

REPORT

THIRD PARTY AUDITING OF RAILWAY BRIDGES (PHASE I)

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

**Br. No. 1204A ($1 \times 16.06\text{m} + 1 \times 9.60\text{m}$) IRS type at km
839/500 – 600 at Kasaragod Station**

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

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 24-12-2019 at 10:00 AM. Officials from Kannur Railway section were also present during the inspection. Photographs of the bridge showing various elements are shown in Fig.1 to 5. This steel foot over bridge consists of two spans. The 16.06 m long first span connects 1st platform and the second platform and the 9.60m long second span connects 3rd platform and the roadside on the west of the station.

(i) Details of 16.06 m span bridge

It was orally transpired that this span was constructed about 35 years back. The superstructure 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 riveted connections. It was noted that the angle sections of top and bottom chords of the truss were corroded at several locations. However the effect of corrosion was found to be minimal at the connections.

(ii) Details of span 2 (9.60m)

It was informed that this span was constructed about 15 year back. It is at a height of 5.6 m from 2nd platform floor level and 6.6m from the ground level near the track. 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 bridge was last painted on January 2019. Also the effect of corrosion is seen to be minimal in this span.

Foundations

For the larger span both the foundations are located in the platform and for the smaller span one foundation is on the platform and the other is on the ground on 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.

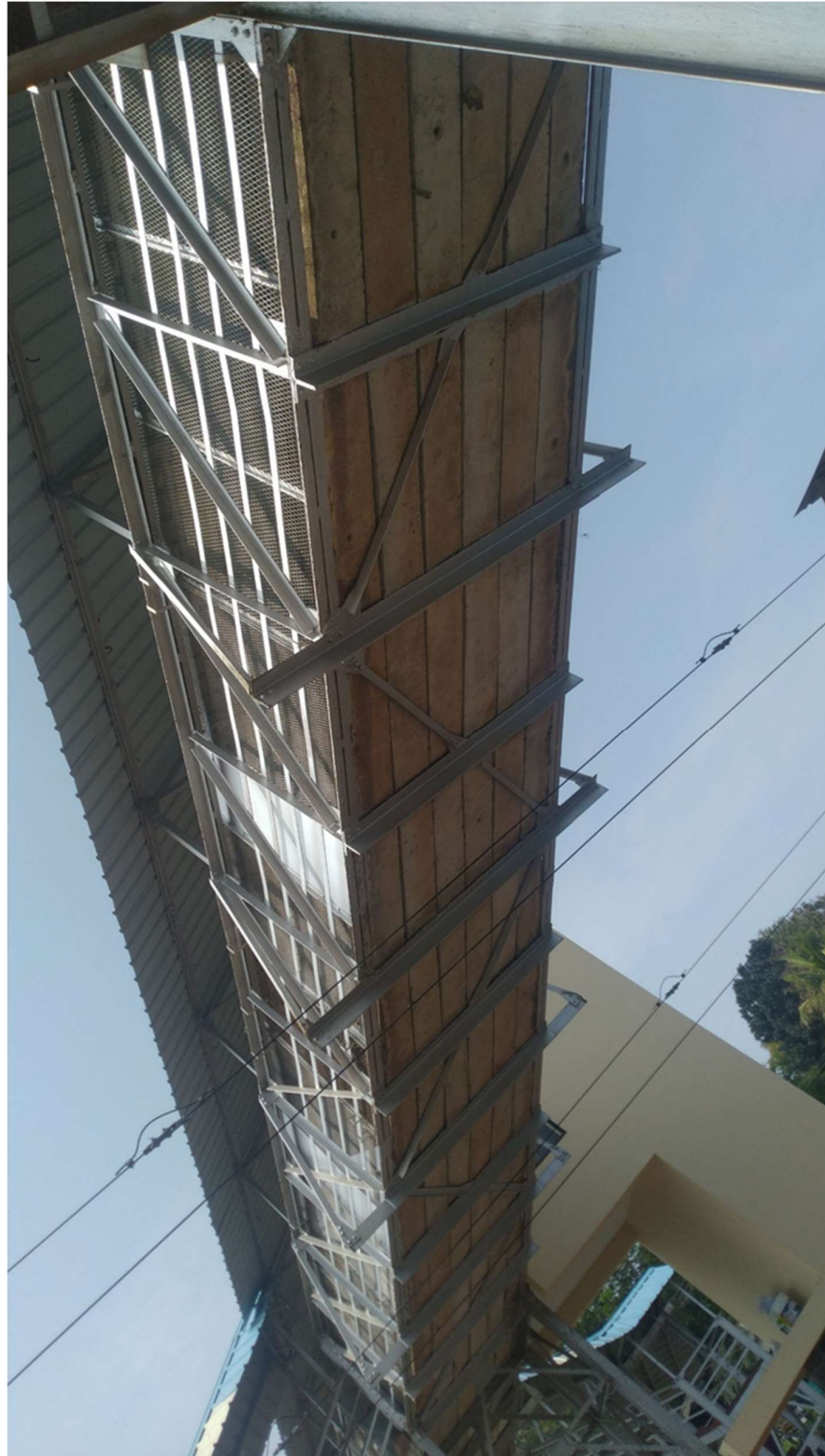


Figure 1. view of FOB at Kasaragod railway station



Figure 2. View of stair of FOB 1204A at Kasaragod railway station



Figure 3. Truss members connected through gusset plates



Figure 4. Stair beam and cross beam



Figure 5. Supporting columns and pedestals

3.2 Field Measurements and condition assessment

The geometry of the FOB is obtained by taking measurements in the field. Fig.6 and Fig.7 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	03		✓		
Bottom chord	03		✓		
Vertical post	00	-	-	-	
Diagonal main ties	00	-	-	-	
Floor beams	03		✓		
Bottom laterals	00	-	-	-	
Supporting Column	00	-	-	-	
Column bracing	00	-	-	-	
Stair beam (inclined)	03		✓		
Pedestal	03		✓		
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

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. Models are shown in Fig. 8 to10.

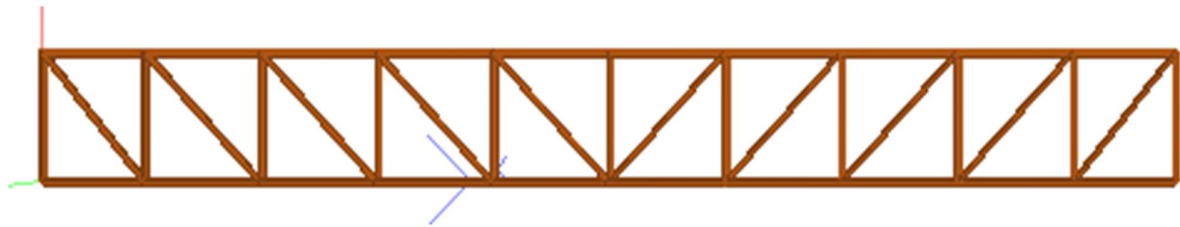


Figure 8. Computational model of 16.06 m span truss

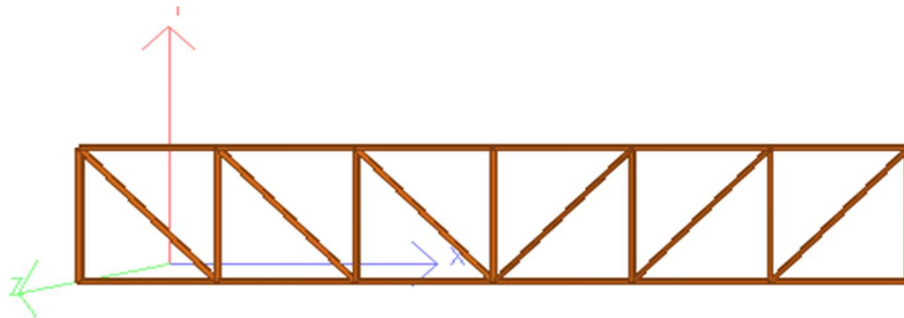


Figure 9. Computational model of 9.60 m span truss

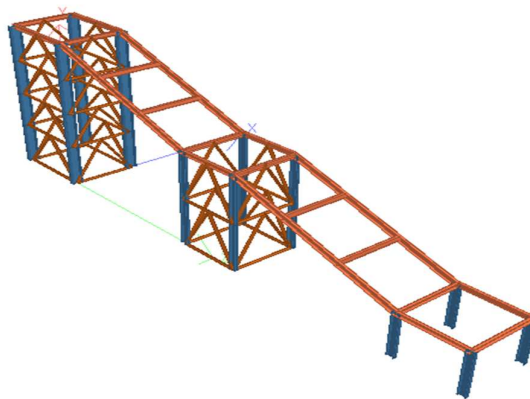


Figure 10. Computational model of stair of the bridge

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 gives a summary of the DCRs for various elements. Utilization ratios of various elements of trusses obtained from the analysis are given in Fig.11 and Fig.12 and that of critical column carrying maximum load is given in Fig 13.

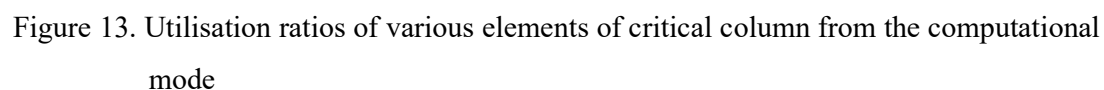
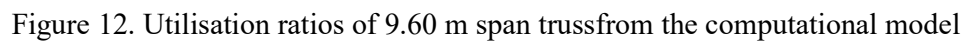
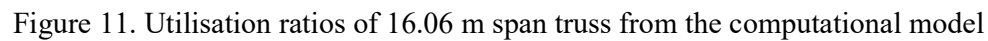


Table 3: Demand capacity ratio for various elements of 16.06 m span (Maximum forces)

Sl No	Element/Section force	Demand (kN/kNm)	Capacity (kN/kNm)	DCR
1	Top chord/ Compression	75	696	0.11
2	Top chord/Tension	168	865	0.19
3	Bottom chord/Compression	110	337	0.33
4	Bottom chord/Tension	231	517	0.45
5	End post/Compression	109	94	1.16
5	Diagonal main tie/Tension	172	259	0.67
6	Cross beam/Moment	15.73	18.46	0.85
7	Bottom lateral/Compression	7	76	0.09
8	Column (Axial force/Moment)	172/15	1164/27	0.70
9	Column bracing/Compression	51	94	0.54
10	Stair beam/Moment	35	48	0.73

Table 4: Demand capacity ratio for various elements of 9.60 m span

Sl No	Element/Section force	Demand (kN/kNm)	Capacity (kN/kNm)	DCR
1	Top chord/Compression	23.5	712	0.04
2	Top chord/Tension	58	865	0.07
3	Bottom chord/Compression	96	337	0.29
4	Bottom chord/Tension	61	517	0.12
5	End post/compression	60	94	0.64
6	Diagonal main tie/Tension	114	258	0.44
7	Cross beam/ Moment	11.3	16.4	0.69
8	Bottom lateral/ Compression	1.6	17.7	0.09

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 3 shows that all the elements of bridge superstructure have a DCR value less than unity except the **end post elements of the 16.06m span truss**. This implies that the end post of the truss and stair beams fail under design loads and thus the condition of the FOB is **not satisfactory**. It should be noted 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 end posts (shown in RED in Fig.11) of the 16.06 m span truss of the FOB with a section ISA 75×75×10 as soon as possible 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 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

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APPENDIX - I

DESIGN CHECK FOR 16.06m SPAN

Live load	=	500 kg/m ²	=	5	kN/m ²	
Weight of RCC slab			=	3	kN/m ²	
Weight of roof sheet			=	0.14	kN/m ²	
weight of vertical post upto roof			=	0.09	kN	
wight of roof beam			=	0.22	kN	
weight of purlin			=	0.587	kN	at alternate nodes
Dead load (safety)			=	1.5	kN/m ²	
Total Load on each panel			=	19.59	kN	
Total Load at the end panels			=	12	kN	

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	=	75	kN (compression)
		168	kN (tension)
• Bottom chord members	=	110	kN (compression)
	=	231	kN (tension)
• End diagonals	=	172	(kN Tension)
• Vertical members	=	109	kN (Compression)

DESIGN CHECK OF TOP CHORD MEMBER

2L ISA100x100x10mm,

a)Check for compression

Design force in the member =	75	kN	compression
Area =	3806	mm ²	
Depth of the section (d) =	100	mm	
Width of the section (b) =	100	mm	
Thickness of the section (t) =	10	mm	
b/t =	10	<15.7ξ	
d/t =	10	<15.7ξ	

Hence the section is semi compact.

r_{xx}	=	30.5	mm
Effective length of member, L_{eff}	=	1650	mm
Slenderness ratio, λ	=	L_{eff}/r	
	=	54.10	

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

Maximum permissible compressive stress, F_{cd}	=	183	N/mm ²
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$$\begin{aligned}
 \text{Load carrying capacity} &= f_{cd} \times A \\
 &= 696.498 \text{ kN} \quad \text{Safe} \\
 \text{Deformation} &= PL/AE \\
 &= 0.15 \text{ mm} \quad \text{Safe}
 \end{aligned}$$

a)Check for Tension

$$\begin{aligned}
 \text{Design Force} &= 168 \text{ kN} \quad (\text{Tension}) \\
 \text{Area} &= 3806 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2 \\
 \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\
 &= 865 \text{ kN} \quad \text{Safe} \\
 \text{Deformation} &= PL/AE \\
 &= 0.02 \text{ mm} \quad \text{Safe}
 \end{aligned}$$

DESIGN CHECK OF BOTTOM CHORD MEMBER

section 2L ISA75x75x8mm,

Properties of the section from steel tables:

a)Check for Tension

$$\begin{aligned}
 \text{Design Force} &= 231 \text{ kN} \quad (\text{Tension}) \\
 \text{Area} &= 2276 \text{ mm}^2 \quad F_y = 250 \text{ N/mm}^2 \\
 \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\
 &= 517.2727 \text{ kN} \quad \text{Safe} \\
 \text{Deformation} &= PL/AE \\
 &= 0.80 \text{ mm} \quad \text{Safe}
 \end{aligned}$$

a)Check for compression

$$\begin{aligned}
 \text{Design force in the member} &= 110 \text{ kN} \quad \text{compression} \\
 \text{Area} &= 2276 \text{ mm}^2 \\
 \text{Depth of the section (d)} &= 75 \text{ mm} \\
 \text{Width of the section (b)} &= 75 \text{ mm} \\
 \text{Thickness of the section (t)} &= 8 \text{ mm} \\
 b/t &= 9.375 < 15.7\xi \\
 d/t &= 9.375 < 15.7\xi \\
 \text{Hence the section is semi compact.} \\
 r_{xx} &= 22.8 \text{ mm} \\
 \text{Effective length of member, } L_{eff} &= 1650 \text{ mm} \\
 \text{Slenderness ratio, } \lambda &= L_{eff} / r \\
 &= 72.37
 \end{aligned}$$

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

$$\begin{aligned}
 \text{Maximum permissible compressive stress, } F_{cd} &= 148.21 \text{ N/mm}^2 \\
 \text{Load carrying capacity} &= f_{cd} \times A \\
 &= 337.326 \text{ kN} \quad \text{Safe}
 \end{aligned}$$

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

$$= 0.38 \text{ mm}$$

Safe

DESIGN CHECK OF INCLINED MEMBER

b) TENSION MEMBER

section ISA75x75x8mm, Properties of the section from steel tables:

$$\text{Design Force} = 172 \text{ kN}$$

(Tension)

$$\text{Area} = 1138 \text{ mm}^2$$

$$F_y = 250$$

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

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

$$= 258.6364 \text{ kN}$$

Safe

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

$$= 0.01 \text{ mm}$$

Safe

DESIGN CHECK OF VERTICAL MEMBER

section ISA75x75x8mm, Properties of the section from steel tables:

$$\text{Design force in the member} = 109 \text{ kN}$$

(Compression)

$$l/r_{vv} = 119.86$$

$$\text{Length} = 1.75 \text{ m}$$

$$\text{Area} = 1138 \text{ mm}^2$$

$$\text{Depth of the section (d)} = 75 \text{ mm}$$

$$\text{Width of the section (b)} = 75 \text{ mm}$$

$$\text{Thickness of the section (t)} = 8 \text{ mm}$$

$$r_{vv} = 14.6 \text{ mm}$$

$$k_1 =$$

$$0.7$$

$$k_2 =$$

$$0.6$$

$$k_3 =$$

$$5$$

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

$$\lambda_{vv} = 1.35$$

$$\lambda_{\phi} = 0.11$$

$$\phi = 1.71$$

$$\chi = 0.365$$

$$\text{equivalent slenderness ratio } \lambda_e = 1.36$$

$$\text{Maximum permissible compressive stress, } F_{cd} = 82.89829 \text{ N/mm}^2$$

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

$$= 94.33825 \text{ kN}$$

Fail

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

$$= 0.80 \text{ mm}$$

Safe

DESIGN CHECK OF COLUMN

DESIGN DATA

$$\text{Width of walkway} = 2.35$$

$$\text{Spacing of columns} = 28 \text{ m}$$

$$\text{Length of the column} = 5.4 \text{ m}$$

$$\text{No. of horizontal bracings} = 4$$

$$\text{Design force in the column} = 172 \text{ kN}$$

$$\text{Design Moment in the column} = 15 \text{ kNm}$$

Choose a section of ISMB 300

Properties according to steel tables are:

Area A =	5626.0	mm ²
Depth of section (h) =	300.00	mm
Width of flange (b) =	140.00	mm
Thickness of flange (t _f) =	12.40	mm
Radius of gyration (r _y) =	28.40	mm
Thickness of web (t _w) =	7.50	mm
Depth of the web (d) =	241.50	mm
b/t _f =	11.29	
=		
d/t _w =	32.20	
=		

Hence the section is semi compact.

Slenderness ratio (λ) = 47.54

h/b_f = 2.14 > 1.2

t_f = 17.20 ≤ 40 mm

Buckling is about z-z axis

Max compressive stress f_{cd} = 207.0 N/mm²
 Load carrying capacity = f_{cd} x A = 1164.58 kN

Safe

I _z =	9E+07	mm ⁴
I _y =	4539000	mm ⁴
Z _{ez} =	573600	mm ³
Z _{pz} =	116984	mm ³
r _{min} =	28.4	mm

SECTION CLASSIFICATION

Moment Capacity, M_d = β_p Z_p f_y / γ_{mo}
 = 26.59 kNm

Safe

check for combined axial force and moment

$$\frac{N}{N_d} + \frac{M_y}{M_{dy}} + \frac{M_z}{M_{dz}} = 0.7 > 1$$

Safe

DESIGN CHECK OF STAIR BEAM

Span of Beam, l = 5 m

BM and SF

Bending Moment, M_u = 35.0 kNm

Shear Force, SF = 41.0 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
Shear Capacity, SF	=	$d t_w f_y / \gamma_{mo} \sqrt{3}$	
	=	124.06	kN

Safe

Safe

DESIGN CHECK OF COLUMN BRACING

Design force in the member = 51 kN

Length	=	1.75	m
Area	=	1138	mm ²
Depth of the section (d)	=	75	mm
Width of the section (b)	=	75	mm
Thickness of the section (t)	=	8	mm
r_{vv}	=	14.6	mm

$$l/r_{vv} = 119.86$$

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

k_1	=	0.7	$\lambda_{vv} = 1.35$
k_2	=	0.6	$\lambda_{\phi} = 0.11$
k_3	=	5	

$$\phi = 1.71$$

$$\chi = 0.365$$

equivalent slenderness ratio , λ_e	=	1.36	
Maximum permissible compressive stress, F_{cd}	=	82.89829	N/mm ²
Load carrying capacity	=	$f_{cd} \times A$	
	=	94.33825	kN
Deformation	=	PL/AE	
	=	0.37	mm

Safe

Safe

DESIGN CHECK FOR 9.60m SPAN

Live load	=	500 kg/m ²	=	5	kN/m ²	
Weight of RCC slab	=		=	3	kN/m ²	
Weight of roof sheet	=		=	0.14	kN/m ²	
weight of vertical post upto roof	=		=	0.09	kN	
wight of roof beam	=		=	0.22	kN	
weight of purlin	=		=	0.587	kN	at alternate nodes
Dead load (safety)	=		=	1.5	kN/m ²	
• Top chord members	=		=	23.5	kN (compression)	
	=		=	58	kN (tension)	
• Bottom chord members	=		=	96	kN (compression)	
	=		=	61	kN (tension)	
• End diagonals	=		=	114	(kN Tension)	
• Vertical members	=		=	60	kN (Compression)	

DESIGN CHECK OF TOP CHORD MEMBER

2L ISA100x100x10mm,

Properties of the section from steel tables:

a)Check for compression

Design force in the member	=	23.5	kN	compression
Area	=	3806	mm ²	
Depth of the section (d)	=	100	mm	
Width of the section (b)	=	100	mm	
Thickness of the section (t)	=	10	mm	
b/t	=	10	<10.5ξ	
d/t	=	10	<10.5ξ	
Hence the section is plastic				
r_{xx}	=	30.5	mm	
Effective length of member, L_{eff}	=	1600	mm	
Slenderness ratio, λ	=	L_{eff}/r		
	=	52.46		

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

Maximum permissible compressive stress, F_{cd}	=	187	N/mm ²	
Load carrying capacity	=	$f_{cd} \times A$		
	=	711.722	kN	Safe
Deformation	=	PL/AE		
	=	0.05	mm	Safe

a)Check for Tension

Design Force	=	58	kN	(Tension)
Area	=	3806	mm ²	$F_y = 250$ N/mm ²
Load carrying capacity	=	$A_g f_y / \gamma_{mo}$		
	=	865	kN	Safe

$$\begin{aligned} \text{Deformation} &= PL/AE \\ &= 0.00 \text{ mm} \end{aligned} \quad \boxed{\text{Safe}}$$

DESIGN CHECK OF BOTTOM CHORD MEMBER

a) Check for Tension

$$\begin{aligned} \text{Design Force} &= 61 \text{ kN} & (\text{Tension}) \\ \text{Area} &= 2276 \text{ mm}^2 & F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= 517.2727 \text{ kN} \end{aligned} \quad \boxed{\text{Safe}}$$

$$\begin{aligned} \text{Deformation} &= PL/AE \\ &= 0.20 \text{ mm} \end{aligned} \quad \boxed{\text{Safe}}$$

a) Check for compression

$$\begin{aligned} \text{Design force in the member} &= 96 \text{ kN} & \text{compression} \\ \text{Area} &= 2276 \text{ mm}^2 \\ \text{Depth of the section (d)} &= 75 \text{ mm} \\ \text{Width of the section (b)} &= 75 \text{ mm} \\ \text{Thickness of the section (t)} &= 8 \text{ mm} \\ b/t &= 9.375 < 15.7\xi \\ d/t &= 9.375 < 15.7\xi \end{aligned}$$

Hence the section is semi compact.

$$\begin{aligned} r_{xx} &= 22.8 \text{ mm} \\ \text{Effective length of member, } L_{\text{eff}} &= 1650 \text{ mm} \\ \text{Slenderness ratio, } \lambda &= L_{\text{eff}} / r \\ &= 72.37 \end{aligned}$$

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

$$\text{Maximum permissible compressive stress, } F_{cd} = 148.21 \text{ N/mm}^2$$

$$\begin{aligned} \text{Load carrying capacity} &= f_{cd} \times A \\ &= 337.326 \text{ kN} \end{aligned} \quad \boxed{\text{Safe}}$$

$$\begin{aligned} \text{Deformation} &= PL/AE \\ &= 0.33 \text{ mm} \\ &= 1.13 \text{ mm} \end{aligned} \quad \boxed{\text{Safe}} \quad \boxed{\text{Safe}}$$

DESIGN CHECK OF END DIAGONAL

section ISA75x75x8mm, Properties of the section from steel tables:

$$\begin{aligned} \text{Design Force} &= 114 \text{ kN} & (\text{Tension}) \\ \text{Area} &= 1138 \text{ mm}^2 & F_y = 250 \text{ N/mm}^2 \\ \text{Load carrying capacity} &= A_g f_y / \gamma_{mo} \\ &= 258.6364 \text{ kN} \end{aligned} \quad \boxed{\text{Safe}}$$

$$\begin{aligned} \text{Deformation} &= PL/AE \\ &= 0.01 \text{ mm} \end{aligned} \quad \boxed{\text{Safe}}$$

DESIGN CHECK OF VERTICAL MEMBER

section ISA75x75x8mm, Properties of the section from steel tables:

Design force in the member =	60	kN	(Compression)	$l/r_{vv} =$	119.86
Length =	1.75	m		$\sqrt{\frac{E\pi^2}{f_y}} =$	88.86
Area =	1138	mm ²			
Depth of the section (d) =	75	mm			
Width of the section (b) =	75	mm	k1=	0.7	$\lambda_{vv} =$ 1.35
Thickness of the section (t) =	8	mm	k2=	0.6	$\lambda_{\phi} =$ 0.11
$r_{vv} =$	14.6	mm	k3=	5	
					$\phi =$ 1.71
equivalent slenderness ratio $\lambda_e =$	1.36				$\chi =$ 0.365
Maximum permissible compressive stress, $F_{cd} =$	82.89829	N/mm ²			
Load carrying capacity =	$f_{cd} \times A$				
	94.33825	kN		Safe	
Deformation =	PL/AE				
	0.40	mm		Safe	