

REPORT

THIRD PARTY AUDITING OF RAILWAY BRIDGES (PHASE I)

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

Br. No. 219D ($1 \times 28.10\text{m} + 1 \times 15.87\text{m} + 1 \times 17.82\text{m} + 1 \times 11.42\text{m} + 1 \times 28\text{m}$)

IRS type at km

106/8-9 at Ernakulam Junction

CLIENT



SOUTHERN RAILWAY PALGHAT DIVISION

CONSULTANT



Department of Civil Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

CONTENTS

1. Preamble	2
2. Scope and Methodology	3
3. Inspection of FOB	4
3.1. Visual examination	4
3.2. Field measurements and condition assessment	9
4. Modelling and analysis	14
4.1. Description of loading	14
4.2. Demand and capacity	15
5. Comments and inference	20
References	22
<i>Appendix: Check for capacity of elements of FOB</i>	

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

2. SCOPE AND METHODOLOGY

Railway foot over bridges (FOB) are constructed to connect platforms separated by railway tracks to carry pedestrians safely from one platform to another platform and also to exit stations. Steel foot over bridges are widely adopted by railways. FOBs which are designed for pedestrian loads are subjected to severe environmental conditions that may lead to damage and failure of the bridge. 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, 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 scope of the present investigation are identified as below

- i. Inspection of the superstructure and foundation.
- ii. Visual assessment of corrosion.
- iii. Collection of necessary data for structural modelling and analysis.
- iv. Overall assessment of the structure and its integrity.

Considering the above aspects, the following methodology is finalised.

- i. Visual inspection of the FOB.
- ii. Field measurements for modelling purpose
- iii. Condition assessment of various elements and presentation of 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 THE FOB

3.1 Visual Examination

The visual inspection along with the field measurements was carried out on the bridge on 11-02-2020 at 10:00 AM. Officials from Trivandrum Railway section were also present during the inspection. It was orally transpired that this foot over bridge was constructed in the years 2010-11. Photographs of the bridge showing various elements are shown in Fig.1 to 5. Prefabricated stair slab were corroded and reinforcement were exposed at some locations (Fig.6).

(i) Details of span 1 (28.1m)

This span is 28.10m long and it connects 1st platform and the second platform. The bottom of the girder of this span is at a height of 5.6 m from platform level. Members of the truss are connected to each other through gusset plate and weld (Fig.3), and the truss itself is connected to the steel column at both ends by bolted connections. The effect of corrosion is seen to be minimal in this span.

(ii) Details of span 2 (15.87m)

This span is 15.87m long and it connects 3rd platform and the 4th platform. The bottom of the girder of this span is at a height of 5.6 m from platform level. Members of the truss are connected to each other through gusset plate with weld and truss itself is connected to the steel column at both ends by bolted connections. ***End diagonal member of the truss was absent at one end of the truss (Fig. 8)***. Also the effect of corrosion is seen to be minimal in this span. Bottom lateral bracing seen to be taken off at one location (Fig.7)

(iii) Details of span 3 (17.82m)

This span is 17.82m long and it connects 4th platform and column near the track. The bottom of the girder of this span is at a height of 5.6 m from platform level and 6.2m from the rail level. Members of the truss are connected to each other through gusset plate with weld and truss itself is connected to the steel column at both ends by bolted connections. It was noted that the angle sections of bottom chords and channel sections of cross beams of the truss were corroded at several locations. However the effect of corrosion is assessed to be minimal.

(iv) Details of span 4 (11.42m)

This span is 11.42m long and it connects 5th platform and column near the track. The bottom of the girder of this span is at a height of 5.6 m from platform level and 6.2m from the rail level. Members of the truss are connected to each other through gusset plate with weld and truss itself is connected to the steel column at both ends by bolted connections. It is seen that truss is discontinuous at one end of the truss. It was noted that the angle sections of bottom chords and channel sections of cross beams of the truss were corroded at several locations. However the effect of corrosion is seen to be minimal.

(v) Details of span 5 (28m)

This span is 28m long and it connects 5th platform and the road side end of railway station. It is at a height of 5.6 m from 5th platform floor level. Members of the truss are connected to each other through gusset plate with weld and truss itself is connected to the steel column at both ends by bolted connections. Also the effect of corrosion is seen to be minimal in this span.

Foundations

For all the spans both the foundations are located in the platform except for the 3rd span for which foundation is on the ground at the western side. ***There were no signs of settlement or other forms of distress as far as the foundations are concerned.*** Hence it is presumed that the foundations are intact.



Figure 1. view of FOB at Ernakulam railway station



Figure 2. Typical stair beam



Figure 3. Truss members connected through gusset plates



Figure 4. Cross beams and bottom bracing



Figure 5. Columns and bracings



Figure 6. Spalling of concrete at stair slabs



Figure 7. Bottom bracings missing in the second span



Figure 8. Diagonal member absent in the second span

3.2 Field Measurements and condition assessment

The geometry of the FOB is obtained by taking measurements in the field. Fig.10 and Fig.11 show the details of geometry and typical member details. Based on a careful examination of the bridge, the results of observations are tabulated in the following 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.

Table 1: Condition assessment of bridge

Element	Defect Type (Ref. Table 2 for details)	Follow-up actions required			Remarks
		DI	Re	De	
Top chord	00	-	-	-	
Bottom chord	03	-	-	-	
Vertical post	00	-	-	-	
Diagonal main ties	00	-	-	-	
Floor beams	03	-	-	-	
Slab at stair case	09	-	✓	-	
Bottom laterals	05	-	✓	-	
Supporting Column	00	-	-	-	
Column bracing	00	-	-	-	
Stair beam (inclined)	00	-	-	-	
Pedestal	00	-	-	-	
Foundation	99	-	-	-	

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

Table 2: Different defect types and their designation

Defect Type	Label	Defect Type	Label
Dampness	01	Cracks in concrete	09
Loss of material due to corrosion	02	Lack of redundancy	10
Staining due to corrosion	03	Foundation settlement	11
Buckling of plate	04	Floor settlement	12
Tearing of steel	05	Vegetation growth	13
Excessive deflection	06	Signs of overloading	14
Excessive deformation	07	No visible defect	00
Connection failure	08	Not inspected	99

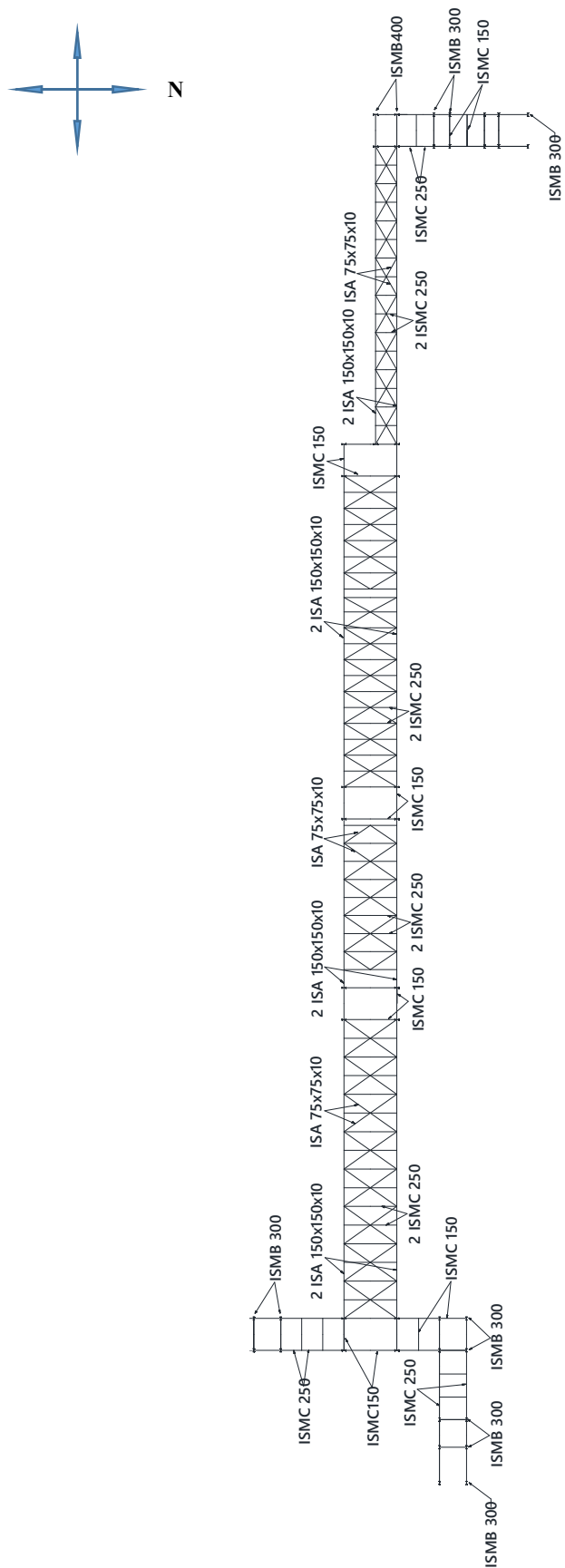


Figure 10. Line sketch of plan Of the FOB

4. MODELING AND ANALYSIS

4.1 Description of loading

In the present work, one of the requirements is to check the adequacy of the bridge to carry loads based on the first revision of Bridge rule 1964. Additionally, earthquake loads as per the provisions of IS 1893 -2016 are considered. The detailed calculation of loads and analysis was done following relevant bridge codes ^{[1][2][3][6]}, and demands of the various elements of the bridge are calculated. The modelling was done in STAAD Pro. 2008. Models is as shown in Fig. 11.

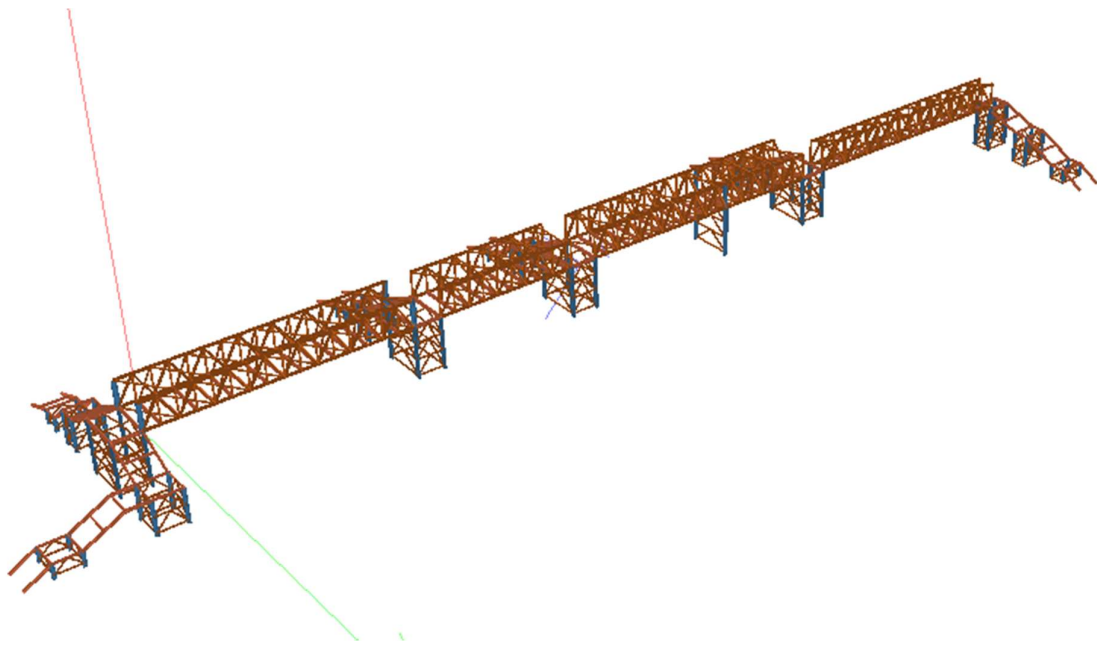


Figure 11. Computational model of FOB

4.2 Demand and Capacity

Here the integrity and safety of the FOB are assessed by the parameter ‘Demand to Capacity Ratio (DCR) of various elements. From the visual inspection, it was seen that the connections were intact and the effects of corrosion were minimal in the joints of the main truss. Therefore, connections are excluded in DCR calculations. Table 3 to 8 gives a summary of the DCRs for various elements. Utilization ratios (a quantity similar to DCR provided by software directly) of various elements of trusses obtained from the analysis are given in Fig.12 and Fig.17 and that of critical column carrying maximum load is given in Fig 18.

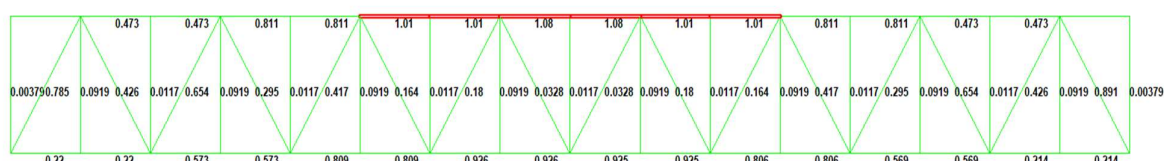


Figure 12. Utilisation ratios obtained in computational model for span 1

Table 3: Demand capacity ratio for various elements of span 1 (28.10 m)

SI No	Element/Section force	Demand (kN/kNm)	Capacity (kN/kNm)	DCR
1	Top chord/ Compression	1303	1194	1.09
2	Bottom chord/Tension	695	1319	0.53
3	End post/Compression	576	797	0.72
4	Diagonal main tie/Tension	498	1160	0.43
5	Vertical member	58	637	0.09
6	Cross beam/Moment	70	91	0.77
7	Bottom lateral	83	319	0.20
8	Top Lateral	10	319	0.03

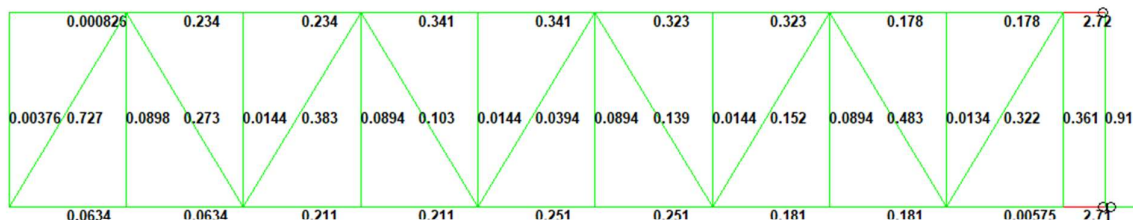


Figure 13. Utilisation ratios obtained in computational model for span 2

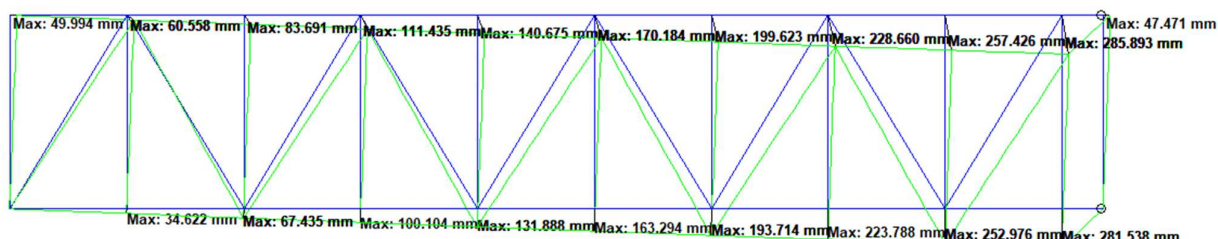


Figure 14. Deflection obtained in computational model for span 2

Table 4: Demand capacity ratio for various elements of span 2 (15.87 m)

Sl No	Element/Section force	Demand (kN/kNm)	Capacity (kN/kNm)	DCR
1	Top chord/Compression	415	1201	0.34
2	Bottom chord/Tension	338	1319	0.26
3	End diagonal/compression	311	424	0.73
4	Diagonal main tie/Tension	279	865	0.68
5	Vertical member	94	637	0.09
6	Cross beam/ Moment	68	91	0.75
7	Bottom lateral	32	319	0.06
8	Top lateral	6	319	0.02
9*	Bottom chord end beam /Axial/Moment	71/90	1365/34	2.70

* Here the DCR value is calculated using the interaction equation in clause 9.3.1.1 of IS800:2007

Important Note: The ROB was unstable when it was modelled and analysed with the diagonal member absent in the second span(see section 3.1). Hence the top chord and bottom chord at the right end of the truss in this particular span is modelled as beams.

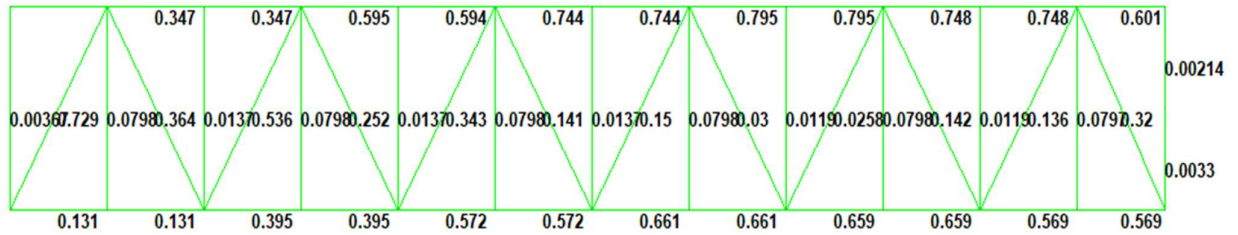


Figure 15. Utilisation ratios obtained in computational model for span 3

Table 5: Demand capacity ratio for various elements of span 3 (17.82 m)

Sl No	Element/Section force	Demand (kN/kNm)	Capacity (kN/kNm)	DCR
1	Top chord/Compression	987	1219	0.81
2	Bottom chord/Tension	872	1319	0.66
3	End post/compression	490	816	0.60
4	Diagonal main tie/Tension	424	1160	0.37
5	Vertical member	51	637	0.08
6	Cross beam/ Moment	61	91	0.67
7	Bottom lateral	58	319	0.18
8	Top lateral	3	319	0.01

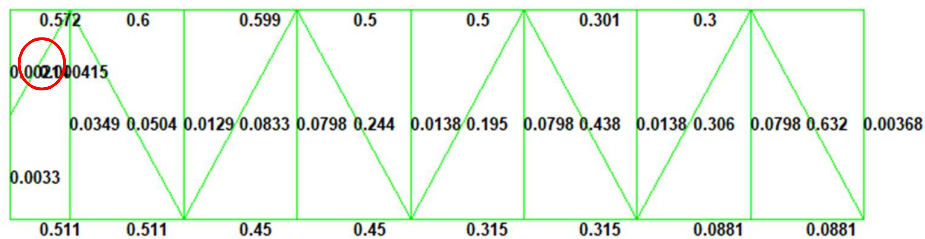


Figure 16. Utilisation ratios obtained in computational model for span 4

Table 6: Demand capacity ratio for various elements of span 4 (11.42 m)

Sl No	Element/Section force	Demand (kN/kNm)	Capacity (kN/kNm)	DCR
1	Top chord/Compression	743	1230	0.6
2	Bottom chord/Tension	673	1319	0.51
3	End post/compression	424	816	0.52
4	Diagonal main tie/Tension	357	1160	0.31
5	Vertical member	50	637	0.08
6	Cross beam/ Moment	61	91	0.67
7	Bottom lateral	35	319	0.11
8	Top lateral	3	319	0.01

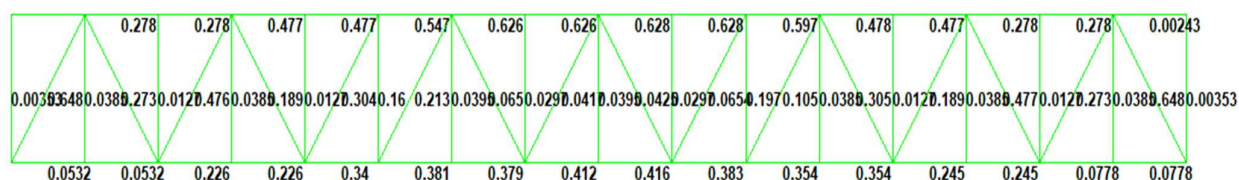


Figure 17. Utilisation ratios obtained in computational model for span 5

Table 7: Demand capacity ratio for various elements of span 5 (28.0 m)

Sl No	Element/Section force	Demand (kN/kNm)	Capacity (kN/kNm)	DCR
1	Top chord/Compression	609	1046	0.58
2	Bottom chord/Tension	483	1160	0.42
3	Diagonal main tie/Tension	238	865	0.27
4	Diagonal main /Compression	276	420	0.66
5	Vertical member	101	637	0.16
6	Cross beam/ Moment	11	125	0.09
7	Bottom lateral	97	319	0.31
8	Top lateral	4	319	0.02

Table 8: Demand capacity ratio for Column and bracings

Sl No	Element/Section force	Demand (kN/kNm)	Capacity (kN/kNm)	DCR
1	Column/Compression & Moments	782/8/4	941/268/35	0.8
2	Column bracing/ Tension	52	60	0.87
3	Stair Beam/Moment	48	81	0.79

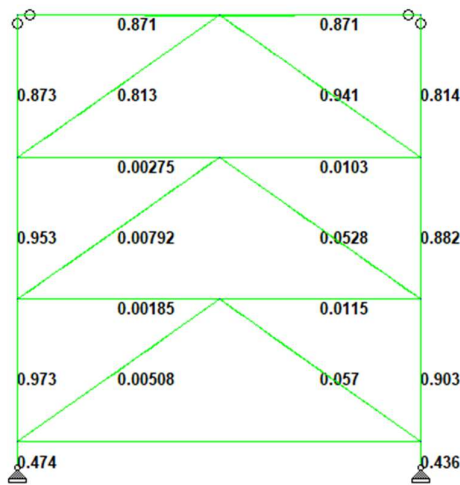


Figure 18. Utilisation ratios for columns obtained in computational model

Important notes

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

5. COMMENTS AND INFERENCE

Table 5 and Table 7 show that all the elements of **17.82m span and 28.0m span trusses** have a DCR value less than unity. This implies conditions of the trusses are **satisfactory**.

Table 3 shows that all the elements of the 28.1m span truss have DCR values less than unity except in the **top chord, which has a DCR value 1.08 (shown in RED in Fig.12)**. This implies that top chord of the truss fails under design loads and thus the condition of the FOB is **not satisfactory. Hence it is recommended to completely replace the top chords of the truss with 2 ISA 150×150×12.**

An excessive deflection is caused in the **15.87m span truss** due to the absence of the diagonal element in the second span of the FOB (See Fig.14). Also **bottom chord shows a DCR value greater than unity**. This implies, the factored force in the member exceeds its capacity under design loads and thus the condition of the FOB is **not satisfactory. Hence it is recommended to provide the missing diagonal member of same size of the remaining diagonal members (2 ISA 150×115×10.). Also it is recommended to provide the missing bottom lateral bracing (Fig.7).**

Table 6 shows that all the elements of the **11.42m span truss** have DCR values less than unity. This implies that condition of the truss is **satisfactory**. However, as observed, there is an incorrect arrangement of diagonal bracing at the left end of the span (Fig.16). There is a chance that this may cause an instability, though it is not observed in the present analysis. **In view of the above it is recommended to remove the member which is marked in red circle in Fig.16 and provide a new member of same size connecting top chord and bottom chord, diagonally.**

Spalling of concrete and corrosion of rebars are noticed under the stair slabs. **Immediate corrective measures may be taken to rectify the same.**

Comment on the maintenance and repair practices

It is observed that repair works are being carried out by Railways to rectify the various kinds of distress in the structure including corrosion. It is also informed that member replacements are occasionally done when the need arises. However, it is felt that there is a delay in implementing the maintenance works, especially tackling the issues arising due to corrosion. It is suggested to carry out 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 structure at any point in time.

Members of the Investigation team

1. Dr. T.M. MadhavanPillai (Coordinator)
2. Dr. P.V. Indira
3. Dr. A.P.Shashikala
4. Dr. Robin Davis P.
5. Dr. Sajith A.S.

Professor & Head
Department of Civil Engineering

REFERENCES

1. Bridge Rules, 1964. Rules Specifying the Loads for the Design of Super-Structure and Sub-Structure of Bridges and for Assessment of the Strength of Existing Bridges. *Government of India, Ministry of Railways (Railway Board)*.
2. RDSO, 2017. Indian Railway Standard Code of Practice for the Design of Steel or Wrought Iron Bridges carrying Rail, Road or Pedestrian Traffic.
3. Standard, I.R., 2013. Code of practice for the design of sub-structures and foundation of bridges. *Research Designs and Standards Organisation, Lucknow*.
4. Macho, M., Ryjáček, P. and Matos, J., 2019. Fatigue Life Analysis of Steel Riveted Rail Bridges Affected by Corrosion. *Structural Engineering International*, 29(4), pp.551-562.
5. Landolfo, R., Cascini, L. and Portioli, F., 2010. Modeling of metal structure corrosion damage: A state of the art report. *Sustainability*, 2(7), pp.2163-2175.
6. Standard, Bureau Indian. "General Construction in Steel-Code of Practice." *3rd Revision, Bureau of Indian Standard, New Delhi, India, IS (2007): 800-2007*.
7. Calgaro, J.A., Tschumi, M. and Gulvanessian, H., 2010. *Designers' Guide to Eurocode 1: Actions on Bridges: EN 1991-2, EN 1991-1-1,-1-3 TO-1-7 and EN 1990 Annex A2*. Thomas Telford Ltd.
8. Zuraski, P.D. and Johnson, J.E., 1990. Fatigue strength of deteriorated steel highway bridges. *Journal of Structural Engineering*, 116(10), pp.2671-269

APPENDIX - I

DESIGN CHECK FOR 28.1m SPAN

Live load	=	500 kg/m ²	=	5	kN/m ²	
Wind Load			=	1	kN/m ²	
Weight of RCC slab			=	3	kN/m ²	
Weight of roof sheet			=	0.18	kN/m ²	
wight of roof beam			=	0.28	kN	
weight of purlin			=	0.63	kN	at alternate nodes
Dead load (safety)			=	1.5	kN/m ²	

The forces in the members were calculated using STAAD and the maximum forces in the members were found to be as follows:

• Top chord members	=	1303	kN (compression)
• Bottom chord members	=	695	kN (tension)
• Diagonal	=	498	(kN Tension)
• End diagonals	=	576	(kN compression)
• Vertical members	=	58	kN (Compression)
• Bottom bracing	=	83	kN (Tension)
• Top bracing	=	3	kN (Tension)

DESIGN CHECK OF TOP CHORD MEMBER

2L ISA150x150x10mm,

a)Check for compression

Design force in the member =	1303	kN	compression
Area =	5806	mm ²	
Depth of the section (d) =	150	mm	
Width of the section (b) =	150	mm	
Thickness of the section (t) =	10	mm	
b/t =	15	<15.7ξ	
d/t =	15	<15.7ξ	

Hence the section is semi compact.

r_{xx}	=	46.3	mm
Effective length of member, L_{eff}	=	1575	mm
Slenderness ratio, λ	=	L_{eff}/r	
	=	34.02	

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

Maximum permissible compressive stress, F_{cd}	=	205.8	N/mm ²
--	---	-------	-------------------

$$\begin{aligned}
 \text{Load carrying capacity} &= f_{cd} \times A \\
 &= 1194.875 \text{ kN} \quad \text{Fail} \\
 \text{Deformation} &= PL/AE \\
 &= 1.68 \text{ mm} \quad \text{Safe}
 \end{aligned}$$

DESIGN CHECK OF BOTTOM CHORD MEMBER

section 2L ISA150x150x10mm, Properties of the section from steel tables:

a) Check for Tension

$$\begin{aligned}
 \text{Design Force} &= 695 \text{ kN} \quad (\text{Tension}) \\
 \text{Area} &= 5806 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2 \\
 \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\
 &= 1319.545 \text{ kN} \quad \text{Safe} \\
 \text{Deformation} &= PL/AE \\
 &= 0.90 \text{ mm} \quad \text{Safe}
 \end{aligned}$$

DESIGN CHECK OF INCLINED MEMBER

a) Check for compression

section 2L ISA150x115x10mm, Properties of the section from steel tables:

$$\begin{aligned}
 \text{Design force in the member} &= 576 \text{ kN} \quad \text{compression} \\
 \text{Area} &= 5104 \text{ mm}^2 \\
 \text{Depth of the section (d)} &= 150 \text{ mm} \\
 \text{Width of the section (b)} &= 115 \text{ mm} \\
 \text{Thickness of the section (t)} &= 10 \text{ mm} \\
 b/t &= 11.5 < 15.7 \xi \\
 d/t &= 15 < 15.7 \xi
 \end{aligned}$$

Hence the section is semi compact.

$$\begin{aligned}
 r_{xx} &= 44.1 \text{ mm} \\
 \text{Effective length of member, } L_{\text{eff}} &= 2970 \text{ mm} \\
 \text{Slenderness ratio, } \lambda &= L_{\text{eff}} / r \\
 &= 67.35
 \end{aligned}$$

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

$$\begin{aligned}
 \text{Maximum permissible compressive stress, } F_{cd} &= 156.24 \text{ N/mm}^2 \\
 \text{Load carrying capacity} &= f_{cd} \times A \\
 &= 797.449 \text{ kN} \quad \text{Safe} \\
 \text{Deformation} &= PL/AE \\
 &= 1.60 \text{ mm} \quad \text{Safe}
 \end{aligned}$$

b) TENSION MEMBER

section 2L ISA150x115x10mm, Properties of the section from steel tables:

$$\begin{aligned}
 \text{Design Force} &= 498 \text{ kN} \quad (\text{Tension}) \\
 \text{Area} &= 5104 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2
 \end{aligned}$$

$$\begin{aligned} \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= \boxed{1160} \text{ kN} \end{aligned} \quad \boxed{\text{Safe}}$$

$$\begin{aligned} \text{Deformation} &= PL/AE \\ &= \boxed{1.53} \text{ mm} \end{aligned} \quad \boxed{\text{Safe}}$$

DESIGN CHECK OF VERTICAL MEMBER

section ISA75x75x10mm, Properties of the section from steel tables:

Design Force =	58 kN	(Tension)	
Area =	$\boxed{2804} \text{ mm}^2$	$F_y = 250$	N/mm^2
Load carrying capacity =	$A_g f_y / \gamma_{mo}$		
=	$\boxed{637.2727} \text{ kN}$	$\boxed{\text{Safe}}$	
Deformation =	PL/AE		
=	$\boxed{0.50} \text{ mm}$	$\boxed{\text{Safe}}$	

DESIGN CHECK OF BOTTOM BRACING MEMBER

section ISA75x75x10mm, Properties of the section from steel tables:

Design Force =	83 kN	(Tension)	
Area =	$\boxed{1402} \text{ mm}^2$	$F_y = 250$	N/mm^2
Load carrying capacity =	$A_g f_y / \gamma_{mo}$		
=	$\boxed{318.6364} \text{ kN}$	$\boxed{\text{Safe}}$	
Deformation =	PL/AE		
=	$\boxed{0.93} \text{ mm}$	$\boxed{\text{Safe}}$	

DESIGN CHECK OF TOP BRACING

section ISA75x75x10mm, Properties of the section from steel tables:

Design Force =	10 kN	(Tension)	
Area =	$\boxed{1402} \text{ mm}^2$	$F_y = 250$	N/mm^2
Load carrying capacity =	$A_g f_y / \gamma_{mo}$		
=	$\boxed{318.6364} \text{ kN}$	$\boxed{\text{Safe}}$	
Deformation =	PL/AE		
=	$\boxed{0.11} \text{ mm}$	$\boxed{\text{Safe}}$	

DESIGN CHECK FOR 15.87m SPAN

The forces in the members were calculated using STAAD and the maximum forces in the members were found to be as follows:

• Top chord members	=	415	kN (compression)
• Bottom chord members	=	338	kN (tension)
• Diagonal	=	279	(kN Tension)
• End diagonals	=	311	(kN compression)
• Vertical members	=	94	kN (Compression)
• Bottom bracing	=	32	kN (Tension)
• Top bracing	=	2	kN (Tension)

DESIGN CHECK OF TOP CHORD MEMBER

2L ISA150x150x10mm,

a)Check for compression

Design force in the member =	415	kN	compression
Area =	5806	mm ²	
Depth of the section (d) =	150	mm	
Width of the section (b) =	150	mm	
Thickness of the section (t) =	10	mm	
b/t =	15	<15.7ξ	
d/t =	15	<15.7ξ	

Hence the section is semi compact.

r_{xx}	=	46.3	mm
Effective length of member, L_{eff}	=	1530	mm
Slenderness ratio, λ	=	L_{eff}/r	
	=	33.05	

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

Maximum permissible compressive stress, F_{cd}	=	207	N/mm ²	
Load carrying capacity	=	$f_{cd} \times A$		
	=	1201.842	kN	Safe
Deformation	=	PL/AE		
	=	0.52	mm	Safe

DESIGN CHECK OF BOTTOM CHORD MEMBER

section 2L ISA150x150x10mm, Properties of the section from steel tables:

a)Check for Tension

Design Force =	338	kN	(Tension)	
Area =	5806	mm ²	$F_y = 250$	N/mm ²

$$= 1319.545 \text{ kN} \quad \text{Safe}$$

$$\begin{aligned} \text{Deformation} &= PL/AE \\ &= 0.42 \text{ mm} \quad \text{Safe} \end{aligned}$$

DESIGN CHECK OF INCLINED MEMBER

a) Check for compression

section 2L ISA100x100x10mm, Properties of the section from steel tables:

$$\begin{aligned} \text{Design force in the member} &= 311 \text{ kN} && \text{compression} \\ \text{Area} &= 3806 \text{ mm}^2 \\ \text{Depth of the section (d)} &= 100 \text{ mm} \\ \text{Width of the section (b)} &= 100 \text{ mm} \\ \text{Thickness of the section (t)} &= 10 \text{ mm} \\ b/t &= 10 < 15.7\xi \\ d/t &= 10 < 15.7\xi \end{aligned}$$

Hence the section is semi compact.

$$\begin{aligned} r_{xx} &= 30.5 \text{ mm} \\ \text{Effective length of member, } L_{\text{eff}} &= 2950 \text{ mm} \\ \text{Slenderness ratio, } \lambda &= L_{\text{eff}}/r \\ &= 96.72 \end{aligned}$$

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

$$\begin{aligned} \text{Maximum permissible compressive stress, } f_{cd} &= 111.6 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= f_{cd} \times A \\ &= 424.7496 \text{ kN} \quad \text{Safe} \\ \text{Deformation} &= PL/AE \\ &= 1.15 \text{ mm} \quad \text{Safe} \end{aligned}$$

b) TENSION MEMBER

section 2L ISA100x100x10mm, Properties of the section from steel tables:

$$\begin{aligned} \text{Design Force} &= 279 \text{ kN} && \text{(Tension)} \\ \text{Area} &= 3806 \text{ mm}^2 && F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= 865 \text{ kN} \quad \text{Safe} \\ \text{Deformation} &= PL/AE \\ &= 1.15 \text{ mm} \quad \text{Safe} \end{aligned}$$

DESIGN CHECK OF VERTICAL MEMBER

section 2L ISA75x75x10mm, Properties of the section from steel tables:

$$\begin{aligned} \text{Design Force} &= 94 \text{ kN} && \text{(Tension)} \\ \text{Area} &= 2804 \text{ mm}^2 && F_y = 250 \text{ N/mm}^2 \end{aligned}$$

$$= \boxed{637.2727} \text{ kN} \quad \boxed{\text{Safe}}$$

$$\begin{aligned} \text{Deformation} &= PL/AE \\ &= \boxed{0.61} \text{ mm} \quad \boxed{\text{Safe}} \end{aligned}$$

DESIGN CHECK OF BOTTOM BRACING MEMBER

section ISA75x75x10mm, Properties of the section from steel tables:

$$\begin{aligned} \text{Design Force} &= 32 \text{ kN} & (\text{Tension}) \\ \text{Area} &= \boxed{1402} \text{ mm}^2 & F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= \boxed{318.6364} \text{ kN} \quad \boxed{\text{Safe}} \\ \text{Deformation} &= PL/AE \\ &= \boxed{0.36} \text{ mm} \quad \boxed{\text{Safe}} \end{aligned}$$

DESIGN CHECK OF TOP BRACING

section ISA75x75x10mm, Properties of the section from steel tables:

$$\begin{aligned} \text{Design Force} &= 6 \text{ kN} & (\text{Tension}) \\ \text{Area} &= \boxed{1402} \text{ mm}^2 & F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= \boxed{318.6364} \text{ kN} \quad \boxed{\text{Safe}} \\ \text{Deformation} &= PL/AE \\ &= \boxed{0.07} \text{ mm} \quad \boxed{\text{Safe}} \end{aligned}$$

DESIGN CHECK FOR 17.82m SPAN

The forces in the members were calculated using STAAD and the maximum forces in the members were found to be as follows:

• Top chord members	=	987	kN (compression)
• Bottom chord members	=	872	kN (tension)
• End diagonals	=	490	kN (compression)
• Diagonals	=	424	kN (Tension)
• Vertical members	=	51	kN (Compression)
• Bottom bracing	=	58	kN (Tension)
• Top bracing	=	3	kN (Tension)

DESIGN CHECK OF TOP CHORD MEMBER

2L ISA150x150x10mm,

a)Check for compression

Design force in the member =	987	kN	compression
Area =	5806	mm ²	
Depth of the section (d) =	150	mm	
Width of the section (b) =	150	mm	
Thickness of the section (t) =	10	mm	
b/t =	15	<15.7ξ	
d/t =	15	<15.7ξ	

Hence the section is semi compact.

r_{xx} =	46.3	mm
Effective length of member, L_{eff} =	1350	mm
Slenderness ratio, λ =	L_{eff}/r	
	29.16	

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

Maximum permissible compressive stress, F_{cd} =	210	N/mm ²	
Load carrying capacity =	$f_{cd} \times A$		
	1219.26	kN	Safe
Deformation =	PL/AE		
	1.09	mm	Safe

DESIGN CHECK OF BOTTOM CHORD MEMBER

section 2L ISA150x150x10mm, Properties of the section from steel tables:

a)Check for Tension

Design Force =	872	kN	(Tension)
Area =	5806	mm ²	$F_y = 250$ N/mm ²

$$= 1319.545 \text{ kN} \quad \text{Safe}$$

$$\begin{aligned} \text{Deformation} &= PL/AE \\ &= 0.97 \text{ mm} \quad \text{Safe} \end{aligned}$$

DESIGN CHECK OF INCLINED MEMBER

a) COMPRESSION MEMBER

section 2L ISA150x115x10mm, Properties of the section from steel tables:

$$\text{Design force in the member} = 490 \text{ kN} \quad \text{compression}$$

$$\text{Area} = 5104 \text{ mm}^2$$

$$\text{Depth of the section (d)} = 150 \text{ mm}$$

$$\text{Width of the section (b)} = 115 \text{ mm}$$

$$\text{Thickness of the section (t)} = 10 \text{ mm}$$

$$b/t = 11.5 < 15.7\xi$$

$$d/t = 15 < 15.7\xi$$

Hence the section is semi compact.

$$r_{xx} = 44.1 \text{ mm}$$

$$\text{Effective length of member, } L_{\text{eff}} = 2860 \text{ mm}$$

$$\begin{aligned} \text{Slenderness ratio, } \lambda &= L_{\text{eff}}/r \\ &= 64.85 \end{aligned}$$

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

$$\text{Maximum permissible compressive stress, } F_{cd} = 160 \text{ N/mm}^2$$

$$\text{Load carrying capacity} = f_{cd} \times A$$

$$= 816.64 \text{ kN} \quad \text{Safe}$$

$$\text{Deformation} = PL/AE$$

$$= 1.31 \text{ mm} \quad \text{Safe}$$

b) TENSION MEMBER

section 2L ISA100x100x10mm, Properties of the section from steel tables:

$$\text{Design Force} = 424 \text{ kN} \quad (\text{Tension})$$

$$\text{Area} = 5104 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2$$

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

$$= 1160 \text{ kN} \quad \text{Safe}$$

$$\text{Deformation} = PL/AE$$

$$= 1.13 \text{ mm} \quad \text{Safe}$$

DESIGN CHECK OF VERTICAL MEMBER

section 2L ISA75x75x10mm, Properties of the section from steel tables:

$$\text{Design Force} = 51 \text{ kN} \quad (\text{Tension})$$

$$\text{Area} = 2804 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2$$

$$\begin{aligned} \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= \boxed{637.2727} \text{ kN} \end{aligned} \quad \boxed{\text{Safe}}$$

$$\begin{aligned} \text{Deformation} &= PL/AE \\ &= \boxed{0.44} \text{ mm} \end{aligned} \quad \boxed{\text{Safe}}$$

DESIGN CHECK OF BOTTOM BRACING MEMBER

section ISA75x75x10mm, Properties of the section from steel tables:

Design Force	=	58 kN	(Tension)	
Area	=	$\boxed{1402} \text{ mm}^2$	$F_y = 250$	N/mm^2
Load carrying capacity	=	$A_g f_y / \gamma_{mo}$		
	=	$\boxed{318.6364} \text{ kN}$	$\boxed{\text{Safe}}$	
Deformation	=	PL/AE		
	=	$\boxed{0.65} \text{ mm}$	$\boxed{\text{Safe}}$	

DESIGN CHECK OF TOP BRACING

section ISA75x75x10mm, Properties of the section from steel tables:

Design Force	=	3 kN	(Tension)	
Area	=	$\boxed{1402} \text{ mm}^2$	$F_y = 250$	N/mm^2
Load carrying capacity	=	$A_g f_y / \gamma_{mo}$		
	=	$\boxed{318.6364} \text{ kN}$	$\boxed{\text{Safe}}$	
Deformation	=	PL/AE		
	=	$\boxed{0.03} \text{ mm}$	$\boxed{\text{Safe}}$	

DESIGN CHECK FOR 11.42m SPAN

The forces in the members were calculated using STAAD and the maximum forces in the members were found to be as follows:

• Top chord members	=	743	kN (compression)
• Bottom chord members	=	673	kN (tension)
• End diagonals	=	424	kN (compression)
• Diagonals	=	357	kN (Tension)
• Vertical members	=	50	kN (Tension)
• Bottom bracing	=	35	kN (Tension)
• Top bracing	=	3	kN (Tension)

DESIGN CHECK OF BOTTOM CHORD MEMBER

section 2L ISA150x150x10mm, Properties of the section from steel tables:

a)Check for compression

Design force in the member =	743	kN	compression
Area =	5806	mm ²	
Depth of the section (d) =	150	mm	
Width of the section (b) =	150	mm	
Thickness of the section (t) =	10	mm	
b/t =	15	<15.7ξ	
d/t =	15	<15.7ξ	

Hence the section is semi compact.

r_{xx}	=	46.3	mm
Effective length of member, L_{eff}	=	1350	mm
Slenderness ratio, λ	=	L_{eff}/r	
	=	29.16	

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

Maximum permissible compressive stress, F_{cd}	=	212	N/mm ²
Load carrying capacity	=	$f_{cd} \times A$	
	=	1230.872	kN
Deformation	=	PL/AE	
	=	0.82	mm

Safe

Safe

DESIGN CHECK OF TOP CHORD MEMBER

2L ISA150x150x10mm,

a)Check for Tension

Design Force =	673	kN	(Tension)
Area =	5806	mm ²	$F_y = 250$ N/mm ²

$$\begin{aligned}\text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= \boxed{1319.545} \text{ kN} \quad \boxed{\text{Safe}}\end{aligned}$$

$$\begin{aligned}\text{Deformation} &= PL/AE \\ &= \boxed{0.83} \text{ mm} \quad \boxed{\text{Safe}}\end{aligned}$$

DESIGN CHECK OF INCLINED MEMBER

a) COMPRESSION MEMBER

section 2L ISA150x115x10mm, Properties of the section from steel tables:

$$\begin{aligned}\text{Design force in the member} &= 424 \text{ kN} \quad \text{compression} \\ \text{Area} &= \boxed{5104} \text{ mm}^2 \\ \text{Depth of the section (d)} &= \boxed{150} \text{ mm} \\ \text{Width of the section (b)} &= \boxed{115} \text{ mm} \\ \text{Thickness of the section (t)} &= \boxed{10} \text{ mm} \\ b/t &= 11.5 < 15.7\xi \\ d/t &= 15 < 15.7\xi\end{aligned}$$

Hence the section is semi compact.

$$\begin{aligned}r_{xx} &= \boxed{44.1} \text{ mm} \\ \text{Effective length of member, } L_{\text{eff}} &= \boxed{2860} \text{ mm} \\ \text{Slenderness ratio, } \lambda &= L_{\text{eff}} / r \\ &= 64.85\end{aligned}$$

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

$$\begin{aligned}\text{Maximum permissible compressive stress, } f_{cd} &= \boxed{160} \text{ N/mm}^2 \\ \text{Load carrying capacity} &= f_{cd} \times A \\ &= \boxed{816.64} \text{ kN} \quad \boxed{\text{Safe}} \\ \text{Deformation} &= PL/AE \\ &= \boxed{1.13} \text{ mm} \quad \boxed{\text{Safe}}\end{aligned}$$

b) TENSION MEMBER

section 2L ISA100x100x10mm, Properties of the section from steel tables:

$$\begin{aligned}\text{Design Force} &= 357 \text{ kN} \quad (\text{Tension}) \\ \text{Area} &= \boxed{5104} \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= \boxed{1160} \text{ kN} \quad \boxed{\text{Safe}} \\ \text{Deformation} &= PL/AE \\ &= \boxed{0.95} \text{ mm} \quad \boxed{\text{Safe}}\end{aligned}$$

DESIGN CHECK OF VERTICAL MEMBER

section 2L ISA75x75x10mm, Properties of the section from steel tables:

$$\begin{aligned}\text{Design Force} &= 50 \text{ kN} \quad (\text{Tension}) \\ \text{Area} &= \boxed{2804} \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2\end{aligned}$$

$$\text{Load carrying capacity} = \frac{A_g f_y}{\gamma_{mo}} = \boxed{637.2727} \text{ kN} \quad \boxed{\text{Safe}}$$

$$\text{Deformation} = \frac{PL}{AE} = \boxed{0.43} \text{ mm} \quad \boxed{\text{Safe}}$$

DESIGN CHECK OF BOTTOM BRACING MEMBER

section ISA75x75x10mm, Properties of the section from steel tables:

$$\begin{aligned} \text{Design Force} &= 35 \text{ kN} & (\text{Tension}) \\ \text{Area} &= \boxed{1402} \text{ mm}^2 & F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= \frac{A_g f_y}{\gamma_{mo}} = \boxed{318.6364} \text{ kN} & \boxed{\text{Safe}} \end{aligned}$$

$$\text{Deformation} = \frac{PL}{AE} = \boxed{0.39} \text{ mm} \quad \boxed{\text{Safe}}$$

DESIGN CHECK OF TOP BRACING

section ISA75x75x10mm, Properties of the section from steel tables:

$$\begin{aligned} \text{Design Force} &= 3 \text{ kN} & (\text{Tension}) \\ \text{Area} &= \boxed{1402} \text{ mm}^2 & F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= \frac{A_g f_y}{\gamma_{mo}} = \boxed{318.6364} \text{ kN} & \boxed{\text{Safe}} \end{aligned}$$

$$\text{Deformation} = \frac{PL}{AE} = \boxed{0.03} \text{ mm} \quad \boxed{\text{Safe}}$$

DESIGN CHECK FOR 28.0m SPAN

The forces in the members were calculated using STAAD and the maximum forces in the members were found to be as follows:

• Top chord members	=	609	kN (compression)
• Bottom chord members	=	483	kN (tension)
• End diagonals	=	276	(kN compression)
• Diagonal	=	238	(kN Tension)
• Vertical members	=	101	kN (Tension)
• Bottom bracing	=	97	kN (Tension)
• Top bracing	=	4	kN (Tension)

DESIGN CHECK OF TOP CHORD MEMBER

2L ISA150x115x10mm,

a)Check for compression

Design force in the member =	609	kN	compression
Area =	5104	mm ²	
Depth of the section (d) =	150	mm	
Width of the section (b) =	115	mm	
Thickness of the section (t) =	10	mm	
b/t =	11.5	<15.7ξ	
d/t =	15	<15.7ξ	

Hence the section is semi compact.

r_{xx}	=	44.1	mm
Effective length of member, L_{eff}	=	1575	mm
Slenderness ratio, λ	=	L_{eff}/r	
	=	35.71	

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

Maximum permissible compressive stress, F_{cd}	=	205	N/mm ²	
Load carrying capacity	=	$f_{cd} \times A$		
	=	1046.32	kN	Safe
Deformation	=	PL/AE		
	=	0.89	mm	Safe

DESIGN CHECK OF BOTTOM CHORD MEMBER

section 2L ISA150x150x10mm, Properties of the section from steel tables:

a)Check for Tension

Design Force =	483	kN	(Tension)
Area =	5104	mm ²	$F_y = 250$ N/mm ²

$$= 1160 \text{ kN} \quad \text{Safe}$$

$$\begin{aligned} \text{Deformation} &= PL/AE \\ &= 0.71 \text{ mm} \quad \text{Safe} \end{aligned}$$

DESIGN CHECK OF INCLINED MEMBER

a) Check for compression

section 2L ISA100x100x10mm, Properties of the section from steel tables:

$$\text{Design force in the member} = 276 \text{ kN} \quad \text{compression}$$

$$\text{Area} = 3806 \text{ mm}^2$$

$$\text{Depth of the section (d)} = 100 \text{ mm}$$

$$\text{Width of the section (b)} = 100 \text{ mm}$$

$$\text{Thickness of the section (t)} = 10 \text{ mm}$$

$$b/t = 10 < 15.7\xi$$

$$d/t = 10 < 15.7\xi$$

Hence the section is semi compact.

$$r_{xx} = 30.5 \text{ mm}$$

$$\text{Effective length of member, } L_{\text{eff}} = 2970 \text{ mm}$$

$$\begin{aligned} \text{Slenderness ratio, } \lambda &= L_{\text{eff}}/r \\ &= 97.38 \end{aligned}$$

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

$$\text{Maximum permissible compressive stress, } F_{\text{cd}} = 110.6 \text{ N/mm}^2$$

$$\begin{aligned} \text{Load carrying capacity} &= f_{\text{cd}} \times A \\ &= 420.9436 \text{ kN} \quad \text{Safe} \end{aligned}$$

$$\begin{aligned} \text{Deformation} &= PL/AE \\ &= 1.03 \text{ mm} \quad \text{Safe} \end{aligned}$$

b) TENSION MEMBER

section 2L ISA100x100x10mm, Properties of the section from steel tables:

$$\text{Design Force} = 238 \text{ kN} \quad (\text{Tension})$$

$$\text{Area} = 3806 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2$$

$$\begin{aligned} \text{Load carrying capacity} &= A_g f_y / \gamma_{m0} \\ &= 865 \text{ kN} \quad \text{Safe} \end{aligned}$$

$$\begin{aligned} \text{Deformation} &= PL/AE \\ &= 0.98 \text{ mm} \quad \text{Safe} \end{aligned}$$

DESIGN CHECK OF VERTICAL MEMBER

section 2L ISA75x75x10mm, Properties of the section from steel tables:

$$\text{Design Force} = 101 \text{ kN} \quad (\text{Tension})$$

$$\text{Area} = 2804 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2$$

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

$$= 637.2727 \text{ kN}$$

Safe

$$\text{Deformation} = \frac{PL}{AE}$$

$$= 0.65 \text{ mm}$$

Safe

DESIGN CHECK OF BOTTOM BRACING MEMBER

section ISA75x75x10mm, Properties of the section from steel tables:

$$\text{Design Force} = 97 \text{ kN} \quad (\text{Tension})$$

$$\text{Area} = 1402 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2$$

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

$$= 318.6364 \text{ kN}$$

Safe

$$\text{Deformation} = \frac{PL}{AE}$$

$$= 1.09 \text{ mm}$$

Safe

DESIGN CHECK OF TOP BRACING

section ISA75x75x10mm, Properties of the section from steel tables:

$$\text{Design Force} = 4 \text{ kN} \quad (\text{Tension})$$

$$\text{Area} = 1402 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2$$

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

$$= 318.6364 \text{ kN}$$

Safe

$$\text{Deformation} = \frac{PL}{AE}$$

$$= 0.04 \text{ mm}$$

Safe

DESIGN CHECK OF COLUMN

DESIGN DATA

Width of walkway	=	5	
Length of the column	=	5.6	m
No. of horizontal bracings	=	3	
Design force in the column	=	782	kN
Design Moment in the column, M _z	=	8	kNm
Design Moment in the column, M _y	=	4	kNm

Choose a section of ISMB 400

Properties according to steel tables are:

Area A =	7846.0	mm ²
Depth of section (h) =	400.00	mm
Width of flange (b) =	140.00	mm
Thickness of flange (t _f) =	16.00	mm
Radius of gyration (r _y) =	28.40	mm
Thickness of web (t _w) =	8.90	mm
Depth of the web (d) =	340.00	mm

$$d/t_w = 38.20$$

Hence the section is plastic

$$\text{Slenderness ratio } (\lambda) = 98.59$$

$$h/b_f = 2.86 > 1.2$$

$$t_f = 17.20 \leq 40 \text{ mm}$$

Buckling is about Y-Y axis

Referring Table 9(a) of IS 800:2007 for buckling class 'b'

$$\text{Max compressive stress } f_{cd} = 120.0 \text{ N/mm}^2$$

$$\text{Load carrying capacity} = f_{cd} \times A = 941.52 \text{ kN}$$

Safe

$$I_z = 2E+08 \text{ mm}^4$$

$$I_y = 6221000 \text{ mm}^4$$

$$Z_{ez} = 1022900 \text{ mm}^3$$

$$Z_{pz} = 1176180 \text{ mm}^3$$

$$Z_{ey} = 88857 \text{ mm}^3$$

$$Z_{py} = 150000 \text{ mm}^3$$

$$r_{zz} = 161.43 \text{ mm}$$

$$r_{yy} = 28.4 \text{ mm}$$

SECTION CLASSIFICATION

$$\text{Moment Capacity, } M_{dz} = \beta Z_p f_y / \gamma_{mo}$$

$$= 267.31 \text{ kNm}$$

Safe

$$\text{Moment Capacity, } M_{dy} = \beta Z_p f_y / \gamma_{mo}$$

$$= 34.09 \text{ kNm}$$

Safe

check for combined axial force and moment

$$\frac{N}{N_d} + \frac{M_y}{M_{dy}} + \frac{M_z}{M_{dz}} = 0.98 > 1 \text{ Safe}$$

DESIGN CHECK OF STAIR BEAM

$$\text{Span of Beam, } l = 4.3 \text{ m}$$

BM and SF

$$\text{Bending Moment, } M_u = 48.0 \text{ kNm}$$

$$\text{Shear Force, } SF = 57.0 \text{ kN}$$

section of ISMC 200 from steel tables is used

$$D = 250 \text{ mm}$$

$$B = 80 \text{ mm}$$

$$t_f = 14.1 \text{ mm}$$

$$t_w = 7.1 \text{ mm}$$

$$\text{depth of web} = 216.7 \text{ mm}$$

I_z	=	4E+07	mm ⁴
I_y	=	2191000	mm ⁴
Z_{ez}	=	305300	mm ³
Z_{pz}	=	356720	mm ³
r_{min}	=	23.8	mm

SECTION CLASSIFICATION

Compression flange	=	b/t_f	
	=	5.67376	<9.4ε
Neutral axis mid depth	=	d/t_w	
t_w	=	30.5211	<84ε
Hence the section is plastic			

Moment Capacity, M_d	=	$\beta Z_p f_y / \gamma_{mo}$	
	=	81.07	kNm
Shear Capacity, SF	=	$d t_w f_y / \gamma_{mo} \sqrt{3}$	
	=	201.88	kN

Safe

Safe

DESIGN CHECK OF COLUMN BRACING

Design force in the member = 52 kN

Length	=	3.06	m
Area	=	1402	mm ²
Depth of the section (d)	=	75	mm
Width of the section (b)	=	75	mm
Thickness of the section (t)	=	10	mm
r_{vv}	=	14.5	mm

$$l/r_w = 211.03$$

$$\sqrt{\frac{E\pi^2}{f_y}} = 88.86$$

$$\lambda_{vv} = 2.37$$

$$\lambda_{\phi} = 0.08$$

$$\phi = 3.01$$

$$\chi = 0.191$$

equivalent slenderness ratio, $\lambda_e = 2.03$

Maximum permissible compressive stress, $F_{cd} = 43.46776$ N/mm²

Load carrying capacity = $f_{cd} \times A$

= 60.94179 kN

Safe

Deformation = PL/AE

= 0.54 mm

Safe