8 over depth of 8 m. Sand piles and slip circle arresting piles were provided before construction of the embankment of a height of 8 m over 200 m of this stretch. However, in spite of all these ground improvement measures the embankment refused to stand and as soon as this embankment was raised above 6 m it collapsed. This situation repeated itself twice finally forcing KRCL to take a decision to span this length by bridging. Due to paucity of time this bridging had to be designed and planned in such a way that it could be completed in four months. A very innovative design was evolved by raising a set of two 1.0 m dia bored piles as columns topped with a RC pier cap on which 11 m span precast RC Slabs were placed in four units to form a deck. A cross diaphragm between each set of two piles was provided at ground level. To integrate the piles along the length longitudinal RC Beams were provided connecting all the piles in one row at the ground level. With this scheme the bridging was completed in four months.

19.6 Some innovative designs and restoration measures during 2001- 2013

19.6.1 Restoration of Bridge 144 near Boisar along Rajdhani Route of Western Railway

A stone masonry arch double line bridge 3 x 12.2 m was severely damaged with one arch collapsing in the monsoons of 2002. The track was temporarily restored by providing relieving girders supported on CC cribs along the same alignment. The challenge was to construct a new bridge along the same alignment in 140 days without interruption to Railway traffic. A novel scheme comprising pile foundations in triangular layout (constructed at the locations of existing masonry piers of the Arch Bridge) under the new RC piers (4 RC Circular Columns) with RC Pier caps and precast PSC girder units to be placed side by side to form a double line deck was evolved *(Fig.19. 20)*. The bridge was completed in May 2003 before the onset of monsoon. Under traffic block of 9 hours for each line these girder units were placed with the help of 100 tonne hydraulic cranes operating from river bed. One of the engineers who worked with the author on this design presented this work for MI (Struct.E) in UK and it received high level of appreciation from the Expert Examiners.

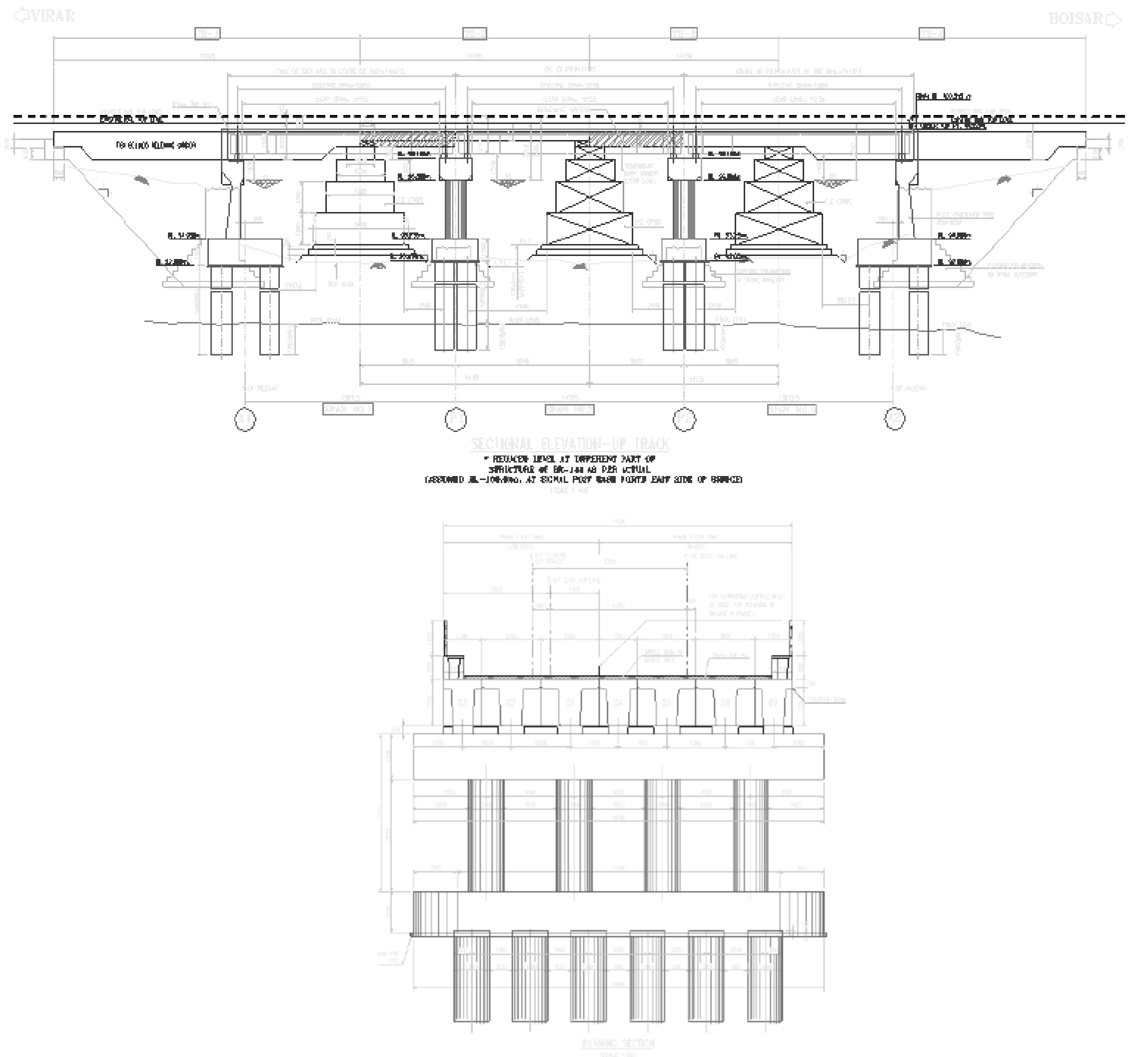

Fig.19. 20   Br No 144 – Western Railway – Restoration Scheme

19.6.2 Foot Over Bridges 12 m wide on Central Railway at Ghatkopar and Dombivli

PSC I girder Foot Over Bridges with 12 m deck width constructed on Central Railway at Dadar suffered from the disadvantage of increased height by as much as 1.5 m vis-a-via steel through girder FOBs. The author had the opportunity to design PSC FOBs 12 m wide at Ghatkopar and Dombivli. Here a novel scheme of hollow core pretensioned slab units 11 m in span were conceived with a depth of 0.5 m. The span could be reduced by following Schedule of Dimension lines for the substructure piers which cantilever out from the platform *(Fig. 19.21)*. The parapets of the bridges were conceived as precast PSC girder units. The substructure was laid on raft foundations resting on well compacted platforms thus obviating the need to provide pile foundations on these busy platforms. These are unique structures wherein the height of FOB is reduced by 1 m vis-à-vis conventional PSC I girder FOBs.

Fig. 19.21 FOB at Ghatkopar

19.6.3 Chakki Highway Bridge at Pathankot – Temporary Remedial Measures

Chakki Bridge is a two lane road bridge of strategic importance connecting Jullandhar to Pathankot (on NH 1 A) and onwards to Jammu and Shrinagar. It comprises 7 spans of 124’ PSC I Girders. The foundations are CC wells of 19’ dia with original grip length of 30’ below scour level. Due to indiscriminate sand mining along the downstream the bed of the river had degraded to such an extent that the grip of Well No 7 got reduced to 6’. The pier and the well had visibly settled at this location. A new bridge was proposed by NHAI parallel to the existing bridge. However, it was necessary to make the existing bridge safe. A scheme of supporting the well on bored piles to be provided outside the perimeter of the wells at risk was evolved and successfully implemented *(Fig. 19.22)*. The existing bridge served for more than six years after the remedial measures were implemented keeping this vital road link operational.

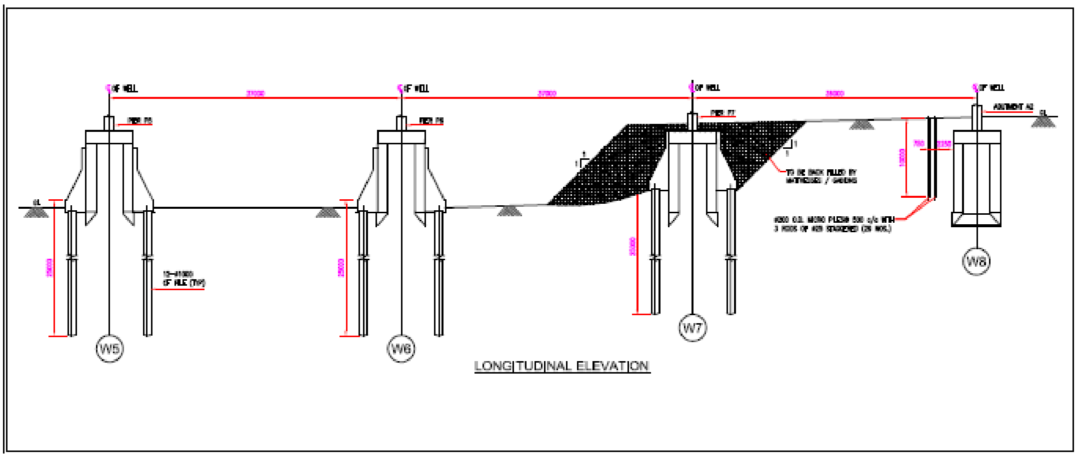

Fig. 19.22 Chakki Bridge - Rehabilitation of Foundations

19.6.4 Mahanadi Railway Bridge at Paradeep

Mahanadi Railway Bridge at Paradeep comprising 20 spans of 45.72 m PSC Box Girders suitable for Heavy Mineral (HM) Loading (30 tonne Axle Load) founded on Well foundations was designed, including its launching scheme during 2006-10. The bridge now stands completed. PSC Box girders for such span were designed for the first time for HM Loading and the girders weighing 700 tonne each were launched by end on launching method using a launching girder.

19.6.5 Extradosed Bridge at Moolchand on DMRC

The extradosed bridge of DMRC at Moolchand comprises 51 + 65 + 51 m spans and carries two standard gauge metro tracks *(Fig. 19.23)*. The bridge features a 1000 m radius curve at one end. A proof check exercise was carried out on this bridge before construction of its deck and certain vital recommendations were made with reference to final cable forces to be applied. It is a unique structure on DMRC.

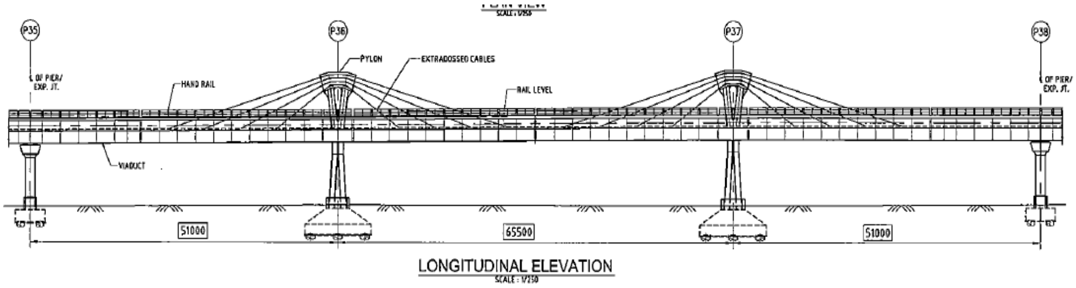

Fig. 19.23 Extradosed Bridge DMRC at Moolchand

19.7 Ballast - less Track for Joy Train around Kankaria Lake in Ahmedabad

As a part of the ambitious scheme of Kankaria Lake Front Development, evolved by the Chief Minister of Gujrat, ballastless track was to be laid for a 2’ gauge Joy Train for children around Kankaria Lake, a length of 2 km. A new design of ballast - less track was evolved and implemented which came to be appreciated by the Loco Engineers from UK who supplied the Joy train for children. This was commissioned in January 2008 *(Fig. 19.24).*

Fig. 19.24 Joy Train – Ballast - less Track at Kankaria Lake

19.8 Ghat Ki Guni Twin Tube Tunnels at Jaipur

Proof checking of all aspects of tunneling including ventilation was carried out for this unique twin tube tunnel with a length of 850 m. The tunnel is situated at the outskirts of Jaipur city and the tunnels have been designed to carry two lanes in each tube with two interconnectors at intermediate locations. These twin tube tunnels were completed in a matter of 267 days by NATM technique. The tunnels were commissioned in 2012 and have eased out the traffic situation on Jaipur Agra National Highway. This project was conceived by JDA and executed under BOT by Rohan-Rajdeep of Pune.

19.9 Kopri Railway Over Bridge

During construction, one of the PSC Segmental girder (43.6 m span) of the Kopri ROB at Thane had tipped and fallen in front of a suburban train in 2009 causing a serious mishap. This necessitated alteration to the scheme to ensure safety and speedy construction of this important ROB (conceived as far back in 2002). The original PSC girders were hump back to meet with the inadequate length of its approaches. A novel scheme with four Composite Steel Plate Girders (4 nos) with hump back profile was evolved. The two PSC hump back girders which were already available spanning across the abutments were checked for their design sufficiency and construction quality and thereafter shifted to the side and used in the footpath part of the bridge.

The steel girders fabricated at Vapi were transported to the site and assembled on the approaches in a consist of two girders each. Each consist was rolled over the footpath and after bringing in position these were hoisted by deploying two 100 tonne hydraulic cranes one behind each abutment and placed in position within a traffic block of 2 hours across six railway tracks at Thane. The bridge was completed in 2011. This was a unique operation and completion of this bridge raised the morale of the Railway and TMC engineers leading them to complete two more railway crossings in short succession (Kanjurmarg ROB along JVLR and Box pushing along Thane – Belapur Road)

19.10 Second Bhairab and Titas Bridges on Bangladesh Railways

During 2012 -13 Planning, Design and Bid Document preparation were carried out by a multinational team working with the author (as Team Leader of STUP- Scott Wilson JV) for second Bhairab (Meghna River) and second Titas Railway Bridge Project on Bangladesh Railways. This project is being funded by Govt of India through EXIM Bank. Conceiving the configuration of these bridges and accommodating the approaches within available ROW which were the challenges which were satisfactorily addressed. Adoption of 2.5 m dia RC bored piles is a unique feature which will give impetus to the Indian Contractors (only Indian Contracting Firms were eligible to compete for this Project) to bring in this technology to India.
The salient features of these bridges are

Bhairab Bridge (Meghana River)

1	Length of the Bridge	**982m** (approx.)
2	Spanning arrangement	3x20.2m Steel Composite Girder + **9x102.4m Steel Through Girders**.
3	Water depth	25 m
4	Foundations	**Cast-in-Situ RCC bored piles of 2.5m**, 2.0 m and 1.2 m dia.
5	Approach track	3 km

Titas Bridge

1	Length of the Bridge	**220 m** (approx.)
2	Spanning arrangement	**Double Girder bridge** of spans arrangements 3x20.2m Steel Composite Girder+ 3x32.5m Steel Through Girders + 3x20.2m Steel Composite Girders.
4	Foundations	Cast-in-Situ RCC bored pile of 1.2 m dia.
5	Approach track	2 km

This part of the Dhaka- Chittagong Main Line is planned along the proposed Trans Asian Railway Route.

19.11 Concluding Remarks

The author’s intention is to give glimpses of some of the important bridge works and track works wherein the opportunities provided to implement new concepts could be effectively utilized due principally to the freedom given by the superiors and excellent team working spirit of the engineers who worked on these projects. It is expected that the young engineers who will be the torch bearers for the enormous task of building state of the art infrastructure in India will get the impetus and motivation from the experiences shared by the author through this paper.