CROSFALL

Confidential Reporting Of Structural Failures And Lessons Learnt

NEWSLETTER

A Publication of Indian Association of Structural Engineers

Volume : 2 | Issue : 3 | July-September, 2023

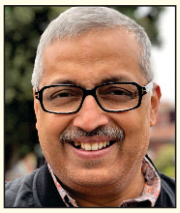
From the Desk of the President

I am happy to note that the editorial board of CROSFALL is coming out with the fifth edition. CROSFALL is a unique newsletter which focuses on highlighting the failure of a structure or a near-miss without revealing the identity of the person or the project. The objective is to educate the readers about such mistakes and caution them to avoid them in their projects.

For bringing out every edition, articles must pass through several review rounds. Our editorial board members & domain experts are doing fantastic work in evaluating, editing & reviewing the reports. This issue contains reports which raise serious concerns on various aspects, such as Loss of a Pier Well Foundation for a HL Bridge over a Major River, Steel truss bridge failure during launching, tilting of hammer-head pier of metro viaduct during service-a case of foundation failure.

The civil & structural engineering fraternity widely appreciated the earlier issues of this newsletter. Gradually people are coming forward to send the reports. I urge civil & structural engineers to send reports freely without any fear or hesitation. Reports may be for any type of structural failure or structures with visible gross structural deficiencies and substantial risk of failure. Do send your feedback & suggestions.

— Prof. R. Pradeep Kumar



Message from Chief Editor

Welcome to CROSFALL Newsletter No. 5.

With the publication of this newsletter, CROSFALL is entering in second year of its operation. CROSFALL started with its first newsletter in 2022 around the same time. This newsletter is being prepared in the aftermath of the catastrophic bridge failure of an extradosed bridge in Bihar. The dramatic and spectacular progressive collapse of this continuous bridge was captured in video and made viral on social media. Such failures once again remind all of us about the need to learn lessons from failures and thereby mitigate future risks.

CROSFALL has attained much prominence and progress since our last newsletter, which was published in 1st week of July 2023. A presentation about the newsletter was made by me in recent IABSE Congress 2023, which was held in New Delhi from 20th September to 23rd September 2023. Title of the paper was "CROSFALL - A knowledge-sharing newsletter to create a safer built environment". The paper and presentation was appreciated widely.

The three reports in this newsletter cover a range of topics on bridges. Based on the reports published so far, we have seen some recurring themes that the majority of the contributors are from bridge engineering field. Practicing engineers working in non-bridge sectors, like buildings, industrial structures, other infrastructure projects are not coming forward to report failures.

Behind the scene, the CROSFALL editorial board is working relentlessly to encourage practicing professionals to fearlessly contribute to CROSFALL by sharing their experiences with the fraternity. I take this opportunity to once again appeal readers to come forward and share their experience of failures.

Happy Reading !

— Alok Bhowmick

Contents

REPORT No. CF-16

Loss of a Pier Well Foundation for a HL Bridge over a Major River

1. Preamble

This is the story of a 2-lane bridge across a stream with tidal variation, where one foundation had to be abandoned during the construction stage due to excessive filting of well foundation. The bridge, as per the original scheme comprised three spans of 37.333 m each with an overall bridge length of 112m between c/c of expansion gap at the abutments. It comprised of two intermediate pier P1 & P2 and two abutment A1 & A2, all resting on well foundations, as shown in Fig. 1.

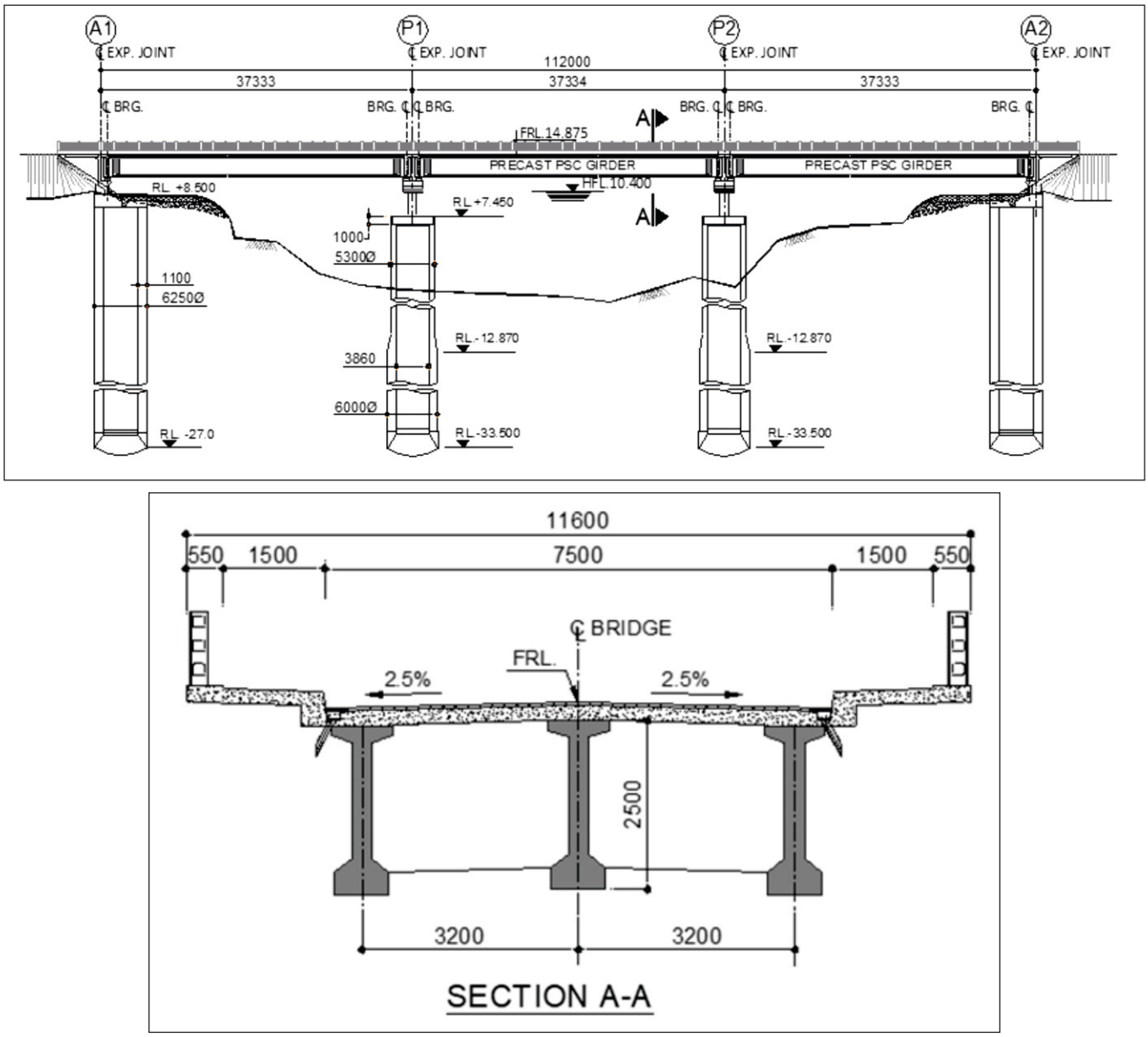


Fig. 1 : Original General Arrangement Drawing

Pier well P1 (location as per original GAD) got tilted excessively during its sinking operations and had to be abandoned. Span arrangement was modified on account of abandonment of original pier well P-1 by introducing a larger span of 49.15m bridging across the abandoned well as shown in Fig. 5. Steel trussed type of superstructure proposed for longer span, in order to control weight on other well foundation P2, which was originally designed to carry 37.33m PSC span.

2. Casting and Sinking of Well P-1

Due to large depth of water (of about 11m), floating caisson had to be resorted to for construction of well foundation. A floating caisson is basically steel shuttering of well having its height (above bed level) more than water level and comprising outer shuttering and inner shuttering as shown in photographs attached in Fig. 2. It is hollow from inside and is towed to the exact location of foundation by tugboats and made to rest on river bed. Concreting of steining between outer and inner steel shuttering is done after steel caisson has been grounded at proper location. In this case of well P-1, concreting was completed in 12 stages, till full height of steel shuttering of caisson as shown in Fig. 2. At this stage height of concreting was 11.8m and sinking was done for 2.1 m.

Fig. 2 : Floating Caisson and Casting of Steining

3. Sinking of Well P1 and its tilting

The stream has tidal variations. During the sinking process, at some stage, due to variation in tidal level from High Tide level to Low Tide level, the well got tilted excessively, became unstable, lost control and fell into river due to insufficient grip into the river bed. All efforts were made to bring it to original position but in vain. The well was tightened by wire ropes using three winch machines, but all efforts for improving the well position was unsuccessful. Photographs in Fig.3 & Fig.4 show tilted and fully submerged well.

Fig. 3 : Excessive Well Tilting

Fig. 4 : Well – Fully Submerged

4. New Proposal for Span Arrangement of the Bridge

When all efforts to set the well right were unsuccessful, it was decided to abandon the tilted well and go for alternative solution. While looking for alternative solution clients requirement also changed in terms of its navigability. In the revised span arrangement, the FRL was raised by nearly 3m to increase the vertical clearance between HFL and soffit of deck so that the central span gets the desired navigational clearance of 30m(H) × 6m(V). Bridge length extended by about 20m on either side by providing RCC box sections

resting on earth. New foundation was installed in place of original P1, which was shifted towards Abutment, thereby increasing the span from 37.33m to 49.15m and reducing the end span from 37.33m to 24.65m. The span between P2 to P3 was provided with steel truss having length of about 50m. Fig. 6 shows the position of well foundation, including the tilted well position.

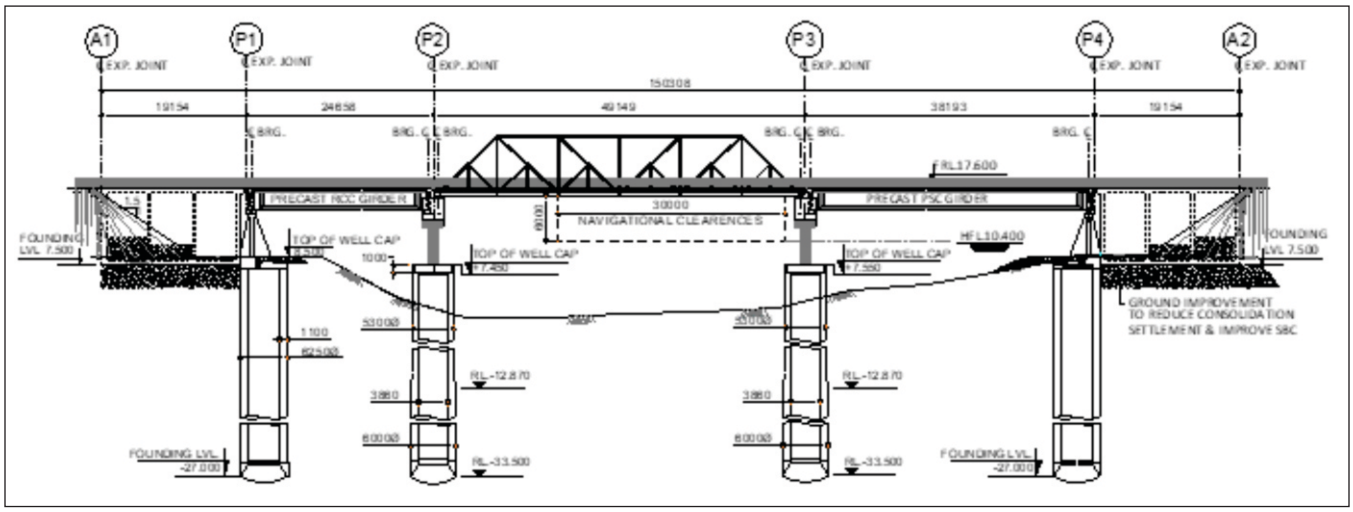


Fig. 5 : Revised GAD with modified Span Arrangement

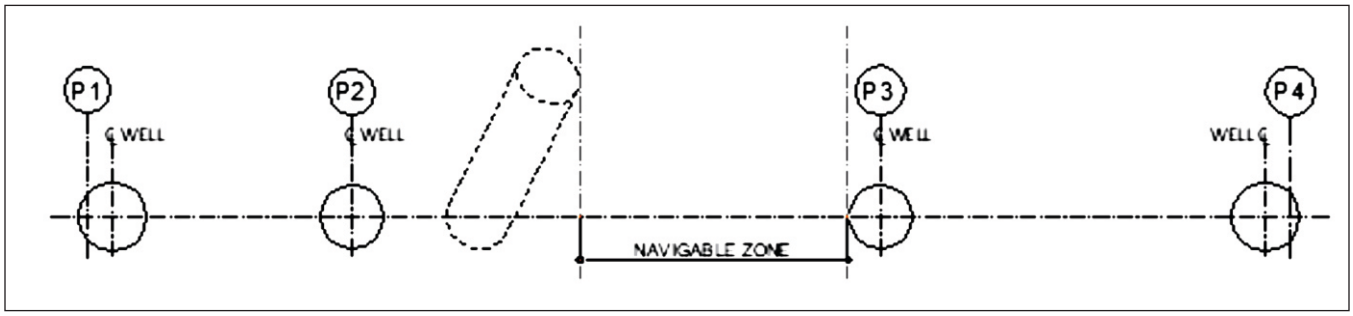


Fig. 6 : Foundation Position with modified Span Arrangement

5. Cause of Tilting

The loss / damage to the well has been caused due to sudden tidal current and tidal variation in the river. It has not been caused by design deficiency and/or defective material and/or bad workmanship.

6. Lesson Learnt

The loss of well foundation along with the floating caisson shuttering is a costly affair. Planning of the well sinking operation should take into account the weather patterns, tidal variations and possibility of flash floods so that sufficient grip length/depth of well into the river bed can be ensured before onset of such an event. Taking up construction activities without having adequate knowledge of river behaviour may result into loss of construction equipment, structure under construction and also manpower in some cases. Once the foundation is abandoned, the repercussions are serious such as change in span arrangement, redesign and approvals, loss of money & reputation and considerable delay to the construction schedule which could be avoided with careful advance planning.

7. Comments of Expert Panel

Ignoring riverine condition of especially high tidal variation and flash flood conditions can lead to serious consequences for well foundation during their construction. The report highlights the adverse impacts for a project involving the complete loss and abandonment of a well foundation with costly implications and affecting the project schedule. Ensuring adequate grip length of the well during construction stage is the key to avoid its instability leading to its abandonment. The knowledge of actual river conditions and regular monitoring of the sinking process should be given due importance during the planning of the well sinking operations.

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REPORT No. CF-17

Steel Truss Bridge Failure During Launching

The report is regarding the failure of a Truss Bridge during launching over a canal. Fortunately, there were no casualties. Ultimately after almost delay of two months the Truss was successfully lifted from the canal banks and placed on support.

1. Details of the Bridge & Launching Scheme

This Trussed Bridge over canal is spanning 81m from abutment to abutment. The incremental launching of Steel Trusses was adopted in this bridge. This technique was adopted because of restricted access to the site and tight project schedule. Moreover, to cross the canal where any kind of temporary supports are not acceptable by the Irrigation Authority; incremental method of launching is most suited. The design of the "Nose" elements, temporary supports etc. used for launching was one of the critical aspects of the overall scheme. The launching "Nose" adopted here was 45 m in length. Trestle supports were provided in front of Abutments on both sides, temporarily supported on abutment pile cap. RE wall was provided behind the abutment creating gap between them; thus needs running beam to span from abutment cap towards the RE wall side. Rails were attached on running beam for smooth movement As per the scheme the main truss along with the attached "Nose" was pushed gently from one side, unless & until the main truss reaches the other side. For smooth movement trolley wheels were attached under each joint, which was running on rails. Fig. 1 shows the launching arrangement and Fig. 2 shows the photo during launching.

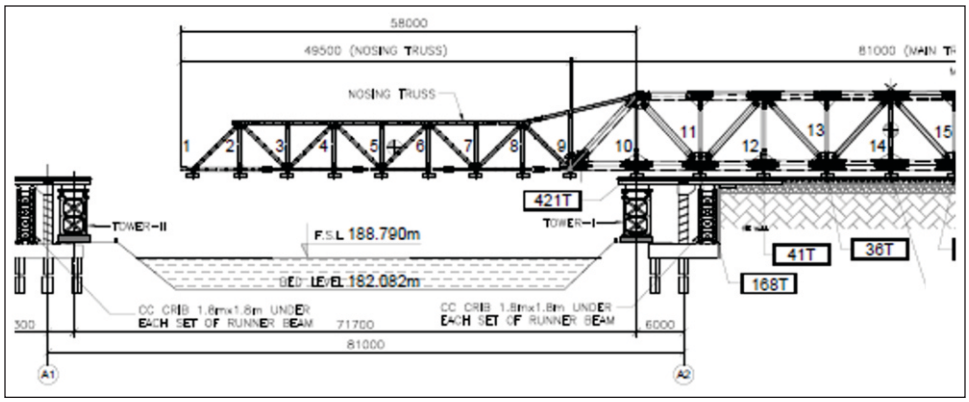

Fig. 1 : Sketch Showing the Launching Arrangement

Fig. 2 : Photograph During Launching of Truss

2. Failure During Launching

1. The first failure occurred when the first TWO wheels under the "Nose" was supported on the other side abutment. Around 40 m length of main truss had crossed from abutment towards spanning side. In this situation some top members of "Nose" got buckled, creating an alarming situation at site. Fig.3 shows the buckled top chord of the nose.

Fig. 3 : Photograph Showing Buckled Top Chord of Nose

2. Launching was halted for a few days for rectification of distressed members, and strengthening of some critical "Nose" members for further launching. After rectification, the launching was started again. It was reported when main truss front portion, which was connected with Nose, was about to touch the support, suddenly the connection between the truss & Nose got teared off, with the result, the end of main truss fell down. Fig.4 & Fig.5 shows the photograph of collapse.

Fig. 4 : Photograph Showing Collapse of Main Truss Launching End

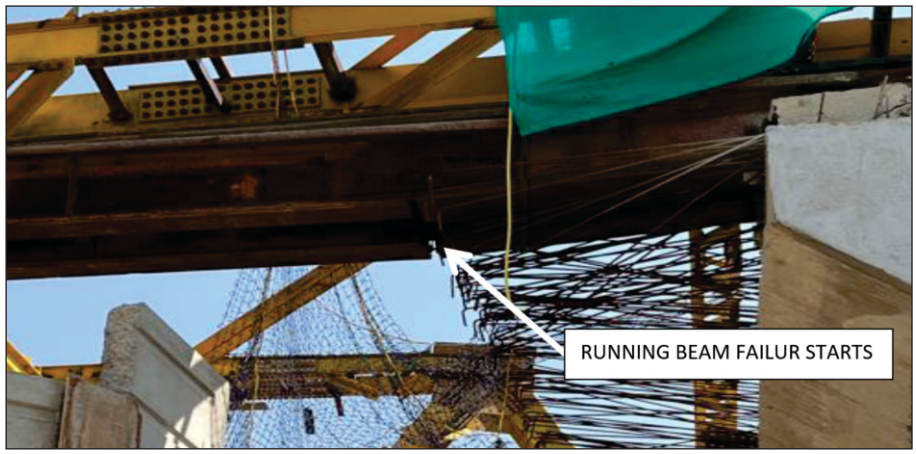

Fig. 5 : Photograph of Running Beam at Failure Side

3. Cause of Failure as per the Reporter

The first failure occurred due to the non-compliance of design drawings for the top chord of the Nose. During cantilevering the Nose top chord is under tension, until it touches down on the support on the far side, when it comes under compression. The spacing between the triangular shaped bracings connected to the top chord, was more than the designed value. Therefore, under compression the top chord buckled due to excessive length of the unsupported member. Generally it is assumed that the weight of the "Nose" is getting distributed equally between the two sides of the truss in an idealized condition. This is theoretically perfect, but in practice it may not be the case. Due to some mismatch or level differences between two sides (which may practically occur at site); one side of truss is more loaded than the other side during launching. It is suggested to consider some additional impact factor over the design load during launching condition.

Second failure was almost a disaster, and could have triggered a catastrophic situation at site. Just before collapse of the main truss, the whole system was supported on the last pair of wheels of Nose on the launching side. Almost the total length of truss was spanning supported on Nose wheels, exerting the maximum reaction under this condition on the running beams through the wheels. It was reported that just before collapse of the running beam (below rail) under "Nose" wheel started buckling, initiating the failure of the connection between main truss and Nose truss. It seems the running beam was not having sufficient strength to take the reaction which it was bearing. Trestle/crib supports which were proposed underneath the running beam were missing. This Trestle/crib supports would have provided sufficient support to running beams, and the collapse could have been avoided.

4. Lessons Learnt

1. Steel truss erection, assembling & launching process requires many safety precautions. A Risk assessment is necessary for determining the level of risk associated with each activity to identify the hazard and to take mitigating measures to avoid any incident.
2. Launching Truss (Nose) should be properly designed and fabrication should be checked at fabrication yard before bringing to site.
3. Construction Drawings should be prepared and validated by the Engineer and should be thoroughly checked for proper implementation at site before and during launching. In no case urgency/project completion date etc. should override the safety at site.
4. Tendencies/general practices are to construct/fabricate the launching truss (Nose) by assembling using the old members, which may have lost their strength on alignment. Moreover, those old/used members are not stored properly, thus chances of corrosions are more. These factors are not usually considered during design of the launching truss.
5. Launching is as serious as construction of new structure; thus a casual attitude during launching is totally unacceptable.
6. Awareness regarding safety needs to be inculcated among staff, employees and engineers by demonstrating the risk level and their consequences.
7. STOP WORK notice should be issued whenever unsafe practices/conditions are observed at site during truss assembly and launching operations.

5. Comments Expert Panel

Trial Assembly and load Test must be conducted at yard. Prior to dispatch of truss to site, assessment of all construction Hazards which are likely to occur associated with the fabrication, site assembly and launching operations must be carried out. Such pre-planning and envisaging of Hazards that may occur will greatly mitigate Risks associated with launching operations of a truss superstructure.

'Buckling' of the running beam on any steel member under rolling loads of the wheels used for launching should be checked at design stage itself. The local point loads introduce high stress concentration through the wheel loads and can lead to local yielding of member, web crippling on overall web buckling due to this point loading.

The truss members of bottom chords which are under compression during launching must be checked for same buckling phenomenon.

The load path of the point load caused by the wheels must pass through the centroid of the 'running beam' and bottom chord section to avoid introducing any destabilising 'out-of-plane' loading to running beams and bottom chord members.

Detailing in fabrications drawings should include all the relevant details and at site, thorough checking of the truss should be carried out to avoid any mismatch between the drawings and actual fabrication & assembly of the truss members. Connections play an important role and should be properly tested/checked as per the approved Quality Assurance Procedure.

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REPORT No. CF-18

Tilting of Hammer-head Pier of a Metro Viaduct During Service - A Case of Foundation Failure

This failure report is regarding the rotational tilt which was observed in one of the hammer-head type piers of an under-operation metro viaduct. Fortunately, due to timely reporting and intervention by authorities, major mishap was averted by adopting remedial measures promptly.

1. Introduction

On a sunny morning, one of the reputed news agency reported that a slight bend was visibly noticed on the running track lying above a particular pier, which clearly indicated that the superstructure itself has shifted or tilted from its original position. This news created panic among the nearby residents of that area and particularly among the daily commuters. There were several rising speculations that train operations could be halted owing to this tilt until the problem is completely resolved, which otherwise could lead to a major mishap. The track was in operation in this zone for more than 5 years at the time of this incident. There was an urgent need for action from the authorities. Authorities restricted the train operation by adopting speed limit at the affected zone. A slow speed < 10Kmph was resorted to in the affected area after the tilting was noticed. The movement of track, superstructure, pier cap & pier at different levels was monitored extensively to check the pattern of tilting and mis-alignment of track.

The affected pier has 23m span superstructure on both sides. The height of pier (from pile cap top up to top of pier cap) is about 14.0m. The diameter of pier is 1.6m. There are 4 numbers of pile provided under the pier. All piles are bored-cast-in-situ piles with diameter of 1.0m, which are designed to be socketed into rock. The length of piles is between 7.0m to 9.7m (refer table in next section for actual length). The last tilt observed at the pier cap top level, as recorded by the survey team was around 102mm in the transverse direction (perpendicular to train movement). Fig. 1 shows the plan arrangement of piles and the pile cap.

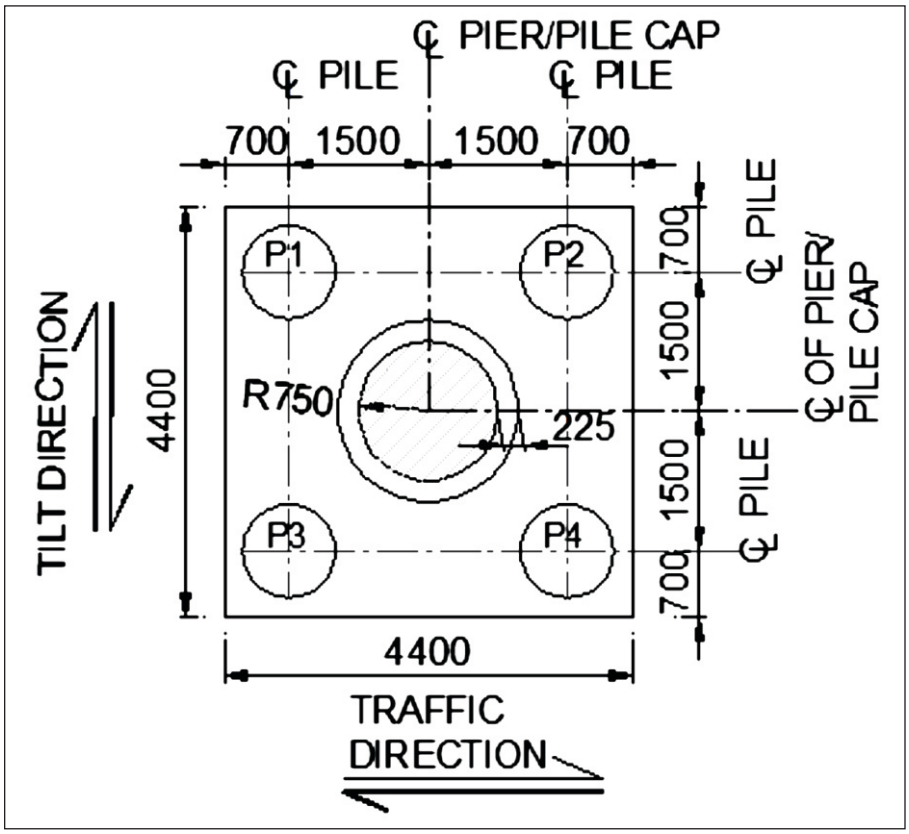

Fig. 1 : Plan of Foundation

2. The Problem

After analyzing the structural tilting which had occurred at the pier location, the probable cause of the problem seemed to be a serious case of execution-related negligence which had taken place during casting of the foundation of this pier. The long-term effects of this utter carelessness were now visible in the form of the tilting and rotation of the substructure foundation due to probable partial settling.

The diagnosis further revealed the actual cause of the tilting which has been discussed in the next section of the report.

3. The Diagnosis

The authorities took the following actions to diagnose the problems:

1. Constant monitoring of tilting of pier and movement of track until the problem was rectified.
2. Two additional bore holes were done adjacent to existing piles, to confirm the rock level.
3. Pile integrity test was performed from top of piles

As per the factual geotechnical reports available (during design stage), the soil strata at this location were "very loose silty sand" till 4m from ground level, followed by "very soft silty clay" until 9.5m from ground, followed by "weathered rock" till 10.1m from ground and "very hard granite" until 15.2m from ground. It may be noted that borehole data was available at 25m from pier location during design stage. As per available as-built pile length and rock level encountered during execution, hard rock had been observed at exact pile locations (two out of four) above the rock level expected from bore hole. Accordingly, two piles had been terminated at higher level based on rock level encountered during execution.

Results of the Pile Integrity Tests conducted are presented below:

Pile No.	Toe Response	Length of Pile from test level (m)	Wave Speed (m/sec)	Shaft Cross-section and Soil Changes (From Test Level)	Pile Integrity	Comments
1	-	11.15	4000	Possible defect seems evident around 10m from test level	Doubtful	Tested from top of pile cap
2	-	10.45	4000	Possible defect seems evident around 9.5m from test level	Doubtful	
3	-	8.55	4000	Possible defect seems evident around 7m from test level	Doubtful	
4	Evident	9.65	4000	Fairly uniform pile shaft	OK	

Inference of the Existing Socketing of the Piles in Rock (Additional Bore holes have been conducted adjacent to existing piles to socket rock levels):

Pile No.	As Built Pile length below Pile cap (m)	Pile length from Pile cap top (m)	Pile length from GL (m)	Rock level from GL based on additional bore hole (m)	Socket length in Rock (m)	Remarks	Report of Integrity Test
P1	9.65	11.15	11.75	10.4	1.35		Defect at 10m from pile cap top
P2	8.95	10.45	11.05	10.23	0.82	Actual Bore hole is not available	Defect at 9.5m from pile cap top
P3	7.05	8.55	9.15	10.23	-1.08		Defect at 7m from pile cap top
P4	8.15	9.65	10.25	10.4	-0.15	Actual Bore hole is not available	No Defect

From the above findings, it is extremely evident that no socket length had been provided for Pile number P-3 and P-4 when they were constructed. This absence of socket in these two piles would have resulted into the settlement of the piles P-3 and P-4, thereby creating a rotation of the substructure in the transverse direction (normal to the direction of traffic), which had been ultimately observed as tilt on a broader scale above the ground.

4. Proposed Remedial Measures

The proposed remedial measures consisted of recommendations which were targeted to strengthen the existing structural arrangement of the foundation keeping in view that the settlement should be completely controlled to ensure structural adequacy in future. It was decided that the existing pile cap should be extended by including 4 new piles. These 4 new piles in the extended pile cap have been recommended to have proper socketing as per design requirement ignoring the existing 4 piles. Fig. 2 shows the proposed arrangement. Fig. 3 shows the cross sectional details.

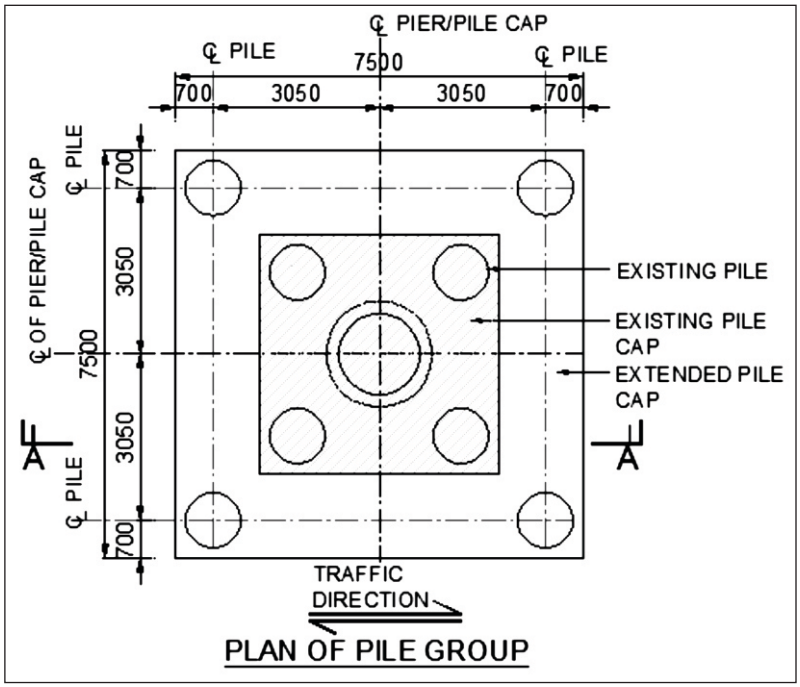

Fig. 2 : Plan of rehabilitated Foundation showing existing/new piles

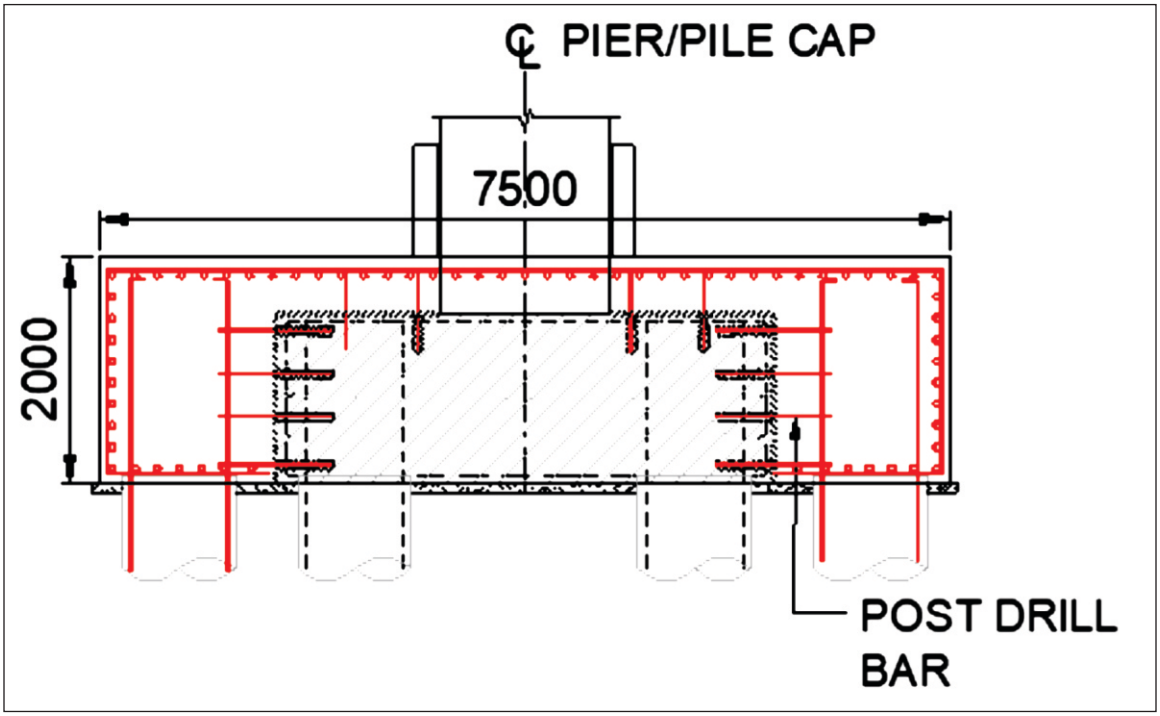

Fig. 3 : Section A-A

It is worthy to note that after concreting the extended pile cap and backfilling the area nearby it (after pile cap attains strength), the superstructure over the pier and rail track above it had been proposed to be restored to their original positions, which nevertheless seem to be a mammoth task altogether alone. The final levels, alignment/coordinates of the rehabilitated structures were recorded after the completion of work at regular intervals of time and circulated to the concerned authorities for their record and review.

5. Lessons Learnt from this failure case

a) It is the negligence of construction team which led to non-detection of the insufficient socketing embedment that had been obtained in the two piles (out of four), which led to the rotation of Pier/pile cap. Verification of pile socketing into rock during construction and its post verification is essential (may be through NDT tests or others) and shall be made mandatory in code & statutory requirement to avoid such type of problems in future.

b) Theoretically, all the engineers are aware of the significance of embedment or socketing in rock for a single pile in terms of the capacity of pile. It is also utmost important to assess the inclination of rock profile within pile group to propose proper minimum embedment of piles into rock.

c) It is important to have clear guidelines in the code for assessment of rock profile vs pile embedment into rock within a pile groups, to avoid any confusion in the construction engineer working at site.

d) It is also important to conduct bore hole at each pier locations, whenever piles are being founded on rock to have clear idea of expected rock level.

Comments of Expert Panel

The importance of correct construction of pile foundation to the desired design length and rock socketing requirement are clearly brought out in this report. Due to inadequate length and socketing of pile, transverse rotation of pier was noticed resulting from the settlement of piles on one side of the foundation. A serious mishap was avoided by timely detection of this rotation and additional piles and jacketing of pile cap were required as remedial measures.

The importance of correct geotechnical investigation and detection of rock level is emphasized. Pile Integrity Test (PIT) is an important QC measures prior to pile cap construction and should be done on all piles in a project. It is an NDT which is quite cheap to conduct. The PIT will serve to accurately give the length of the pile, quality of the toe response as rock socketed or otherwise and whether the pile itself has any defects along its length. Current IRC 78 Code and even the relevant BIS Code do not require PIT for 100% piles in a project. These clauses should be revised accordingly. Suitable notes should be added in drawings to caution the site engineers for possibility of the varying rock levels within a pile group which require change in pile lengths vis-à-vis lengths mentioned in the drawing.

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About the CROSFALL Newsletter

CROSFALL is a newsletter created by Indian Association of Structural Engineers (IAStructE). Its purpose is to share lessons learnt from structural failures, near-misses and safety concerns. CROSFALL is greatly encouraged and inspired by CROSS (Confidential Reporting on Structural Safety), UK, which is a collaborative effort of three institutions (IStructE, ICE and HSF). There is however no connection between CROSFALL-IAStructE and CROSS-UK.

CROSFALL has a confidential reporting system, which allow safety issues and failures to be reported by professionals, without exposing their identity. Any identifiable details, such as a project, product, individual or organisation, remain completely confidential to CROSFALL editorial team. Reporters' personal information will be collected to only verify the contents of the report, and to communicate with the reporter as and when necessary. The newsletter will report only failures and safety related issues with the objective to learn lessons from such failures and to help prevent future structural failures, by providing insight into root causes of such failures and spurring the development of safety improvement measures. CROSFALL team will depend on professionals to submit reports, whenever they can share their concerns about what they witness around or what they experience on any real-life projects. Anyone involved in the construction industry is welcome to submit a report. The more reports submitted, the better CROSFALL can identify and quantify safety issues across the industry. This will help the entire industry to learn lesson from CROSFALL publications

What can be reported?

- Structural failures,
- Poor Design and Detailing, Lack of Seismic Safety in planning
- Safety concerns about high risk erection schemes at Site
- Safety concerns on Temporary Works
- Near misses or observations relating to procedures followed at site, which may lead to failures or collapses.

To submit the report :

Visit : www.iastructe.co.in/crosfall.php

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