

REPORT

THIRD PARTY AUDITING OF RAILWAY BRIDGES (PHASE I)

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

**Br. No. 754 ($1 \times 11.20\text{m} + 1 \times 14\text{m} + 1 \times 23.6\text{m} + 1 \times 18\text{m}$) IRS type at km
578/700-800 at Shornur Junction**

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 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 04-02-2020 at 09:00 AM. Officials from Calicut Railway section were also present during the inspection. Photographs of the bridge showing various elements are shown in Figures 1 to 8. This steel foot over bridge consists of four spans. First to four spans are 11.2m, 14m, 23.6m, and 18m long in the respective order. The superstructure of first three spans are at a height of 5.15 m from platform level and that of fourth span is at a height of 5.6 m from platform level. It was noted that the sections of bottom chords, floor beams, and bottom laterals of the truss were corroded at some locations in first three spans. However, the effect of corrosion was found to be minimal at the connections in all four spans.

(i) Details of span 1 and 2 (11.2m and 14 m)

First and second spans are 11.2m and 14m long respectively. These two spans together connect 1st platform and the 2nd platform. The bottom of the girder of this span is at a height of 5.15 m from platform level. Members of the truss are connected to each other through rivets and bolts (Figure.3), and the truss itself is connected to the steel column at both ends by bolted connections. It was noted that the section of bottom chords, floor beams, and bottom laterals of the truss were corroded at some locations. In these spans MS flat (65 mm×6 mm) are used as bracing (Figure.1)

Details of span 3 (23.6m)

This span is 23.6m long and it connects third platform and the fourth platform. The bottom of the girder of this span is at a height of 5.15 m from platform level. Members of the truss are connected to each other through rivets and bolts (Figure.3), and the 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. Bottom lateral bracing is seen to be taken off at one location (Figure.7). It was noted that the section of bottom chords, floor beams, and bottom laterals of the truss were corroded at some locations.

However the effect of corrosion is assessed to be minimal. Here also MS flat (65mm × 6mm) are used as bracing.

(ii) Details of span 4 (18m)

This span is 18m long and it connects 5^h platform and the 6th 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. It was noted that the angle sections of bottom chords and channel sections of cross beams of the truss were corroded at several locations. The effect of corrosion is assessed to be minimal in this span.

Foundations

All the foundations are located in the platform except for the 1st 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.



Figure1. FOB Shornur



Figure 2. Stair side beams and tie beams



Figure 3. Truss members connected through gusset plates

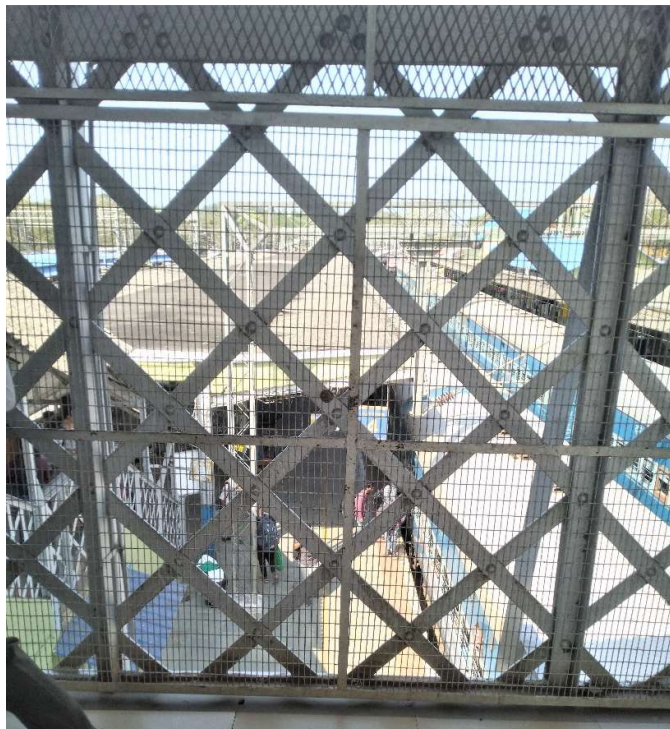


Figure 4. Truss members connected through rivets



Figure 5. Typical floor beams and bottom laterals of first three spans



Figure 6. Floor beams and bottom laterals of fourth span



Figure 7. Columns and bracings



Figure 8. Corrosion of bottom laterals

3.2 Field Measurements and condition assessment

The geometry of the FOB is obtained by taking measurements in the field. Figure. 9 and Figure.10 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 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	-	-	-	
Bottom laterals	02	-	-	-	
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

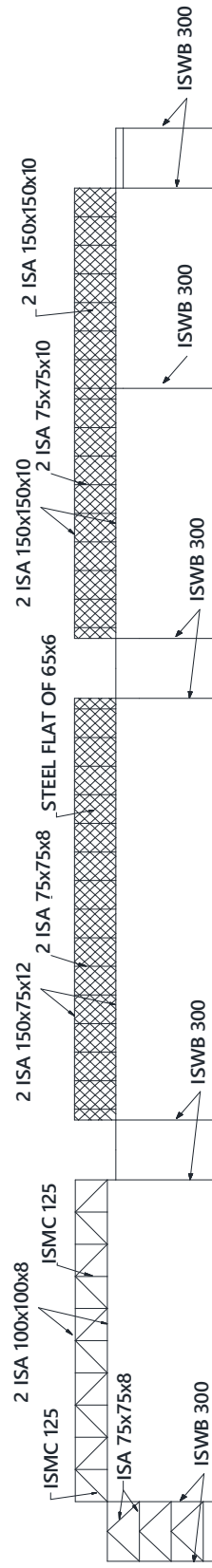


Figure 9. Line sketch of elevation of the FOB

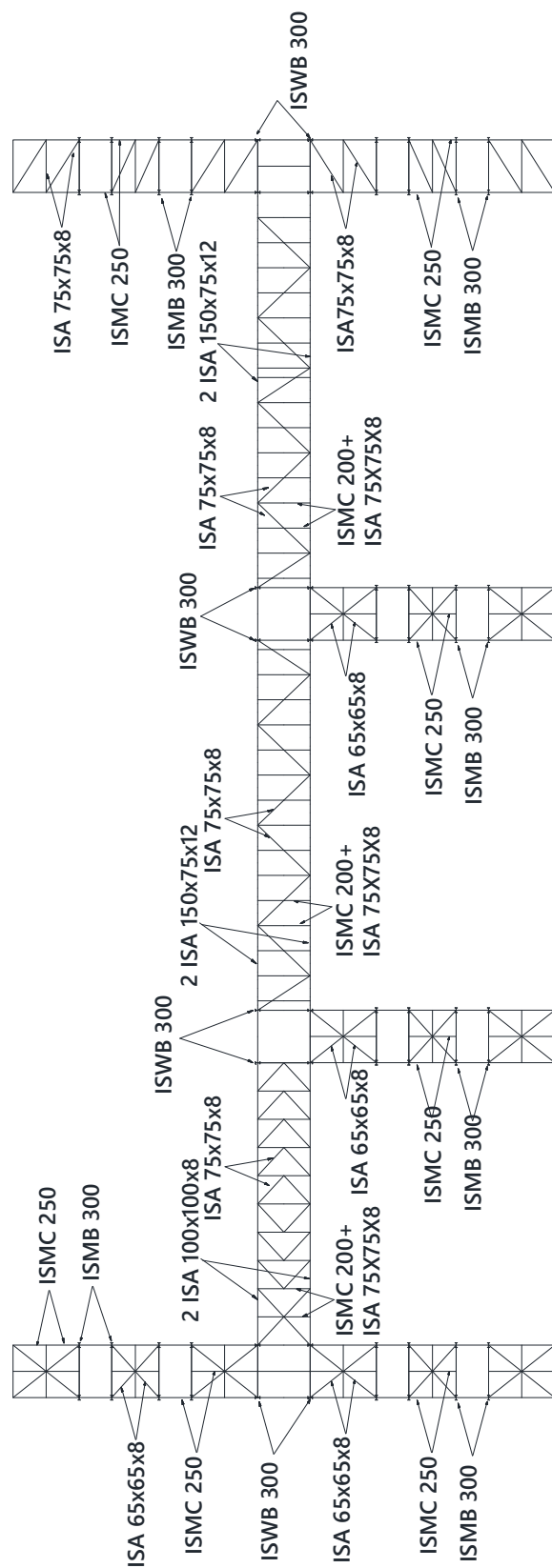


Figure 10. Line sketch of plan of the FOB

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. 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. Computational model is shown in Figure. 11.

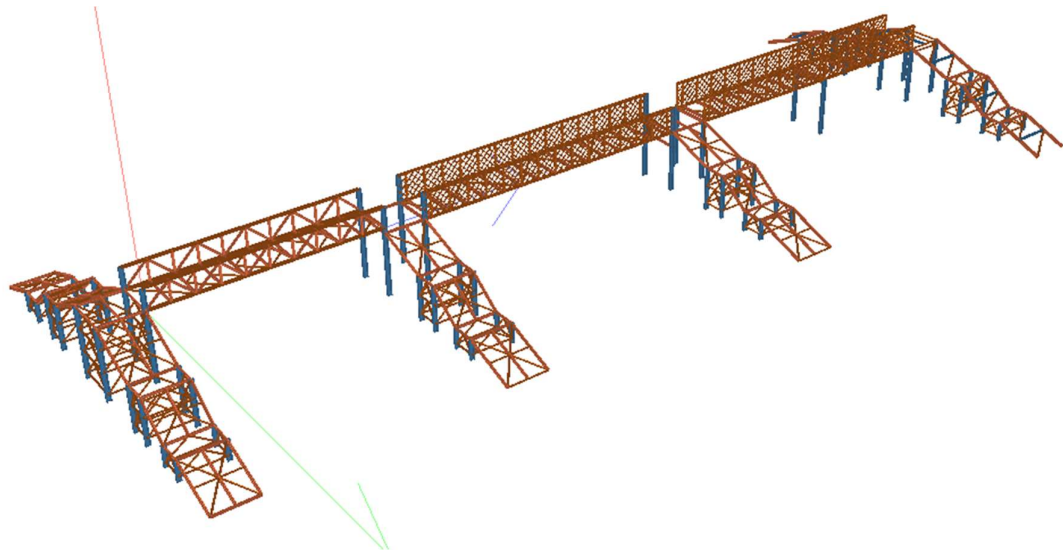


Figure 11. Computational model FOB

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 6 gives a summary of the DCRs for various elements in all four spans. The elements of the 23.6m span truss with DCR values exceeding unity are indicated in RED in Figure.12. Utilization ratios of various elements of truss of the fourth span (18.0 m) obtained from the analysis is given in Figure.13 .

Table 3: Demand capacity ratio for various elements of 11.20 m span (Maximum forces)

Sl No	Element/Section force	Demand (kN/kNm)	Capacity (kN/kNm)	DCR
1	Top chord/ Compression	533	1142	0.47
2	Top chord/Tension	168	1164	0.15
3	Bottom chord/Compression	110	1142	0.10
4	Bottom chord/Tension	645	1164	0.55
5	Vertical/Compression	272	505	0.54
6	Diagonal /Compression	33	66.9	0.49
7	Diagonal /Tension	51	68	0.75
8	Cross beam/Moment	15.73	18.46	0.85
9	Bottom lateral/Compression	14	367	0.04

Table 4: Demand capacity ratio for various elements of 14m span (Maximum forces)

Sl No	Element/Section force	Demand (kN/kNm)	Capacity (kN/kNm)	DCR
1	Top chord/ Compression	621	1142	0.54
2	Top chord/Tension	203	1164	0.17
3	Bottom chord/Compression	131	1142	0.11
4	Bottom chord/Tension	749	1164	0.64
5	Vertical/Compression	308	505	0.61
6	Diagonal /Tension	41	68	0.60
7	Cross beam/Moment	17	19	0.85
8	Bottom lateral/Compression	17	367	0.05

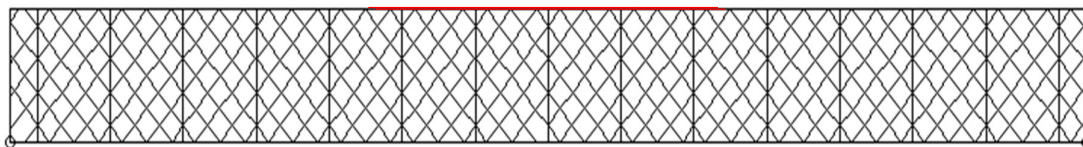


Figure 12. Elements with DCR value more than unity in the 23.6m span truss

Table 5: Demand capacity ratio for various elements of 23.6 m span (Maximum forces)

Sl No	Element/Section force	Demand (kN/kNm)	Capacity (kN/kNm)	DCR
1	Top chord/ Compression	1204	1142	1.05
2	Top chord/Tension	352	1164	0.30
3	Bottom chord/Compression	201	1142	0.18
4	Bottom chord/Tension	1120	1164	0.96
5	Vertical/Compression	342	505	0.68
6	Diagonal /Tension	62	68	0.91
7	Cross beam/Moment	15.73	18.46	0.85
8	Bottom lateral/Compression	16	367	0.04

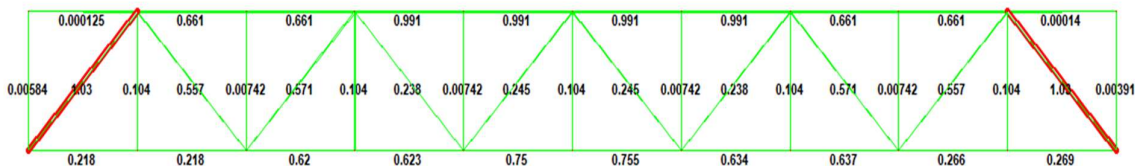


Figure 13. Utilisation ratios of 18.0m span truss from the computational model

Table 6: Demand capacity ratio for various elements of 18 m span

Sl No	Element/Section force	Demand (kN/kNm)	Capacity (kN/kNm)	DCR
1	Top chord/Compression	522	529	0.99
2	Bottom chord/Tension	512	699	0.74
3	End post/compression	40	368	0.11
4	Diagonal	272	266	1.02
5	Cross beam/ Moment	32	36.7	0.88
6	Bottom lateral/ Compression	14	56	0.28
7	Column/(Axial Force, M_x , M_y)	401/15/4	601/169/38	0.91
8	Stair beam/Moment	45.3	48.01	0.94
9	Column Bracing	49	68	0.72

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

Tables 3 to 6 show that the diagonal main ties of the 18m span truss are having a utilization ratio greater than 1. Also in the 23.6m span truss the topchord has the utilization ratio exceeding unity. Hence these members require replacements so as to keep the condition of the girders satisfactory. It is noted here that the effects of material loss due to corrosion is not considered for the calculation of capacity of the elements as it is minimal.

In view of the above, it is recommended to replace the diagonal main ties (shown in RED in Figure.13) of the 18 m span truss of the FOB with a section ISMC 150. Also the topchord of 23.6m span truss is to be replaced with 2 ISA 150×100×12 (shown in RED in Figure.12). This may be done at the earliest considering safety of the users.

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 treating 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

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APPENDIX - I

DESIGN LOADS

Live load	=	500 kg/m ²	=	5	kN/m ²
Wind load			=	1.15	kN/m ²
Weight of RCC slab			=	3	kN/m ²
Weight of roof sheet			=	0.22	kN/m ²
Weight of roof beam			=	0.2	kN
Weight of purlin			=	0.08	kN
Dead load (safety)			=	1.5	kN/m ²

Earthquake load is considered as per IS 1893:2016 and IRC 6:2014

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

DESIGN CHECK FOR 18.0m SPAN

• Top chord members	=	521	kN (compression)
• Bottom chord members	=	512	kN (tension)
• End diagonals	=	272	(kN Compression)
• Vertical members	=	40	kN (Compression)
• Bottom lateral	=	14	kN (Compression)

DESIGN CHECK OF TOP CHORD MEMBER

2L ISA100x100x8mm,

Properties of the section from steel tables:

a) Check for compression

Design force in the member	=	521	kN	compression
Area	=	3078	mm ²	
Depth of the section (d)	=	100	mm	
Width of the section (b)	=	100	mm	
Thickness of the section (t)	=	8	mm	
b/t	=	12.5	<15.7ξ	
d/t	=	12.5	<15.7ξ	

Hence the section is semi compact.

r_{xx}	=	30.7	mm
Effective length of member, L_{eff}	=	1800	mm
Slenderness ratio, λ	=	L_{eff}/r	
	=	58.63	

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

$$\text{Maximum permissible compressive stress, } f_{cd} = 172 \text{ N/mm}^2$$

$$\begin{aligned} \text{Load carrying capacity} &= f_{cd} \times A \\ &= 529.416 \text{ kN} \end{aligned} \quad \text{Safe}$$

$$\begin{aligned} \text{Deformation} &= PL/AE \\ &= 1.45 \text{ mm} \end{aligned} \quad \text{Safe}$$

DESIGN CHECK OF BOTTOM CHORD MEMBER

section 2L ISA100x100x8mm,

Properties of the section from steel tables:

a) Check for Tension

$$\begin{aligned} \text{Design Force} &= 512 \text{ kN} \\ \text{Area} &= 3078 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= 699.5455 \text{ kN} \end{aligned} \quad \text{Safe}$$

$$\begin{aligned} \text{Deformation} &= PL/AE \\ &= 1.43 \text{ mm} \end{aligned} \quad \text{Safe}$$

DESIGN CHECK OF INCLINED MEMBER

a) COMPRESSION MEMBER

section ISMC 200, Properties of the section from steel tables:

$$\begin{aligned} \text{Design force in the member} &= 272 \text{ kN} \\ \text{Length} &= 2.47 \text{ m} \\ \text{Area} &= 2821 \text{ mm}^2 \\ \text{Depth of the section (d)} &= 200 \text{ mm} \\ \text{Width of the section (b)} &= 75 \text{ mm} \\ \text{Thickness of the flange (t)} &= 11.4 \text{ mm} \\ \text{Thickness of the web (t)} &= 6.1 \text{ mm} \\ r_{vv} &= 22.3 \text{ mm} \end{aligned}$$

$$\begin{aligned} \text{Slenderness ratio, } \lambda &= 110.76 \\ \text{Maximum permissible compressive stress, } f_{cd} &= 94.6 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= f_{cd} \times A \\ &= 266.8666 \text{ kN} \\ \text{Deformation} &= PL/AE \\ &= 1.13 \text{ mm} \end{aligned} \quad \begin{array}{l} \text{Fail} \\ \text{Safe} \end{array}$$

DESIGN CHECK OF VERTICAL MEMBER

A) TENSION MEMBER

section ISMC 125, Properties of the section from steel tables:

$$\text{Design Force} = 40 \text{ kN} \quad (\text{Tension})$$

$$\begin{aligned}
 \text{Area} &= 1619 \text{ mm}^2 & F_y &= 250 \text{ N/mm}^2 \\
 \text{Load carrying capacity} &= A_g f_y / \gamma_{m0} \\
 &= 367.9545 \text{ kN} & & \text{Safe}
 \end{aligned}$$

DESIGN CHECK OF BOTTOM LATERAL

a) COMPRESSION MEMBER

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

$$\begin{aligned}
 \text{Design force in the member} &= 14 \text{ kN} \\
 \text{Length} &= 2.46 \text{ m} \\
 \text{Area} &= 1138 \text{ mm}^2 \\
 \text{Depth of the section (d)} &= 75 \text{ mm} \\
 \text{Width of the section (b)} &= 75 \text{ mm} \\
 \text{Thickness of the web (t)} &= 6.1 \text{ mm} \\
 r_{vv} &= 14.6 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Load carrying capacity} &= f_{cd} \times A \\
 &= 55.7 \text{ kN} & \text{Safe} \\
 \text{Deformation} &= PL/AE
 \end{aligned}$$

DESIGN CHECK FOR 11.2m SPAN

- Top chord members = 533 kN (compression)
- Bottom chord members = 168 kN (tension)
- Vertical members = 110 kN (compression)
- Bottom lateral = 645 (kN Tension)
- Vertical members = 272 kN (Compression)
- Bottom lateral = 14 kN Tension)

DESIGN CHECK OF TOP CHORD MEMBER

2L ISA150x75x12mm,

Properties of the section from steel tables:

a) Check for Compression

$$\begin{aligned}
 \text{Design force in the member} &= 533 \text{ kN} & \text{compression} \\
 \text{Area} &= 5124 \text{ mm}^2 \\
 r_{xx} &= 26 \text{ mm} \\
 \text{Effective length of member, } L_{\text{eff}} &= 560 \text{ mm} \\
 \text{Slenderness ratio, } \lambda &= L_{\text{eff}} / r \\
 &= 21.54
 \end{aligned}$$

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

$$\begin{aligned}
 \text{Maximum permissible compressive stress, } F_{cd} &= 223 \text{ N/mm}^2 \\
 \text{Load carrying capacity} &= f_{cd} \times A \\
 &= 1142.652 \text{ kN} & \text{Safe}
 \end{aligned}$$

b)Check for Tension

$$\begin{aligned}
 \text{Design Force} &= 168 \text{ kN} & (\text{Tension}) \\
 \text{Area} &= 5124 \text{ mm}^2 & F_y = 250 \text{ N/mm}^2 \\
 \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\
 &= 1164.545 \text{ kN} & \text{Safe}
 \end{aligned}$$

DESIGN CHECK OF BOTTOM CHORD MEMBER

2L ISA150x175x12mm,

Properties of the section from steel tables:

a)Check for Compression

$$\begin{aligned}
 \text{Design force in the member} &= 110 \text{ kN} \\
 \text{Area} &= 5124 \text{ mm}^2 \\
 r_{xx} &= 26 \text{ mm} \\
 \text{Effective length of member, } L_{eff} &= 560 \text{ mm} \\
 \text{Slenderness ratio, } \lambda &= L_{eff} / r \\
 &= 21.54 \\
 \text{buckling class 'c' of table 9(c) of IS800:2007,} \\
 \text{Maximum permissible compressive stress, } F_{cd} &= 223 \text{ N/mm}^2 \\
 \text{Load carrying capacity} &= f_{cd} \times A \\
 &= 1142.652 \text{ kN} & \text{Safe}
 \end{aligned}$$

b)Check for Tension

$$\begin{aligned}
 \text{Design Force} &= 645 \text{ kN} & (\text{Tension}) \\
 \text{Area} &= 5124 \text{ mm}^2 & F_y = 250 \text{ N/mm}^2 \\
 \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\
 &= 1164.545 \text{ kN} & \text{Safe}
 \end{aligned}$$

DESIGN CHECK OF VERTICAL MEMBER

2L ISA75x75x12mm,

Properties of the section from steel tables:

$$\begin{aligned}
 \text{Design force in the member} &= 272 \text{ kN} & \text{compression} \\
 \text{Area} &= 2276 \text{ mm}^2 \\
 r_{xx} &= 22.8 \text{ mm} \\
 \text{Effective length of member, } L_{eff} &= 540 \text{ mm} \\
 \text{Slenderness ratio, } \lambda &= L_{eff} / r \\
 &= 23.68 \\
 \text{buckling class 'c' of table 9(c) of IS800:2007,} \\
 \text{Maximum permissible compressive stress, } F_{cd} &= 222 \text{ N/mm}^2 \\
 \text{Load carrying capacity} &= f_{cd} \times A \\
 &= 505.272 \text{ kN} & \text{Safe}
 \end{aligned}$$

DESIGN CHECK OF BOTTOM LATERAL

b) TENSION MEMBER

section ISA75x75x8mm, Properties of the section from steel tables:

$$\begin{aligned}\text{Design Force} &= 14 \text{ kN} && (\text{Tension}) \\ \text{Area} &= 1619 \text{ mm}^2 && F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= 367.9545 \text{ kN} && \text{Safe}\end{aligned}$$

DESIGN CHECK FOR 14.0m SPAN

- Top chord members = 621 kN (compression)
- Bottom chord members = 203 kN (tension)
- Vertical members = 131 kN (compression)
- Bottom lateral = 749 (kN Tension)
- Vertical members = 308 kN (Compression)
- Bottom lateral = 17 kN Tension)

DESIGN CHECK OF TOP CHORD MEMBER

2L ISA150x75x12mm,

Properties of the section from steel tables:

a) Check for Compression

$$\begin{aligned}\text{Design force in the member} &= 621 \text{ kN} \\ \text{Area} &= 5124 \text{ mm}^2 \\ r_{xx} &= 26 \text{ mm} \\ \text{Effective length of member, } L_{eff} &= 560 \text{ mm} \\ \text{Slenderness ratio, } \lambda &= L_{eff} / r \\ &= 21.54\end{aligned}$$

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

$$\begin{aligned}\text{Maximum permissible compressive stress, } F_{cd} &= 223 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= f_{cd} \times A \\ &= 1142.652 \text{ kN} && \text{Safe}\end{aligned}$$

b) Check for Tension

$$\begin{aligned}\text{Design Force} &= 203 \text{ kN} && (\text{Tension}) \\ \text{Area} &= 5124 \text{ mm}^2 && F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= 1164.545 \text{ kN} && \text{Safe}\end{aligned}$$

DESIGN CHECK OF BOTTOM CHORD MEMBER

2L ISA150x175x12mm,

Properties of the section from steel tables:

a) Check for Compression

$$\begin{aligned}\text{Design force in the member} &= 131 \text{ kN} \\ \text{Area} &= 5124 \text{ mm}^2 \\ r_{xx} &= 26 \text{ mm} \\ \text{Effective length of member, } L_{\text{eff}} &= 560 \text{ mm} \\ \text{Slenderness ratio, } \lambda &= L_{\text{eff}} / r \\ &= 21.54 \\ \text{buckling class 'c' of table 9(c) of IS800:2007,} \\ \text{Maximum permissible compressive stress, } f_{cd} &= 223 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= f_{cd} \times A \\ &= 1142.652 \text{ kN} \quad \text{Safe}\end{aligned}$$

b) Check for Tension

$$\begin{aligned}\text{Design Force} &= 749 \text{ kN} \quad (\text{Tension}) \\ \text{Area} &= 5124 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= 1164.545 \text{ kN} \quad \text{Safe}\end{aligned}$$

DESIGN CHECK OF VERTICAL MEMBER

2L ISA75x75x12mm,

Properties of the section from steel tables:

$$\begin{aligned}\text{Design force in the member} &= 308 \text{ kN} \quad \text{compression} \\ \text{Area} &= 2276 \text{ mm}^2 \\ r_{xx} &= 22.8 \text{ mm} \\ \text{Effective length of member, } L_{\text{eff}} &= 540 \text{ mm} \\ \text{Slenderness ratio, } \lambda &= L_{\text{eff}} / r \\ &= 23.68 \\ \text{buckling class 'c' of table 9(c) of IS800:2007,} \\ \text{Maximum permissible compressive stress, } f_{cd} &= 222 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= f_{cd} \times A \\ &= 505.272 \text{ kN} \quad \text{Safe}\end{aligned}$$

DESIGN CHECK OF BOTTOM LATERAL

b) TENSION MEMBER

section ISA75x75x8mm, Properties of the section from steel tables:

$$\begin{aligned}\text{Design Force} &= 17 \text{ kN} \quad (\text{Tension}) \\ \text{Area} &= 1619 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= 367.9545 \text{ kN} \quad \text{Safe}\end{aligned}$$

DESIGN CHECK FOR 23.6m SPAN

• Top chord members	=	1204	kN (compression)
	=	354	kN (tension)
• Bottom chord members	=	131	kN (compression)
	=	1120	(kN Tension)
• Vertical members	=	342	kN (Compression)
• Bottom lateral	=	16	kN Tension)

DESIGN CHECK OF TOP CHORD MEMBER

2L ISA150x75x12mm,

Properties of the section from steel tables:

a)Check for Compression

Design force in the member =	1204	kN
Area =	5124	mm ²
r_{xx} =	26	mm
Effective length of member, L_{eff} =	560	mm
Slenderness ratio, λ =	L_{eff}/r	
	21.54	

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

Maximum permissible compressive stress, F_{cd} =	223	N/mm ²
Load carrying capacity =	$f_{cd} \times A$	
	1142.652	kN

Fail

b)Check for Tension

Design Force =	354	kN	(Tension)
Area =	5124	mm ²	$F_y = 250$ N/mm ²
Load carrying capacity =	$A_g f_y / \gamma_{mo}$		
	1164.545	kN	Safe

DESIGN CHECK OF BOTTOM CHORD MEMBER

2L ISA150x175x12mm,

Properties of the section from steel tables:

a)Check for Compression

Design force in the member =	131	kN
Area =	5124	mm ²
r_{xx} =	26	mm
Effective length of member, L_{eff} =	560	mm
Slenderness ratio, λ =	L_{eff}/r	
	21.54	

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

Maximum permissible compressive stress, F_{cd} =	223	N/mm ²
Load carrying capacity =	$f_{cd} \times A$	
	1142.652	kN

Safe

b)Check for Tension

$$\begin{aligned}\text{Design Force} &= 1120 \text{ kN} & (\text{Tension}) \\ \text{Area} &= 5124 \text{ mm}^2 & F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= 1164.545 \text{ kN} & \text{Safe}\end{aligned}$$

DESIGN CHECK OF VERTICAL MEMBER

2L ISA75x75x12mm,

Properties of the section from steel tables:

$$\begin{aligned}\text{Design force in the member} &= 342 \text{ kN} & \text{compression} \\ \text{Area} &= 2276 \text{ mm}^2 \\ r_{xx} &= 22.8 \text{ mm} \\ \text{Effective length of member, } L_{eff} &= 540 \text{ mm} \\ \text{Slenderness ratio, } \lambda &= L_{eff} / r \\ &= 23.68\end{aligned}$$

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

$$\begin{aligned}\text{Maximum permissible compressive stress, } F_{cd} &= 222 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= f_{cd} \times A \\ &= 505.272 \text{ kN} & \text{Safe}\end{aligned}$$

DESIGN CHECK OF BOTTOM LATERAL

b) TENSION MEMBER

section ISA75x75x8mm, Properties of the section from steel tables:

$$\begin{aligned}\text{Design Force} &= 16 \text{ kN} & (\text{Tension}) \\ \text{Area} &= 1619 \text{ mm}^2 & F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= 367.9545 \text{ kN} & \text{Safe}\end{aligned}$$

DESIGN CHECK OF COLUMN

DESIGN DATA

$$\begin{aligned}\text{Width of walkway} &= 3 \\ \text{Length of the column} &= 4.65 \text{ m} \\ \text{Design force in the column} &= 414 \text{ kN} \\ \text{Design Moment in the column, } M_z &= 15 \text{ kNm} \\ \text{Design Moment in the column, } M_y &= 4 \text{ kNm}\end{aligned}$$

Choose a section of ISWB 300

Properties according to steel tables are:

$$\text{Area } A = 6133.0 \text{ mm}^2$$

Depth of section (h) =	300.00	mm
Width of flange (b) =	200.00	mm
Thickness of flange (t _f) =	10.00	mm
Radius of gyration (r _y) =	40.20	mm
Thickness of web (t _w) =	7.40	mm
Depth of the web (d) =	241.50	mm
b/t _f =	20.00	
=		
d/t _w =	32.64	
=		

Hence the section is plastic

$$\text{Slenderness ratio } (\lambda) = 115.67$$

$$h/b_f = 1.50 > 1.2$$

Buckling is about Y-Y axis

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

$$\begin{aligned} \text{Max compressive stress } f_{cd} &= 98.0 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= f_{cd} \times A = 601.03 \text{ kN} \end{aligned}$$

Safe

I _z =	1E+08	mm ⁴
I _y =	9900000	mm ⁴
Z _{ez} =	654800	mm ³
Z _{pz} =	744000	mm ³
Z _{ey} =	99000	mm ³
Z _{py} =	168258	mm ³
r _{zz} =	126.6	mm
r _{yy} =	40.2	mm

SECTION CLASSIFICATION

$$\begin{aligned} \text{Moment Capacity, } M_{dz} &= \beta Z_p f_y / \gamma_{mo} \\ &= 169.09 \text{ kNm} \quad \text{Safe} \\ \text{Moment Capacity, } M_{dy} &= \beta Z_p f_y / \gamma_{mo} \\ &= 38.24 \text{ kNm} \quad \text{Safe} \end{aligned}$$

check for combined axial force and moment

$$\frac{N}{N_d} + \frac{M_y}{M_{dy}} + \frac{M_z}{M_{dz}} : = 0.9 < 1 \quad \text{Safe}$$

DESIGN CHECK OF COLUMN BRACING

Design force in the member = 49 kN

Length =	2.381	m			
Area =	1138	mm ²			
Depth of the section (d) =	75	mm			
Width of the section (b) =	75	mm	k1=	0.7	
Thickness of the section (t) =	10	mm	k2=	0.6	
r _{vv} =	14.5	mm	k3=	5	

$$l/r_w = 164.21$$

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

$$\lambda_{vv} = 1.85$$

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

$$\phi = 2.25$$

$$\chi = 0.266$$

equivalent slenderness ratio, $\lambda_e = 1.67$

Maximum permissible compressive stress, $F_{cd} = 60.37062$ N/mm²

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

= 68.70177 kN

Safe

Deformation = PL/AE

= 0.49 mm

Safe

DESIGN CHECK OF STAIR BEAM

stair beams are of same section for all spans of truss,

Span of Beam, l = 5 m

BM and SF

Bending Moment, $M_u = 45.3$ kNm

Shear Force, SF = 53.0 kN

section of ISMC 200 from steel tables is used

D	=	200	mm
B	=	75	mm
t _f	=	11.4	mm
t _w	=	6.1	mm
depth of web	=	155	mm
I _z	=	2E+07	mm ⁴
I _y	=	1404000	mm ⁴
Z _{ez}	=	181900	mm ³
Z _{pz}	=	211250	mm ³
r _{min}	=	22.3	mm

SECTION CLASSIFICATION

Compression flange	=	b/t _f	
	=	6.57895	<9.4ε
Neutral axis mid depth	=	d/t _w	
	=	25.4098	<84ε

Hence the section is plastic

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

Moment Capacity, M_d	=	$\beta Z_p f_y / \gamma_{mo}$		
	=	48.01	kNm	Safe
Shear Capacity, SF	=	$d t_w f_y / \gamma_{mo} \sqrt{3}$		
	=	124.06	kN	Safe