

REPORT

THIRD PARTY AUDITING OF RAILWAY BRIDGES (PHASE I)

(Job No: CED/CON/TMMP/SAS/2019312)

**Br. No. 1274 DN (16 × 45.72 m) Steel Girder at km. 881/600 – 882/480
between Ullal and Netravathi stations**

CLIENT



SOUTHERN RAILWAY PALGHAT DIVISION

CONSULTANT



**Department of Civil Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT**

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1. PREAMBLE

Director, NIT Calicut received a request from Chief Bridge Engineer, Headquarters office, Chennai Works Branch, Southern Railway vide letter No. W.439/4/61/Vol.IV(W.245/I/1 Spl. Drive) dated 18 – 09 - 2018, exploring the possibility of whether NIT Calicut can undertake a one - time third party auditing of some selected railway bridges. This was consequent to the instruction issued by Railway Board to various railway divisions for undertaking such inspections of railway bridges through expert institutions. The letter was forwarded to the Civil Engineering Department (CED) and the Structural Consultancy Group of CED followed the matter up. The Railway Board was represented by Palakkad division of Indian Railway. Subsequently, on 05 – 10 - 2018 railway officials came to CED, NITC for discussions. Soft copies of the available drawings of some of the bridges were also shared by Railways to CED for initial assessments. Subsequently, CED expressed its willingness to take up the work and communicated the matter by letter, No. CED/CON/RLY/TPAUD/2018/1 dated 08-11- 2018. Through this letter it was conveyed to Railways that the work could be taken up in two phases, outlining the scope of work to be carried out in the different phases. This was accepted by Railways and they requested the details of consultancy charges for carrying out phase I of the work.

CED replied vide letter No. CED/CON/RLY/TPAUD/2019/1 dated 10 - 01- 2019, the requisite details regarding consultancy charges and scope of the work. Railways replied to this letter showing their interest to award the work to NITC and sought the signing of an MoU to proceed further. Mutual discussions followed and an MoU was signed in the FN of 19-09-2019.

The details of communications are given below:

- i. W.439/4/61/Vol.IV(W.245/I/1 Spl. Drive) dated 18-09-2018.
- ii. Meeting held on 28-09-2018 at NIT Calicut with railway officials.
- iii. J/W/71/G dated 23-10-2018 from Divisional Office, Palakkad division furnishing details of some of the bridges.
- iv. CED/CON/RLY/TPAUD/2019/1, dated 10th January 2019
- v. MoU between Southern Railway and NIT Calicut, dated 19-09-2019.
- vi. CED/CON/HOD/TMMP/SAS/2019312, dated 3rd October 2019
- vii. J/W.71/G, dated 03-12-2019
- viii. CED/CON/HOD/TMMP/SAS/2019312/1, dated 02-01-2020
- ix. CED/CON/HOD/TMMP/SAS/2019312/2, dated 02-01-2020
- x. CED/CON/HOD/TMMP/SAS/2019312/3 dated 23-01-2020

- xi. CED/CON/HOD/TMMP/SAS/2019312/4 dated 11-03-2020
- xii. CED/CON/HOD/TMMP/SAS/2019312/5 dated 12-03-2020
- xiii. CED/CON/HOD/TMMP/SAS/2019312/6 dated 13-03-2020
- xiv. CED/CON/HOD/TMMP/SAS/2019312/7 dated 11-05-2020
- xv. No. J/W.71/G dated 27-07-2020
- xvi. CED/CON/HOD/TMMP/SAS/2019312/8 dated 22-07-2020
- xvii. CED/CON/HOD/TMMP/SAS/2019312/9 dated 22-07-2020
- xviii. CED/CON/HOD/TMMP/SAS/2019312/10 dated 14-08-2020
- xix. No. J/W.71/G dated 26-09-2020
- xx. CED/CON/HOD/TMMP/SAS/2019312/13 dated 21-09-2020
- xxi. CED/CON/HOD/TMMP/SAS/2019312/15 dated 17-11-2020
- xxii. CED/CON/HOD/TMMP/SAS/2019312/17 dated 24-12-2020
- xxiii. CED/CON/HOD/TMMP/SAS/2019312/18 dated 19-01-2021

2. SCOPE AND METHODOLOGY

Railway bridges, which are known for their permanent resistance to heavy movable loads, are exposed to large load ranges and severe environmental conditions that may lead to damage and failure of the system. Keeping in mind the large risk and economic ramifications, it is necessary to assess the health of these structures systematically by considering all loading types namely, gravity loading, wind loading and seismic loading and effect of corrosion and fatigue. In view of the above and based on the terms and conditions laid down in the MoU, the scopes of the present investigation are identified as below.

- i. Inspection of the superstructure of the bridge, bearings, piers and abutments and top surface of the bridge along with load transfer mechanism.
- ii. Visual assessment of corrosion in the bridge.
- iii. Collection of data pertaining to the state of the bearings and water drainage.
- iv. Collection of necessary data for structural modelling and analysis.
- v. Preliminary analysis of the bridges to check the adequacy of the bridge to carry 25 t axle load since the bridge was designed in the past for loads lesser than 25 t axle load.
- vi. Overall assessment of the bridge and its integrity.

Analysis for earthquake loads is not carried out as dimensions pertaining to the substructure and its condition is not completely available. This can be performed after the underwater inspection and measurements in phase II of the audit.

In general, estimation of fatigue, corrosion, and their combined effects pose practical

difficulties. However, an attempt will be made to collect all relevant data for predicting the residual life ^{[4][8]}, as part of phase II of the audit.

Considering the above aspects, the following methodology is finalised.

- i. Visual inspection of the bridge
- ii. Field measurements for modelling purpose
- iii. Condition assessment of various elements of the bridge and to summarize the results in a tabular form
- iv. Structural modelling and analysis of the bridge for stipulated loads
- v. Assessment of the residual strength and safety based on the analysis results

3. INSPECTION OF BRIDGE

3.1 Visual Examination

The visual inspections were carried out on the bridge on 10-01-2020 (Tuesday) at 4:00 pm and 11-01-2020 (Wednesday) at 8:30 am. Officials from Kannur Railway section were also present during the inspection. Photographs of the bridge showing various elements are shown in Figure 1 to 7. The bridge is a steel truss type through bridge with sixteen spans each of 45.72 m, supported on Random Rubble (RR) masonry piers. Cement Concrete bed - blocks are provided on top of the RR masonry pier. It was noted that the abutments were also of RR masonry. The abutment at the shornur end was noted to develop some distress.

It was orally transpired during the visit that the stinger beams are replaced as and when required. It was also reported that speed restrictions are imposed on the trains travelling through the bridge. On 15/01/2021 one more visit was conducted at this bridge site to assess the condition and for taking a few measurements pertaining to various members.



Figure 1. Side view of Br.1274 DN between Ullal and Netravathi Station



Figure 2. Inside view of the bridge



Figure 3. Steel roller type bearing



Figure 4. Bottom chord and end diagonal members



Figure 5. Pier and Bed block



Figure 6. End cross beam



Figure 7. Connection between truss elements

3.2 Field Measurements and condition assessment

All the missing dimensions to complete the geometry of the bridge were measured from the site. The available drawings were also referred. Figures 8 and 9 show the details of schematic diagrams of the bridge and typical member details. Based on a careful examination of the bridge, the results of observations are tabulated in Table 1. The Table shows various elements of the bridge, defect type, follow up actions required and remarks. Labels are assigned to various types of defects as given in Table 2.

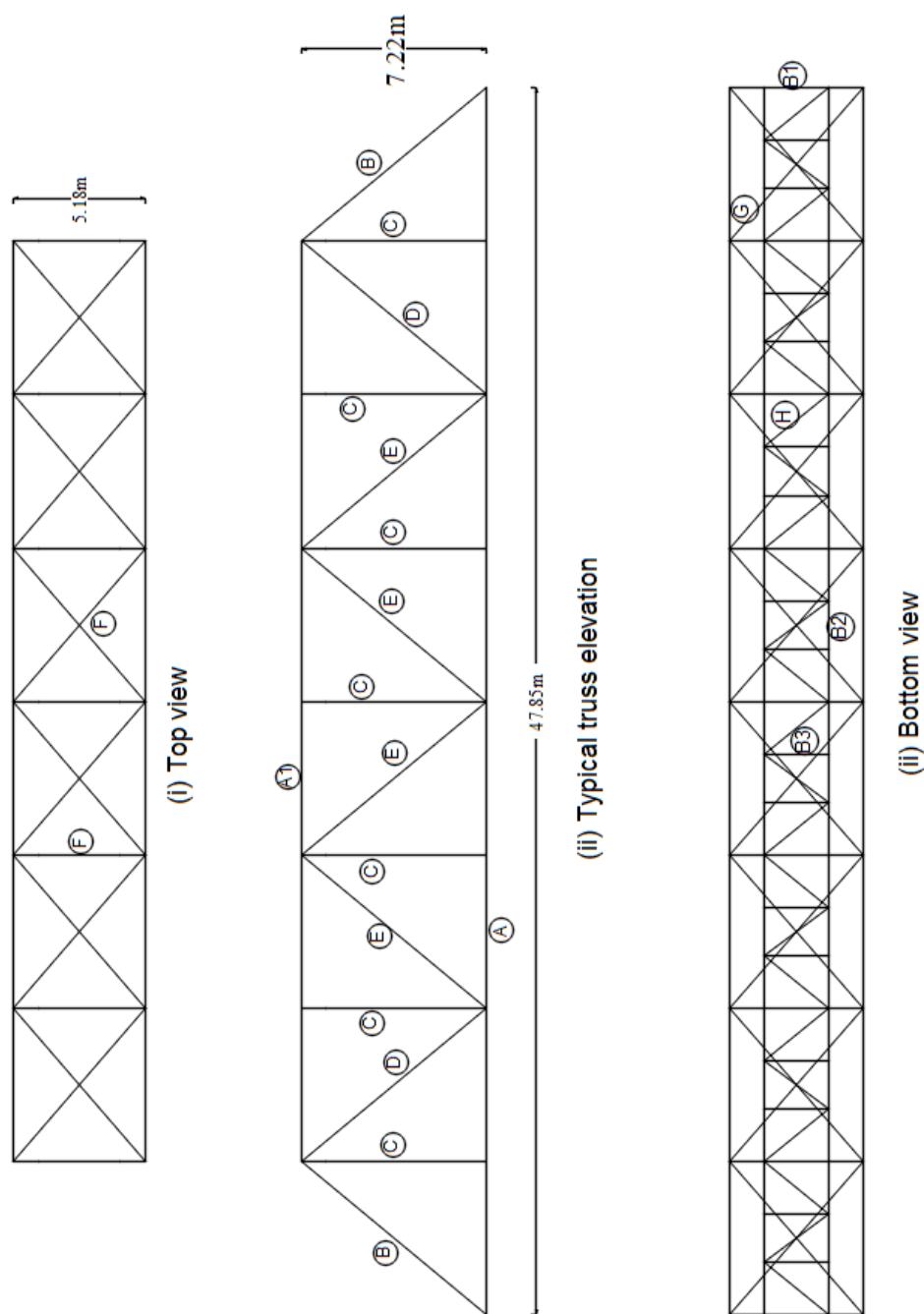


Figure 8. Geometrical details of a typical span (not to scale)

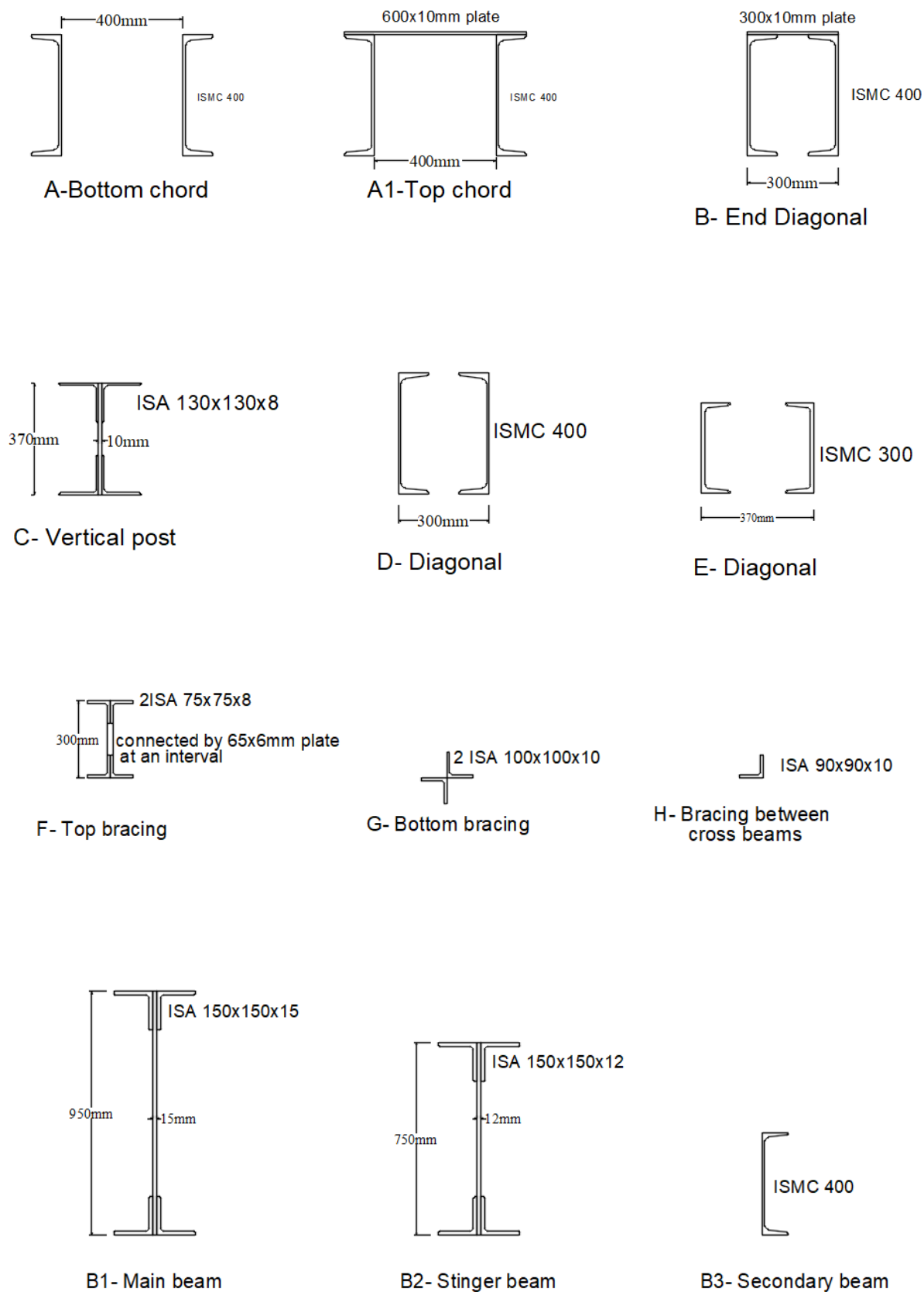


Figure 9. Section details of each elements

Table 1: Condition assessment of bridge

Element	(Ref. Table 2 for details)	Follow-up actions required			Remarks
		DI	Re	De	
Abutments	14	✓	-	-	
Piers	14	-	-	-	Minor distress in pier No.11
Bed-blocks	00	-	-	-	
Girder bearings	00	-	-	-	
Top chords	02, 03	-	✓	-	
Bottom chords	03	-	✓	-	
Diagonals	03	-	✓	-	
Verticals	02, 03, 08	✓	-	-	
Bottom bracings	03, 08	-	✓	-	
Top bracings	00	-	✓	-	
Main beams	02, 03	-	✓	-	
Cross beams	03	-	✓	-	
Secondary beams	03	-	✓	-	
Beam bracings	02	-	✓	-	

* Legend: DI – Detailed Investigation; Re – Repair; De – Demolition

Table 2: Different defect types and their designation

Defect Type	Label	Defect Type	Label
Dampness	01	Lack of redundancy	10
Loss of material due to corrosion	02	Foundation settlement	11
Staining due to corrosion	03	Percolation of water through RR masonry	12
Buckling of plate	04	Vegetation growth	13
Tearing of steel	05	Cracks in stone masonry	14
Excessive deflection	06	Floor settlement	15
Excessive deformation	07	Signs of overloading	16
Distress in Connection	08	No visible defect	00
Cracks in concrete	09		

3.2.1 Extent of corrosion

The corrosion process of steel is affected by many factors, such as the kind of steel and surface protection; environmental impact; and the presence of pollutants, cracks, and stresses. The loss of material may result in reduction in the cross-sectional area and subsequent increase in the stress level for a given load or increase the stress range for cyclic loads^[5]. Besides, it can lead to a reduction in the buckling resistance of elements or the initiation of fractures. In general, the loss of cross-sectional area results in a decrease in geometric parameters such as the moment of inertia and radius of gyration and overall stiffness degradation of the structure.

In the present bridge, it is seen that the main beams were corroded at several locations and at some places head of the rivets were fully deteriorated as shown in Figure 10 and 11. At all other places, the rivets were intact and seen with aluminium paint coating. As shown in Figure 12 and 13, bottom bracings were corroded at many locations. Corrosion in the main truss elements is minimal, but in verticals, it is observed that considerable amount of loss of material is observed at the bottom as shown in Figure 14 and 15. It was informed that at many instances in the past, distressed members were replaced, mainly owing to the corrosion and subsequent material loss occurring in members. This accelerated corrosion is attributed to the close proximity of the bridge to the Arabian sea.



Figure 10. Corrosion in bottom flange main beam



Figure 11. Corrosion in main beam



Figure 12. Loss of material in bottom bracing



Figure 13. Corrosion in bottom bracing



Figure 14. Corrosion in the bottom of verticals



Figure 15. Corrosion in the vertical

3.2.2 Comments on the condition of the abutment

The stone masonry abutment at the southern side (Shornur End) has a crack originating from the top identically on both sides (West and East) and extending downward (at approximately 45° to the horizontal) as shown in Figure 16. A close up image is shown in Figure 17, which shows that the crack width is ranging from 5 mm to 10 mm and hence it is not negligibly small. Vegetation growth in the crack is also noted which can widen the crack further. **This is a matter requiring immediate attention and repair/strengthening.**

The abutment at the northern side (Mangalore end) is observed to be intact and will only require frequent inspection and routine maintenance.

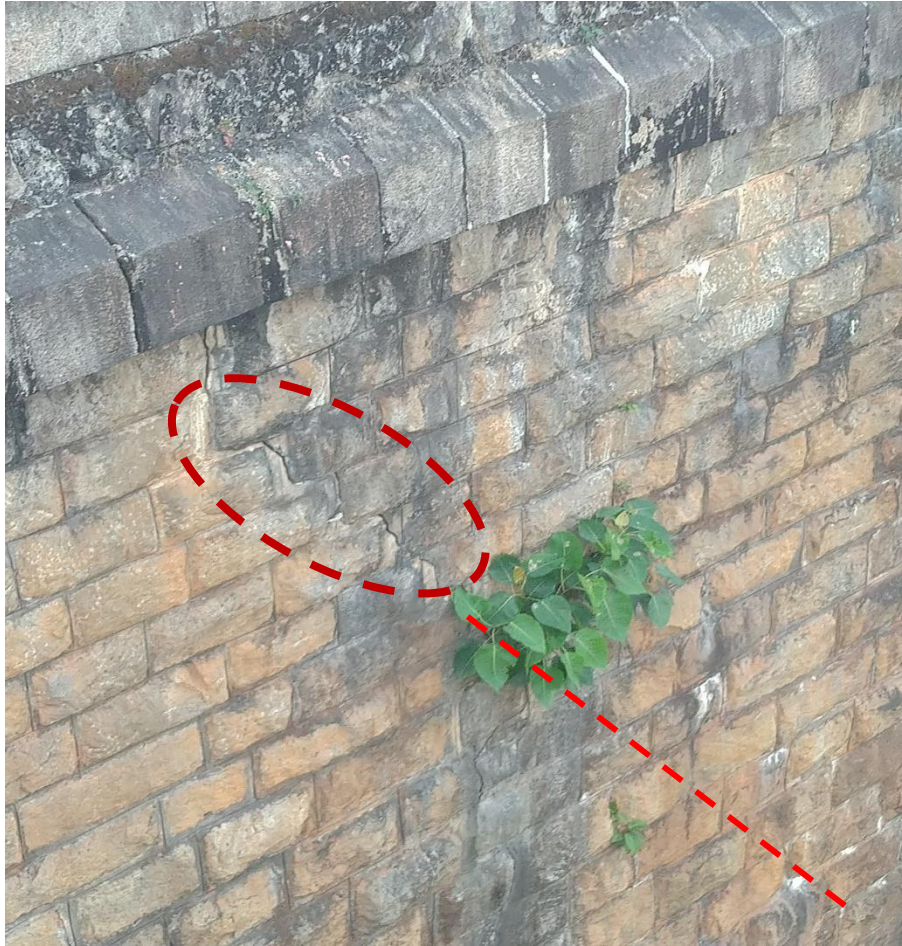


Figure 16. Cracks and vegetation growth in the abutment



Figure 17. Cracks in the abutment

4. MODELING AND ANALYSIS

4.1 Description of loading

It is presumed that the design of the bridge is as per Bridge rules 1941. In the present work, one of the requirements is to check the adequacy of the bridge to carry 25-ton axle loading. In this report, the specification of loads is based on the first revision of Bridge rule 1964. Accordingly, equivalent uniformly distributed load (EUDL) specified for 25-ton axle load (Cl. 3.6) has been used for calculations. Also as per clause 2.4.1.1 of Bridge Rules, the augmentation in load due to dynamic effect is considered. Also racking load and wind load are calculated as per clause 2.9.2.

DESIGN LOADS

Dead load

2.5m MCP 150@16.8kg/m sleepers are placed at a spacing of 40cm

weight of sleeper per meter on each girder = 0.515 kN/m

Weight of rail per meter = 0.43 kN/m

weight of corrugated sheeting per meter = 0.10 kN/m

self weight of the structural elements were taken by default by the modelling software

Live Load (From IRBM Appendix-XXIII)

EUDL for bending moment for span 47.85m = 4379 kN

EUDL for Shear force for span 47.85m = 4823 kN

Impact factor CDA = 0.298

Total EUDL for bending moment on each girder = 2842 kN

Total EUDL for shear force on each girder = 3130 kN

Live Load (From IRBM Appendix-XXIII)

Basic wind pressure as per IS 875 part 3 = 0.85 m/s

Wind acting in the windward direction = 3.27 kN/m

Wind acting in the leeward direction = 0.81 kN/m

Wind acting on the train = 3.15 kN/m

Racking force = 5.88 kN/m

Load combinations are taken as per IS 800:2007

4.2 Result of Analysis

The modelling and analysis were done in STAAD Pro. 2008 using the measured geometry and calculated loads. Model of the typical single span of 45.72 m is shown in Figure 18 and 19.

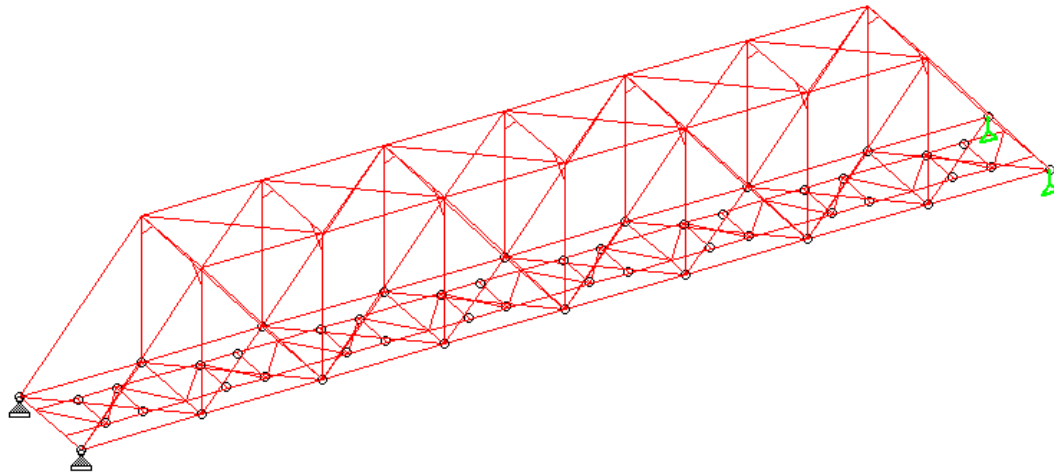


Figure 18. STAAD Pro. Model of the truss bridge

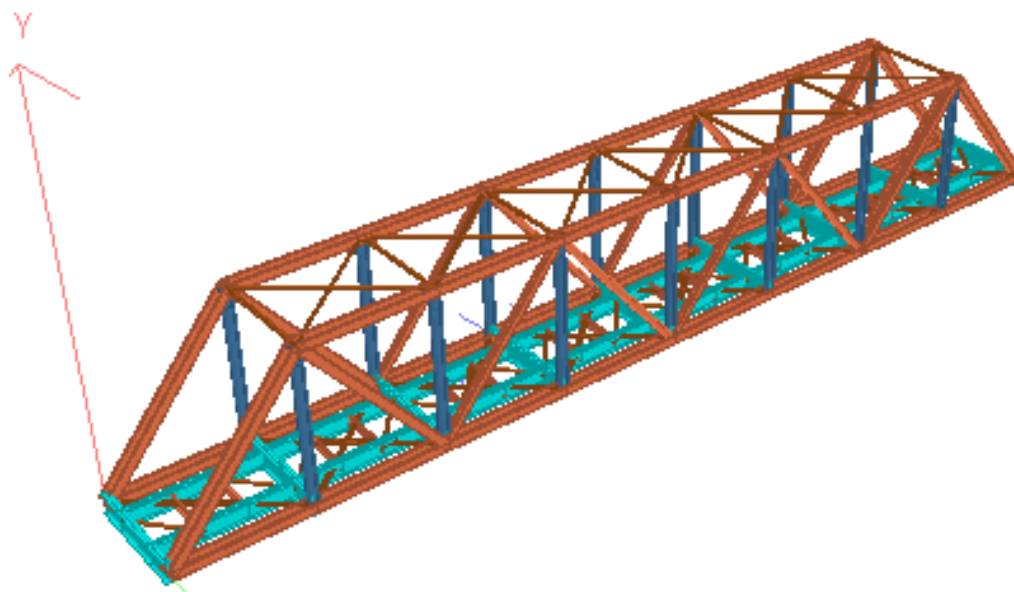


Figure 19. 3D rendered view of the bridge

Analysis was done and the design forces in each member is found out. The design forces in all elements of bridge is given in Table 3 and 4.

Table 3: Design Forces of the truss members

Member	Forces (kN)	Type
Top chord members (A)	3846	compression
Bottom chord members(A1)	1158	tension
End diagonals (B)	2748	Compression
Diagonals (D)	1966	tension
Diagonals (E)	1179	Compression
	396	tension
Vertical members (C)	581	Compression
Bottom bracings (G)	380	Compression
Top Bracings (F)	145	Compression

Table 4: Design Forces in beams

Beam	Moment (kNm)	Shear force (kN)
Main beam (B1)	752.5	563
Stinger beam (B2)	375	278
Bracing (H)	43kN (axial compression)	

4.3 Demand and Capacity

Here the integrity and safety of the bridge are assessed by the parameter ‘Demand to Capacity Ratio’ (DCR) of various elements. The capacity of various elements of the superstructure is evaluated considering the effective section incorporating the material loss due to corrosion, judged conservatively, during the condition assessment.

DESIGN CHECK OF TOP CHORD MEMBER (A)

Check for compression

Design force in the member	=	3846	kN	compression
Area	=	18815	mm ²	
Moment of Inertia , I_{xx}	=	4.8E+08	mm ⁴	
Radius of gyration, r_{yy}	=	159.34	mm	

As per Table 2 IS 800:2007, the section is plastic.

Effective length of member, L_{eff}	=	5.265	m
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$$\begin{aligned}\text{Slenderness ratio, } \lambda &= L_{\text{eff}} / r \\ &= 33.04\end{aligned}$$

buckling class 'c' of table 9(c) of IS800:2007,

$$\text{Maximum permissible compressive stress, } F_{cd} = 207 \text{ N/mm}^2$$

$$\begin{aligned}\text{Load carrying capacity} &= f_{cd} \times A \\ &= 3894.705 \text{ kN} \quad \boxed{\text{Safe}}\end{aligned}$$

DESIGN CHECK OF BOTTOM CHORD MEMBER(A)

Check for Tension

$$\begin{aligned}\text{Design Force} &= 1158 \text{ kN} \\ \text{Area} &= 12586 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= 2860.45 \text{ kN} \quad \boxed{\text{Safe}}\end{aligned}$$

DESIGN CHECK OF END DIAGONAL (B)

Check for compression

$$\begin{aligned}\text{Design force in the member} &= 2748 \text{ kN} \quad \text{compression} \\ \text{Area} &= 15815 \text{ mm}^2 \\ \text{Moment of Inertia, } I_{yy} &= 2.4\text{E}+08 \text{ mm}^4 \\ \text{Radius of gyration, } r_{yy} &= 122 \text{ mm}\end{aligned}$$

As per table 2 IS 800:2007, the section is plastic.

$$\begin{aligned}\text{Effective length of member, } L_{\text{eff}} &= 8.352 \text{ m} \\ \text{Slenderness ratio, } \lambda &= L_{\text{eff}} / r \\ &= 68.46\end{aligned}$$

buckling class 'c' of table 9(c) of IS 800:2007,

$$\text{Maximum permissible compressive stress, } F_{cd} = 156 \text{ N/mm}^2$$

$$\begin{aligned}\text{Load carrying capacity} &= f_{cd} \times A \\ &= 2467.14 \text{ kN} \quad \boxed{\text{Low FOS}}\end{aligned}$$

DESIGN CHECK DIAGONAL (D)

Check for Tension

$$\begin{aligned}\text{Design Force} &= 1966 \text{ kN} \\ \text{Area} &= 12586 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= 2860.45 \text{ kN} \quad \boxed{\text{Safe}}\end{aligned}$$

DESIGN CHECK OF END DIAGONAL (E)

Check for compression

$$\begin{aligned}\text{Design force in the member} &= 1179 \text{ kN} \quad \text{compression} \\ \text{Area} &= 9128 \text{ mm}^2\end{aligned}$$

$$\text{Moment of Inertia, } I_{yy} = 1.3\text{E}+08 \text{ mm}^4$$

$$\text{Radius of gyration, } r_{yy} = 118 \text{ mm}$$

As per table 2 IS 800:2007, the section is plastic.

$$\text{Effective length of member, } L_{eff} = 8.352 \text{ m}$$

$$\text{Slenderness ratio, } \lambda = L_{eff} / r$$

$$= 70.78$$

buckling class 'c' of table 9(c) of IS800:2007,

$$\text{Maximum permissible compressive stress, } F_{cd} = 151 \text{ N/mm}^2$$

$$\begin{aligned} \text{Load carrying capacity} &= f_{cd} \times A \\ &= 1378.328 \text{ kN} \end{aligned}$$

Safe

Check for Tension

$$\text{Design Force} = 396 \text{ kN}$$

$$\text{Area} = 9128 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2$$

$$\text{Load carrying capacity} = A_g f_y / \gamma_{mo}$$

$$= 2074.55 \text{ kN}$$

Safe

DESIGN CHECK OF VERTICAL MEMBER(C) TENSION MEMBER

$$\text{Design Force} = 581 \text{ kN} \quad (\text{Tension})$$

$$\text{Area} = 11871 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2$$

$$\text{Load carrying capacity} = A_g f_y / \gamma_{mo}$$

$$= 2697.95 \text{ kN}$$

Safe

DESIGN CHECK OF BOTTOM BRACING (G) COMPRESSION MEMBER

section 2ISA 100X100X10, Properties of the section from steel tables:

$$\text{Design force in the member} = 380 \text{ kN}$$

$$\text{Effective Length} = 3.56 \text{ m}$$

$$\text{Area} = 4518 \text{ mm}^2$$

$$r_{yy} = 30.3 \text{ mm}$$

$$\text{Slenderness ratio, } \lambda = L_{eff} / r$$

$$= 117.49$$

buckling class 'c' of table 9(c) of IS800:2007,

$$\text{Maximum permissible compressive stress, } F_{cd} = 124 \text{ N/mm}^2$$

$$\begin{aligned} \text{Load carrying capacity} &= f_{cd} \times A \\ &= 560.232 \text{ kN} \end{aligned}$$

Safe

DESIGN CHECK OF TOP BRACING (F) COMPRESSION MEMBER

section 4 ISA 75X75X8, Properties of the section from steel tables:

Design force in the member	=	145	kN		
Effective Length	=	3.56	m		
Area	=	4552	mm ²		
Moment of Inertia , I _{yy}	=	4549656	mm ⁴		
r _{yy}	=	40.4	mm	k3=	20
Slenderness ratio, λ	=	L _{eff} / r			
	=	88.12			

buckling class 'c' of table 9(c) of IS800:2007,

Maximum permissible compressive stress, F _{cd}	=	91	N/mm ²		
Load carrying capacity	=	f _{cd} x A			
	=	414.232	kN		Safe

DESIGN CHECK OF MAIN BEAM B1

Span of Beam, l	=	5.18	m		
BM and SF					
Bending Moment ,Mu	=	752.5	kNm		
Shear Force,SF	=	563.0	kN		

$$Z_{pz} = 7399228 \text{ mm}^3$$

$$\text{Web area, } A_w = 11400 \text{ mm}$$

SECTION CLASSIFICATION

$$\begin{aligned} \text{Neutral axis mid depth} &= d/t_w \\ &= 79.167 < 84\epsilon \end{aligned}$$

Hence the section is plastic

Cross beams are provide connecting two beams , hence it is laterally supported beam

Moment Capacity, M _d	=	βZ _p f _y /γ _{mo}			
	=	1681.64	kNm		Safe
Shear Capacity, SF	=	d _t wf _y /γ _{mo} √3			
	=	1495.86	kN		Safe

DESIGN CHECK OF CROSS BEAM B2

Span of Beam, l	=	5.98	m		
BM and SF					
Bending Moment ,Mu	=	375.0	kNm		
Shear Force,SF	=	278.0	kN		

$$Z_{pz} = 4615690 \quad \text{mm}^3$$

$$\text{Web area, } A_w = 7500 \quad \text{mm}$$

SECTION CLASSIFICATION

$$\begin{aligned} \text{Neutral axis mid depth} &= d/t_w \\ &= 75 < 84\epsilon \end{aligned}$$

Hence the section is plastic

Cross beams are provide connecting two beams , hence it is laterally supported beam

Moment Capacity, M_d	=	$\beta Z_p f_y / \gamma_{mo}$		
	=	1049.02	kNm	Safe
Shear Capacity, SF	=	$d t_w f_y / \gamma_{mo} \sqrt{3}$		
	=	984.12	kN	Safe

DESIGN CHECK OF BOTTOM LATERAL BETWEEN CROSS BEAMS (H) COMPRESSION MEMBER

section ISA 90x90x10, Properties of the section from steel tables:

Design force in the member	=	43	kN	
Effective Length	=	3.55	m	
Area	=	1703	mm ²	
Moment of Inertia, I_{yy}	=	516000	mm ⁴	
r_{yy}	=	17.4	mm	
Slenderness ratio, λ	=	L_{eff} / r		
	=	204.02		
buckling class 'c' of table 9(c) of IS800:2007,				
Maximum permissible compressive stress, F_{cd}	=	34.5	N/mm ²	
Load carrying capacity	=	$f_{cd} \times A$		
	=	58.75	kN	Safe

From the visual inspection, it was noted that the effect of corrosion was minimal in the connections when compared to the members. Therefore, connections are excluded in DCR calculations. Table 5 gives a summary of the DCRs for various elements.

Table 5: Demand capacity ratio for various elements

Sl No	Element/Section force	Demand (kN/kNm)	Capacity (kN/kNm)	DCR
1	Top chord members (A) - compression	3846	3894	0.99
2	Bottom chord members(A1) - tension	1158	2860	0.41
3	End diagonals (B) - compression	2748	2467	1.11
4	Diagonals (D) - tension	1966	2860	0.69
5	Diagonals (E) - Compression	1179	1378	0.86
6	- tension	396	2074	0.19
7	Vertical members(C) -	581	2697	0.22
8	Bottom bracings (G) - compression	380	560	0.68
9	Top Bracings (F) - compression	145	414	0.35
10	Main beam (B1) - moment	752.5	1681	0.45
	-Shear force	563.0	1496	0.38
11	Stinger beam (B2) - moment	375.0	1049	0.35
	-Shear force	278.0	984	0.28
12	Bracing (H) - Compression	43	58	0.74

Important notes

- i. The demand includes load factor and capacity includes partial safety factors
- ii. Here the analysis is performed for the superstructure alone presuming that the foundations are intact.

5. MEASUREMENT OF CAMBER IN THE BRIDGE SPANS

It was informed that an upward camber of 50 mm is provided at the centre of each span. A loss of this camber can give a quick measure of any kind of degradation in the structure such as stiffness degradation. In view of this, two spans were chosen arbitrarily and the camber was measured using a Total Station unit. Measurements revealed that in one of the spans, the camber was intact (no loss) while in the other the camber was only 20mm, which means a **loss of 60%** in camber. This is indicative of an overall stiffness reduction which may be due to the material loss in members due to corrosion, yielding of joints, support movements etc. It is inferred that more systematic assessment in this direction is required as part of the investigations in the Phase II of the audit.

6. COMMENTS AND INFERENCE

- Table 5 shows that all the elements of bridge superstructure have a DCR value less than unity except the end diagonal from which it can be inferred that the condition of the superstructure is **by and large satisfactory**.
- The DCR value of 1.11 in the end diagonal implies that the **margin of safety available for that member is lower than that required by the code**.
- As mentioned earlier, the condition of the abutment at the southern side (Shornur end) is **a matter of concern**.
- The measurement of camber in two arbitrary spans indicates that in one of them there is no loss of camber while in the other there is a loss of camber of 60%. This points to the need for conducting investigations to assess the possible stiffness degradation of the bridge spans which is envisaged in the Phase II of this audit.
- It is informed that speed restrictions are imposed on this bridge. At present, adequate data is not available to conduct studies and to make recommendations on restricted speed. Hence this aspect is kept out of the scope of the present study.

On the basis of the above points it is felt that conclusions on the stability and safety of the bridge can be made only after conducting phase II of the audit. Till then it is recommended to continue the safety precautions being followed currently including the restricted speed of trains through the bridge.

Comment on the maintenance and repair practices

It is observed that repair works are being carried out by Railways to rectify the issues especially due to corrosion. It is also informed that member replacements are occasionally done when the need arises. However, looking at the present condition of the bridge with regard to corrosion it is felt that there is a delay in implementing the maintenance works. It is suggested to conduct more regular and systematic maintenance. Moreover, the need for a record-keeping of the member replacements performed at various instances is felt. This can be achieved by maintaining the as-built drawing and recording the interventions as and when it is performed. This will help in assessing the overall integrity of the bridge at any point of time during its life span.

7. ASSESSMENT PROPOSED IN PHASE II

It is proposed to do the underwater inspection and condition assessment of the substructure in phase II. This will also provide necessary data for performing analysis for earthquake loads. Assessment of corrosion-fatigue strength of components and their life expectancy is required as

there can be strength degradation due to corrosion and repeated loadings. Tests required for the above assessments as well as forecasting of residual life of the bridge are planned to be carried out in phase II. Dynamic testing and tests for assessing the stiffness degradation, if any, of the super structure also are envisaged in the Phase II of the audit.

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