Confidential Reporting Of Structural Failures And Lessons Learnt

NEWSLETTER

A PUBLICATION OF INDIAN ASSOCIATION OF STRUCTURAL ENGINEERS

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From the Desk of the President

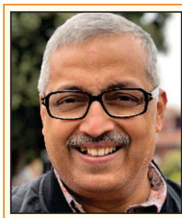
I am happy to note that the editorial board of CROSFALL is coming out with the fourth edition. CROSFALL is a unique newsletter which focuses on highlighting the failure of a structure or a near-miss without revealing the identity of the person or the project. The objective is to educate the readers about 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 wrong installation of bridge bearings, failure of steel truss during launching and issues of corrosion due to lack of maintenance.

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



I have great pleasure in releasing the April-June 2023 issue of CROSFALL. This is the 4th issue of the newsletter and we are presenting 3 interesting failure reports in this newsletter (CF-13 to CF-15).

Continuous improvement in safety standards through sharing of lessons learnt from failures, near-misses, and similar incidents is critical to sustainability of any profession or industry. However, we have seen a steady decline in the trend in last few decades. Incidence of structural failures are increasing at alarming level clearly pointing out to the fact that we are not learning enough lessons. The structural engineers are either not finding time to investigate and report failures or they are shying away from reporting failures due to fear of getting exposed to their clients and peers.

Bringing out this newsletter has been a challenging but very enjoyable task for the editorial board so far. We have received lot of bouquets and accolades for this effort. However in terms of contribution to the newsletter, the response has been rather lukewarm so far. Very few engineers are coming forward to report failures confidentially. I take this opportunity to once again appeal to all structural engineers to take interest in this effort and contribute reports, share their experience. I strongly advise all readers to visit our website periodically and study the reports of CROSFALL and use the information in your organisation to mitigate risks. Most importantly, please contribute reports confidentially.

Happy Reading !

— Alok Bhowmick

Contents

REPORT No. CF-13

Few Cases of Wrong Installation of Bridge Bearings

1. Introduction

The main reason for the damage of modern bridge bearings is that they do not receive the attention in design, manufacture and installation, that this important component deserves. Malfunctioning of bearings can lead to bigger problems. It can lead to distress in the superstructure/substructure or even failure of some elements of the bridge.

This report highlights three case studies of the wrong installation of bridge bearings, which led to a situation of failure and distress. Two cases are of Road Bridges and one pertains to a metro project. The following cases are included by the reporter in this report:

a. ***Case 1:*** Reverse installation of bearing fixing bolt in the connecting top plate of Pot cum PTFE bearing in case of a Flyover.

b. ***Case 2:*** Wrong orientation of metallic guided bearings in a Bow String Arch Bridge, crossing a major stream.

c. ***Case 3:*** Poor workmanship in the elastomeric bearings' installation led to major distress in the deck, forcing the closure of the corridor till the bearings were replaced.

2. Case Studies

2.1. ***Case 1:*** Reverse installation of bearing fixing bolt in the connecting top plate of Pot cum PTFE bearing for a Flyover Project.

Salient Features of the Project:

It is a 4-lane flyover, 1.4 Km long, with a divided carriageway, constructed in a heavily congested urban setting. The stilted portion is about 780m long having a series of spans in the range of 24m to 25m. The structural scheme for the superstructure comprises precast pretensioned girders with an in-situ deck slab. Expansion joints are provided at every 3rd span. The continuity of superstructure is established by deck continuity only. Girders are all simply supported. The bearing arrangement proposed is shown in Fig.1 below:

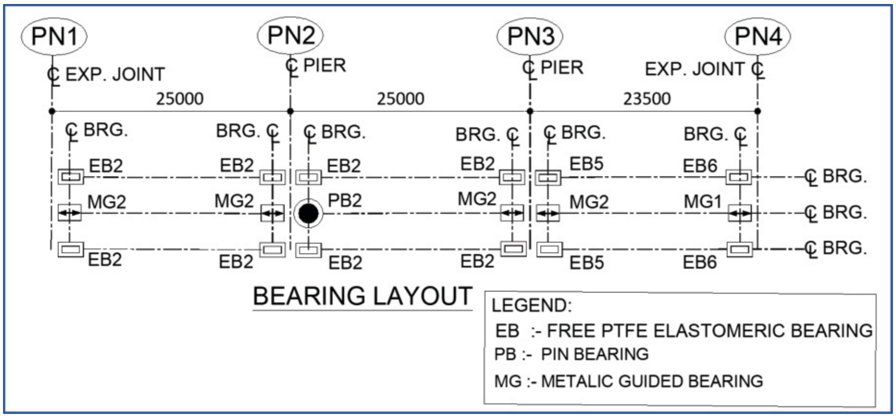


Fig. 1 : Bearing Layout for a typical module

Photo 1 : Hanging Sleeves from Bearing top plate

The Problem:

The elastomeric bearings provided in this case are of Type H (Bearings with sliding interface). During a site visit, post-construction, the reporter, noted that sleeves of free elastomeric bearings are not embedded into the concrete of the diaphragm. Rather these sleeves are hanging downward from the top plate! Photo-1 shows the observed detail. Fig. 2 shows the arrangement of fixing of the top plate of bearings, 'as per the GFC drawing' and 'as constructed.'

This was a serious construction lapse, which should have been avoided. Therefore, the following actions were taken by the Execution agency :

a) Removed hanging sleeves by lifting the superstructure through jacking positions.

b) Provided appropriate nut (in accordance with the grade of the bolt) and lower the superstructure to rest on bearings.

c) Precaution was taken to lift the entire unit of three spans at the same time.

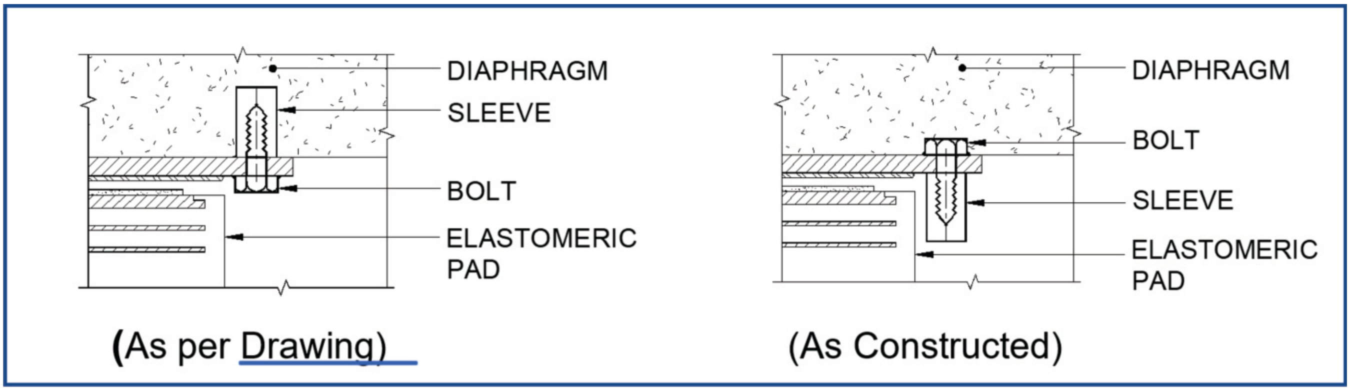


Fig. 2 : Fixing of the Bolt for Top Plate of Bearing

Lessons Learnt:

Such mistakes in the installation of Bearings are possible, only when the installation process is carried out by people who are incompetent and who have no experience in bearing installation. Bearing positioning on supports requires a proper installation manual with clear specifications and specialist supervision, as it is the most vital element of bridge and should assure proper functioning of supporting elements.

Comments of Expert Panel:

One of the major causes of wrong installation of bearings is that their installation manual or sequence is not given either by the bearing vendor or by the designer. Designer normally submits a drawing showing the bearing loads and movements and their schematic layout. Bearing manufacturer submits drawing showing only bearing details without giving proper guidance notes for the site staff. The bearing drawings should include the installation procedure by showing superstructure and pedestals and correct orientation of sleeves etc. in their drawings. At site, the engineer in charge should study the drawings thoroughly and understand the correct orientation of bearings so that he may guide the site staff properly.

2.2. *Case 2 :* Wrong orientation of metallic guided bearings in a Bow String Arch Bridge, crossing a major stream.

Salient Features of the Project:

It is a river bridge having a main span of 80m over the waterway and viaduct approach spans on both sides of the main span. The main span is provided as a steel bow-string tied arch. The overall width of the bridge is 12.5m, comprising a 7.5m carriageway, with a footpath on either side of the carriageway.

The Problem:

The reporter made a visit to the project site after the completion of the project and found that the bearing layout of the main span, as observed at the site does not match with the bearing layout as per the approved drawings. At one end of the span, the bearing should have been 'transversely' guided, which was found to be wrongly oriented as 'longitudinally' guided. Fig. 3 shows the bearing layout as per the approved drawing while Fig. 4 shows what was executed at the site. At the 'free' end of the bearing system at P5, close inspections of both bearings indicate that the bearings are 'not jammed'. They are functioning normally and there is visible longitudinal movement of the span.

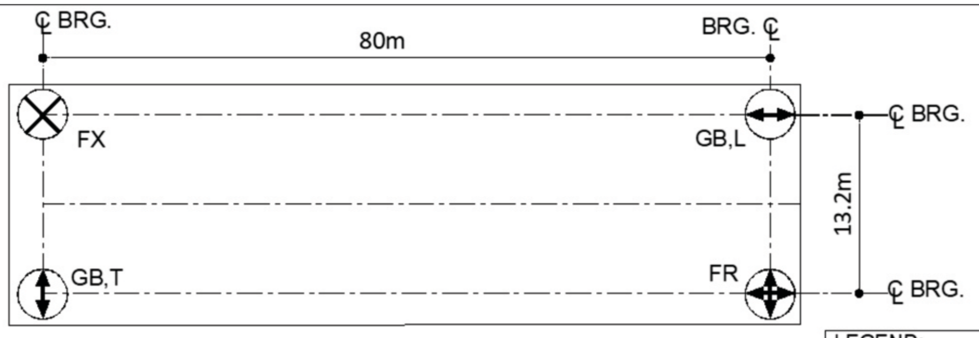


Fig. 3 : Bearing Layout as per Approved Drawing

LEGEND:
FR :- FREE POT/PTFE BEARING
FX :- FIX BEARING
GB,L :- LONGITUDINAL GUIDED BEARING
GB,T :- TRANSVERSE GUIDED BEARING

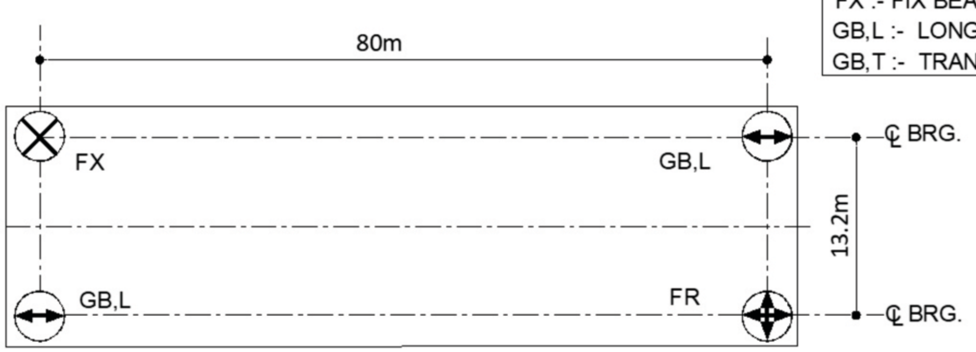


Fig. 4 : Bearing Layout as Executed at Site

Lessons Learnt:

Once again, this case study has demonstrated that the installation process is carried out by people who are incompetent and who have no experience in bearing installation. The bearings should have been installed in accordance with the specifications of the bearing installation plan. Bearing positioning on supports requires a proper installation manual with clear specifications and specialist supervision, as it should assure proper functioning supporting elements.

Comments of Expert Panel:

Care should be taken while installing the bearings. The comments given for Case-1 apply here too.

2.3. ***Case 3:*** Poor workmanship in the installation of elastomeric bearings led to major distress in the deck and forced the closure of the corridor for traffic till the bearings were replaced.

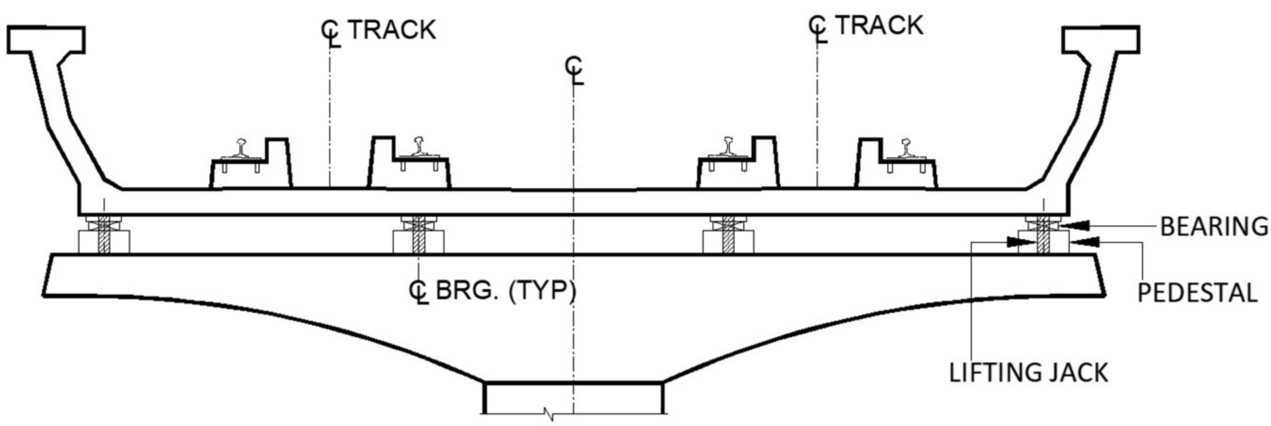


Fig. 5: Typical Cross-Sectional Sketch of Superstructure with Bearings & Pier Cap

Photo 2 : Photograph of a typical bearing before and after replacement.

The Problem faced

This is the case of failed elastomeric bearings (caused by poor installation) which reportedly led to the closure of the metro line and the replacement of bearings. Vibrations in a few of the spans in this corridor were noticed by train motormen who brought it to the knowledge of higher authorities. The Metro lane of this section was discontinued for traffic after an inspection of the same was carried out to find the root cause. According to the reporter, proper installation of elastomeric bearing was not done in as many as 86 spans. A total of 688 numbers of bearings had to be replaced.

Fig. 5 shows a typical cross-sectional sketch of the metro corridor showing the layout of Bearings and Pier Caps. Photo-2 shows the photograph of a typical bearing before and after replacement.

Lessons Learnt:

Bedding material as it is used to join bearing with superstructure and substructure should have appropriate resistance. Particular attention should be needed to the accurate filling of space under the bearing bottom plate.

Comments of Expert Panel:

Whenever elastomer bearings without anchor bolts are installed, there are fitted inside a recess provided in the pedestal and superstructure above. This prevents lateral movement of bearings during installation. Further, if superstructure is on grade, wedges are provided below the superstructure so that contact surface of superstructure is horizontal and bearing surface is in full contact with top & bottom surfaces. The photo 2 shows poor quality of concrete at top and bottom of the bearing which has resulted in uneven load distribution. The bearing installation procedure should be given in drawings explaining step by step installation procedure including Do's and Don'ts.

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REPORT No. CF-14

Failure of a Steel Truss during Launching

1. Preamble

This report presents a failure case of a of 68.25 m long steel truss during its launching over a deep gorge in a hilly terrain. The overall length of the steel truss bridge is 130m with the span arrangement of 97.5m + 32.5m as shown Fig. 6.

The bridge was designed to cater for two lane traffic for which a deck type steel composite bridge was designed comprising two parallel steel trusses with a cast-in-situ deck slab at the top.

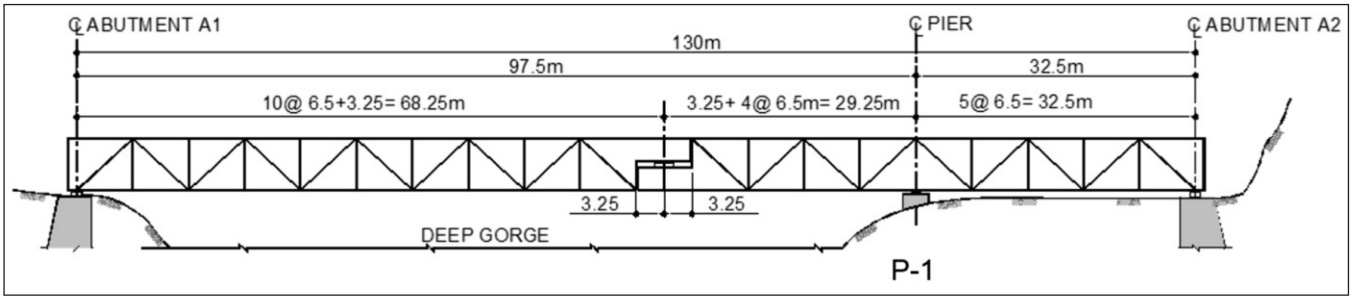

Fig. 6 : Elevation - Completed Bridge

2. Construction Sequence and Failure during Launching

Due to space constraints, only right hand side (RHS) bank was approachable with a very limited space of about 10m behind the abutment A-2. The sequence of the construction envisaged included the following steps:

a) Cast the pier P-1 and abutments A-1 and A-2.

b) Fabrication and welding of all the truss members was done at site.

c) Erect steel truss between pier P-1 and Abutment A-2 from the ground supports. A-2 end of the truss is anchored into the concrete abutment to resist uplift.

d) Erect steel truss 29.25 m as a cantilever beyond pier P-1 by cantilever method of erection of the truss members. The cantilever truss has an articulation over which balance 68.25 m truss will be supported over bearings. Free roller bearings are provided over pier P-1.

e) The scheme for balance 68.25 m truss length included its launching over the already erected truss as stated in c) & d) above. A launching nose of 26 m length was attached to the front end of the truss during launching so that the cantilever unbalanced moment is reduced. Fig. 7 shows the launching of the

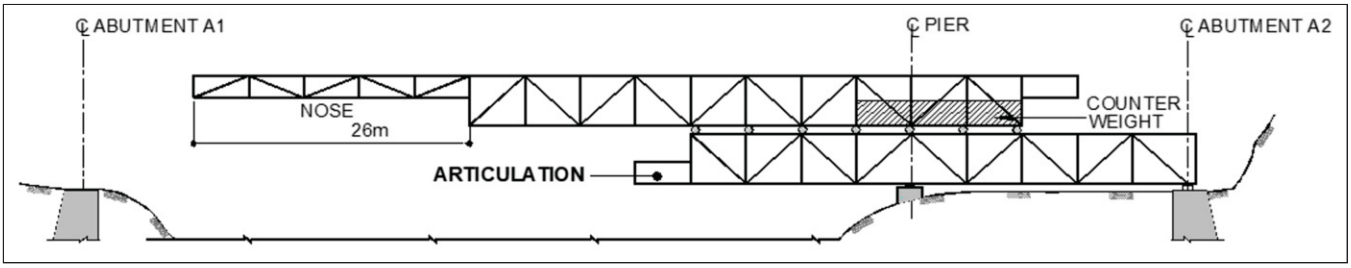

Fig. 7 : Launching of 68.25 m Truss

68.25m truss. To counterbalance the cantilever moments and ensure a factor of safety of 1.5 during construction, counter weights are added at the rear end of the truss during launching as shown below.

f) The main 68.25m long truss was erected over the already erected truss behind the pier P-1 in stages of one panel at a time which was of 6.5m length. First four panels with overall length of 26 m length were assembled first over the already erected truss between P-1 and A-2 and a Nose of length 26 m was fixed to the front end of truss.

g) Counterweight was placed in the last panel towards A-2 side and the truss was rolled forward by one panel length at a time. Counterweight was adjusted every time a panel length was added behind and truss was moved forward.

h) The forward movement was done with a wire rope and winch arrangement fixed over the abutment. An expert erection gang was engaged for launching of the truss.

i) The above procedure was followed till the Nose reached the abutment A-1 as shown in Fig. 8. Adequate counterweight was added at A-2 end to balance the cantilever moment of truss and Nose and to ensure desired factor of safety against overturning till the truss the truss moves as a cantilever.

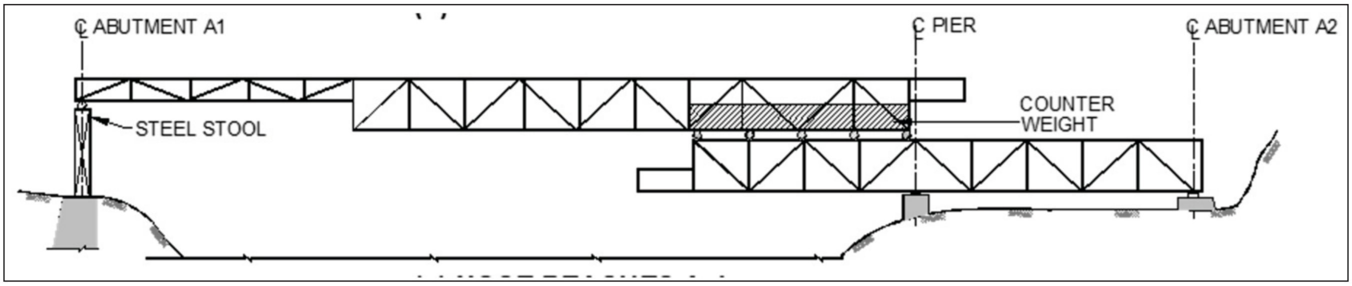

Fig. 8 : Launching Nose reaches Abutment A-1

j) The scheme envisaged removal of the counterweight at A-2 end once the nose rests over the A-1 end over a steel stool with roller so that the truss with nose is simply supported over A-1 end. The nose was to be dismantled panel by panel once it crossed the A-1 end. This process was to be continued till the entire length of nose is dismantled and front end of the main truss rests over the A-1 side temporary support. The truss end on P-1 also was to be supported over temporary supports over the articulation. In the next operation, 68.25 m long truss which was resting on top of the lower truss and over steel stools on A-1 was to be lowered onto the bearings on articulation and also on A-1 end.

k) However, when the counter weight was removed, the connection between the main truss and nose failed due to the reversal of forces and the entire top truss with nose collapse into the gorge as shown in Fig. 9.

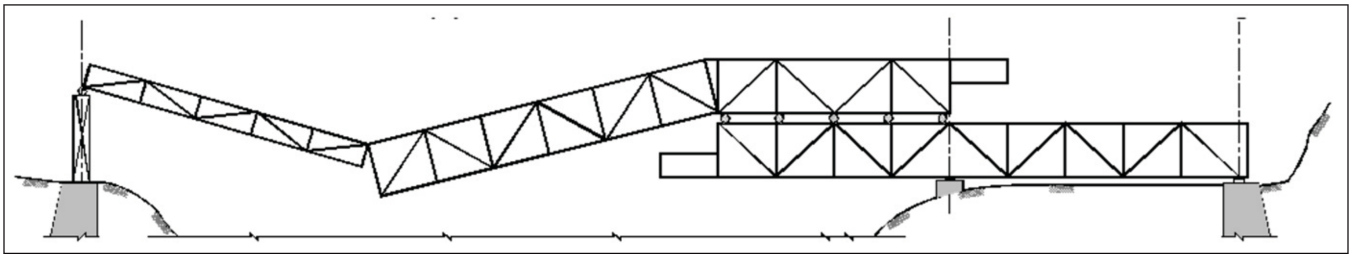

Fig. 9 : General Arrangement of the Bridge

3. Reason for Failure

The Nose was not properly designed for the forces after it became simply supported. During launching, the entire truss and nose were behaving as a cantilever. The top chord of the nose was connected to top chord of the main truss. However, its bottom chord was connected to the vertical member of the main truss. Once it became simply supported after removal of the counterweight at A-2 end, the connection of its lower chord failed since the tension in the bottom chord was not transferred to the bottom member of the main truss. The whole truss collapsed into the gorge and the welding, mainly butt welding in the truss members on P-1 side got damaged.

4. Remedial Measures

The truss between P-1 and A-2 side was thoroughly inspected and splice plates were welded to the truss plates which were originally spliced through butt welding. All the welds and splices were tested for quality. Once the damaged truss between P-1 and A-2 was repaired and found to be safe, the 68.25 m long truss was refabricated with a nose fixed to the top and bottom chord for proper transfer of forces once it becomes simply supported.

The truss was launched successfully with the improved Nose design and it was lowered on the articulation over P-1 and A-1 end by lowering it step by step by using the hydraulic jacks and packings.

5. Lessons Learnt

a) Such risky schemes involving launching and lowering should be avoided in the first place. The main truss was mounted on already erected truss below between P-1 and A-2. Once the launching was completed, the truss was lowered onto the articulation which was quite risky.

b) Articulated joints as provided in this bridge is very risky and cause maintenance problems and should be avoided.

c) Design and detailing of nose are very important and it should be designed properly for its connection with the main truss and transfer of forces during cantilever and simply supported stages. Top and bottom chord members of the nose should be connected to top and bottom chords of the main truss respectively.

d) Most of the plates were more than 32 mm thickness and the entire welding was done at site. At splice locations, plates of the built-up section of top and bottom chords were directly butt welded. Such weddings are not permitted at site. Bolted connections should be provided with gusset plates at locations of joints and splicing. Only the truss members should be fabricated with welding of individual components which should be done in the workshop under controlled environment. Quality of welds and fabrication must be ensured by following the applicable specifications.

Comments of Expert Panel

This important Forensic Engineering report emphasises the need for developing a sound erection and launching scheme for a steel bridge and the need for a through construction stage analysis and design.

Site welding, especially at splice locations and between built-up plate sections of top and bottom chord should not be permitted. Instead, bolted connections should be used. Welding of all built up members shall be done under controlled factory environment.

When a launching nose is used for erection, all construction stages during cantilevering as well as when the nose has touched down on the other side creating a simple support system, are to be thoroughly addressed in analysis and design. Force transfer from the bottom chord of the nose should be directly in line and into the bottom chord of the truss to which it is attached in the temporary condition during launching. As such articulated joints also called half-joints must be avoided.

A comprehensive Risk Assessment must be done for the entire launching, erection and lowering process with the view to design out any potential partial or full failure during these operations.

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REPORT No. CF-15

Story of a Steel Truss Bridge - How Severe Corrosion can play havoc due to Lack of Maintenance

The reporter in this case has highlighted an issue of lack of inspection and maintenance of a Steel Truss Bridge (Highway), which led to a situation of near failure where the structure fails to function in the way it was been designed for. This is the story of a bridge, which was constructed in 1920s and in the recent times has shown considerable signs of distress

Background

A steel truss bridge over a drainage canal was constructed in 1920 to carry highway traffic. It is a petit type truss, an advanced version of pratt truss of 75m. Span c/c of Bearing with 18 equal panels of 4.16m each. The Bridge had shown signs of distress in the Ninteen eighties and in keeping the road link functional, authority constructed additional steel truss girders with 3 spans founded on piles underneath the existing bridge with the sole intention of supporting the bridge with the load from existing carriageway load passing through the deck system to the truss girder installed underneath. In this process the structural function of the original truss bridge was changed. Fig. 10 shows the photo of the bridge post-retrofit carried out in 1980s.

At a later date (during 2020s), further distress was observed on the bridge and this time authority engaged specialist Consultants for thorough structural health investigation of the bridge and for preparing plans and schemes for remedial action.

Fig. 10 : Photo of Old Steel Trussed Bridge (YoC : 1920) which was retrofitted in 1980s

Salient Technical Details of the Bridge

The deck structure of the bridge consists of concrete deck slab and stringers supported on steel troughs spanning across stringers which in turn are resting on cross girders that are hung from the bottom chords of the truss with diaphragm plates extending below verticals of the main truss.

The main carriage way for the road traffic is at the central portion of 12.2m length of cross girder spanning between the two trusses and footpath is provided on cantilever portion of cross girders on 2.43m length with additional footpath of 3.048m length on either side of the cantilever portion of cross-girder. Fig. 11 shows sectional details of truss members. The total dead load of superstructure including structural steel of truss, cross girder, stringer and trough concrete is reported to be approximately 1,600 MT with the loads from superstructure passing from trough concrete to the stringers and then to cross girders at each of the 17 panel points which is connected to the bottom chord by hangar plates at each of the 17 panel point. Finally, the load is transferred as concentrated load at each of the 17 panel points and taken up by the truss. At mid span the height between center of bottom chord and center of top chord is 11.6 meters and the transverse distance between two truss is 12.2metres.

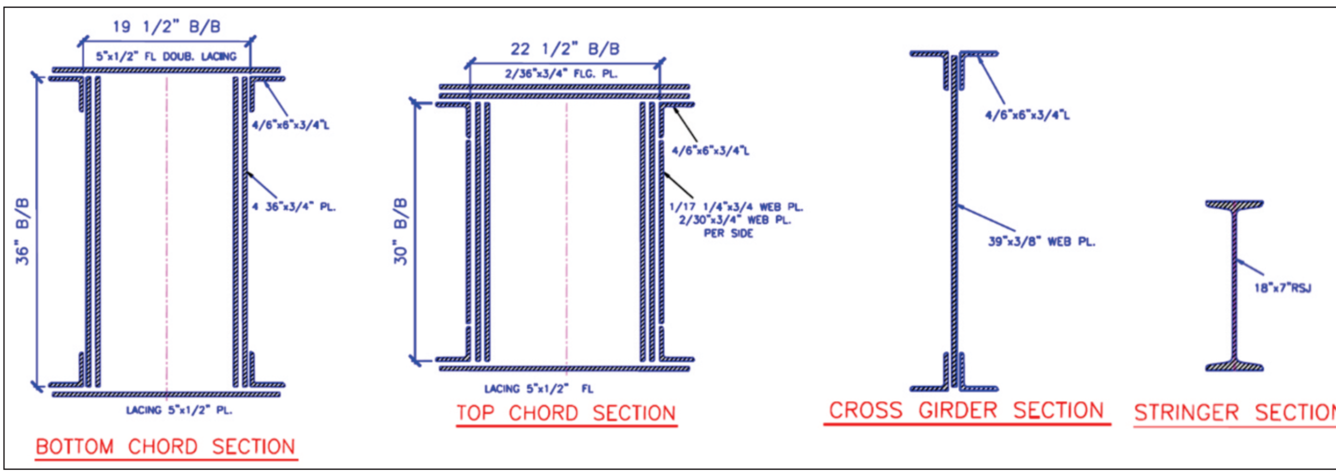

Fig. 11 : Sectional Details of Truss Members

Diagnosis & Probable cause of Distress

While carrying out detailed investigations, reporter found that a major portions of the upstream and downstream top chords were badly corroded and part of the 20mm thick top plates along with their rivets are totally eroded out. Fig. 12 shows the extent of corrosion noticed in the top flange of the truss. Such heavy corrosion of the top plates was caused by the Caracas of dead cattle picked up and stored on the top chords by the vultures from the drainage canal.

Fig. 12 : Photo showing extent of top-chord corrosion in the bridge

Such corrosion was also observed in many of the lateral bracings as well the Portal Bracing Joints. Vultures found the location of Portal Bracing joints with the gusset plates quite comfortable for nesting and as a result those locations also suffered severe corrosion. Fig. 13 shows the severity of the corrosion in such locations.

Fig. 13 : Photo showing extent corrosion in the Lateral Bracings & Portal Joints

From the records, it was clearly understood by the reporter that no inspection, especially at the top chord level, was undertaken by the authorities during last 50 years or even before. Unfortunately, the bridge was being cleaned and painted every 5 years and such painting work is generally left with the unskilled laborers. As a result, such distress or damages were never reported by those painting / cleaning gangs to the authority. Severity and extent of corrosion distress was certainly beyond their knowledge and understanding.

Remedial Measures undertaken to bring back the structure to its use after the diagnosis of the probable cause of distress:

Once the detailed investigations were carried out and the causes of distresses were found out, the rehabilitation scheme was prepared. Major actions taken were as under:

a. The Tram Services on the bridge was discontinued.

b. Part by part the major damaged components were replaced by fabricating new members.

c. This bridge being on a major road connecting the Kolkata Port with the city, this could not be closed for rehabilitation work. Instead, the heavy traffic was diverted to another road closer to bank of Ganges and only the central part of the bridge was kept open for the movement of light vehicles during the rehabilitation work.

d. Wherever a joints was opened out removing the damaged or highly corroded rivets (fasteners), the rivets for entire joints was replaced by appropriate HSFG Bolts.

e. The work was carried out day & night under strict supervision of the Consultant's team with supported by the client's supervisors, in ensuring quality work with total safety.

Lesson learned:

Lack of maintenance to any bridges & structures can play havoc in destroying the structure prematurely, which otherwise could have serviced its purpose much longer.

Sustainability of structures is an important component and that is more relevant in case of any rehabilitation work of bridge structures. There are numerous numbers of Steel Bridges existing for road and railway network for more than 100 years, and appropriate inspection at a regular interval (at least yearly inspection by competent persons is desired) and taking up remedial work from time to time in keeping the health of the structures in rendering desired services. Such in-service health inspection & safety assessment should be carried out and reports along with remedial actions taken are to be documented, which will be the initial guideline for the subsequent inspections.

Comments of Expert Panel

Normally corrosion in steel members occurs due to presence of water and oxygen. This bridge being too old, is also subjected to atmospheric corrosion in addition to the corrosion caused carcasses stored by vultures on top chord and also nesting inside the bracings. In addition, any steel bridge undergoes deterioration due to other factors too such as cracks, stress corrosion, brittle fracture, buckling, fatigue cracking and several other manmade causes. It is imperative to thoroughly inspect such old bridges on a regular basis. A dedicated and trained team is required having knowledge of bridge history and various causes of deterioration. Once the causes are known, it is easier to understand the types of damages, defects and deterioration. A manual should be developed for inspection and study of all the components of the bridge. Quality and composition of paint is very important to prevent corrosion and there are specifications available for the same developed by Railways in particular. A though knowledge of causes of deterioration, types of painting specifications and repair and rehabilitation process by the inspection team will be very useful in preventing the corrosion and other types of deterioration.

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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 :

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