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Analysis and Design of Concrete Filled Steel Tubular Chord and Brace Bridge Girder under Flexural Loading.

[1]Sharath H P, [2]Dr. Raviraj S, [3]Dr. Chandradhara G P

[1]Assistant professor, Department of Civil Engineering
Sri Jayachamarajendra College of Engineering
JSS Science and Technology University
Mysuru, Karnataka, India.
[2]Professor, Department of Civil Engineering
Sri Jayachamarajendra College of Engineering
JSS Science and Technology University
Mysuru, Karnataka, India.
[3]Professor (Rtd), Department of Civil Engineering
Sri Jayachamarajendra College of Engineering
JSS Science and Technology University
Mysuru, Karnataka, India.

Abstract-This study focuses on the flexural behavior of a composite construction consisting of three concrete filled steel tubular (CFST) chords connected by a circular steel braces. The CFST members exhibit advantages such as stiffness, strength, capacity, and ductility compared to conventional steel and reinforced concrete members. The study uses CATIA V5 software for modelling the truss specimens, and ANSYS software for finite element analysis. The main parameters examined include shear span ratio, angle between brace and chord, presence of infilled concrete, subsequent flexural behavior, and material interaction. The moment of resistance of the CFST truss with braces is calculated using the working stress method, and a design table for ultimate load carrying capacity of different circular sections is generated. The study aims to understand the effects of shear span ratio, angle of chord, brace, and presence of infill concrete on the CFST chord and brace girder.
Keywords—CFST(concrete filled steel tube), CHS(circular hollow section), RC (reinforced concrete).

1. Introduction

Composite structures are materials that combine materials with different physical and chemical properties to create a material with desired properties. Concrete-Filled Steel Tubes (CFTs) are a type of composite structure that consists of a steel tube filled with concrete. They offer several advantages over steel-reinforced concrete members, such as increased strength, stiffness, and resistance to earthquake and static vibrations. The steel tube supports evenly spaced concrete reinforcements and speeds up the erection process. Concrete creates the perfect core to handle compressive loading, delays localized steel buckling, and increases ductility. CFST members can bear larger loads without buckling inward, demonstrate higher cross-sectional ductility, and reduce load distribution caused by corrosion. CFST trusses are often used in large-scale constructions, particularly in bridges where they serve as girders, piers, and arch ribs.

2. Modelling

In the present study, the modelling of all four truss specimens was done using CATIA V5 software and advanced finite element analysis is done using Ansys software.

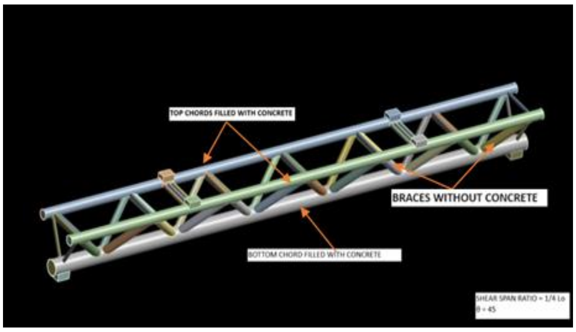
2.1 Different models considered for present study

- M-1: Truss with concrete filled steel tubular chord and hollow tubular braces (shear span ratio of 1/4Lo and θ=45).
- M-2: Truss with concrete filled steel tubular braces and hollow tubular chords (shear span ratio 1/8 Lo and θ =45)

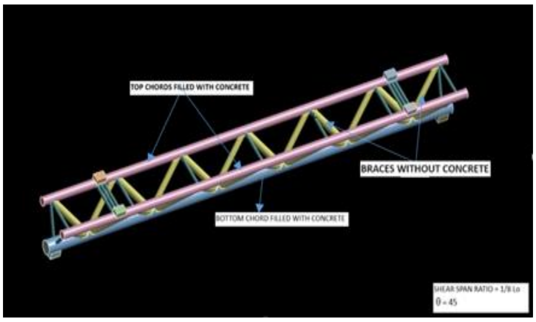
- M-3: Truss with concrete filled steel tubular braces and hollow tubular chords (shear span ratio of 1/4 Lo and θ = 45)
- M-4: Truss with concrete filled steel tubular braces and hollow tubular chords (shear span ratio of 1/8 Lo and θ =45)

Table.1: Dimensions of models

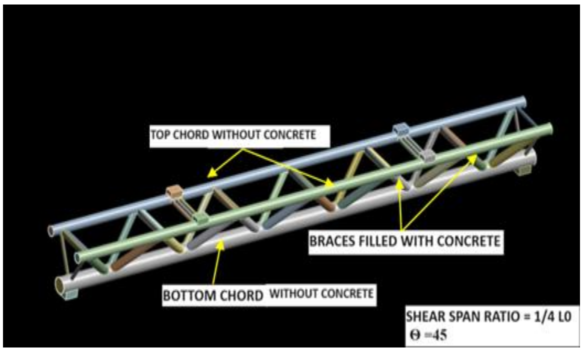
Label	Specimen		Lo (mm)	hi (mm)	b (mm)	bi (mm)	θ	D*t (mm)
	Chord	Brace						
M-1	CFST	CHS	4800	375	512	432	45	140*4
M-2	CFST	CHS	4800	375	512	432	45	140*4
M-3	CHS	CFST	4800	375	512	432	45	140*4
M-4	CHS	CFST	4800	375	512	432	45	140*4



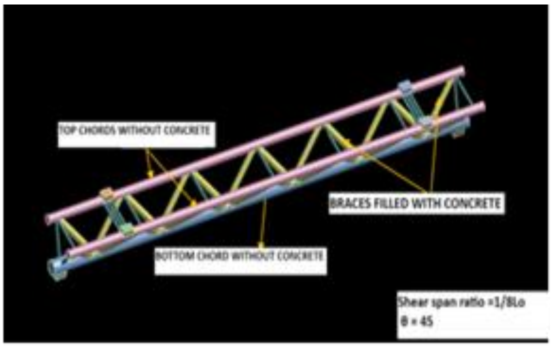
M-1



M-2



M-3



M-4

Fig.2.1: Different models considered for present study

2.2 Loading and Boundary Conditions

The response of the loads and supports depends on the degrees of freedom (DOF) permitted for the elements used. Solid geometry has three degrees of freedom (DOF): X, Y, and Z Translations (for shells and beams). Vector components may be used to specify most loads and supports. To imitate real-world situations in the experimental test setup, the boundary conditions for all models are taken into consideration. All of the trusses were subjected to two-point loading, as seen in Fig. 2. The real truss and the finite element models were both loaded at the same locations. The bearing distance was left by placing the support in the finite element model 100mm from both of the truss's edges. Likewise, 1200mm loading points were selected.

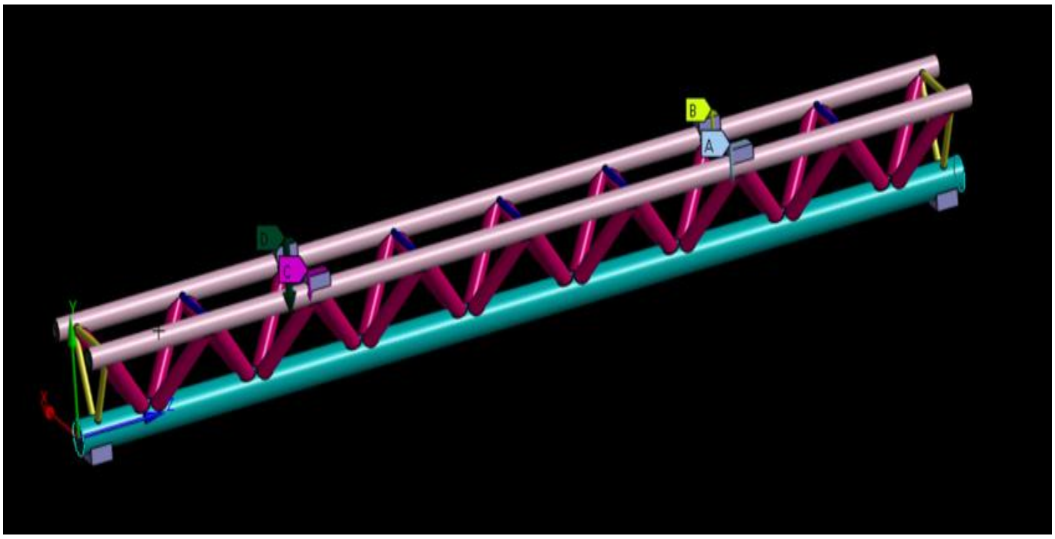


Fig.2.2: Shows loading positions

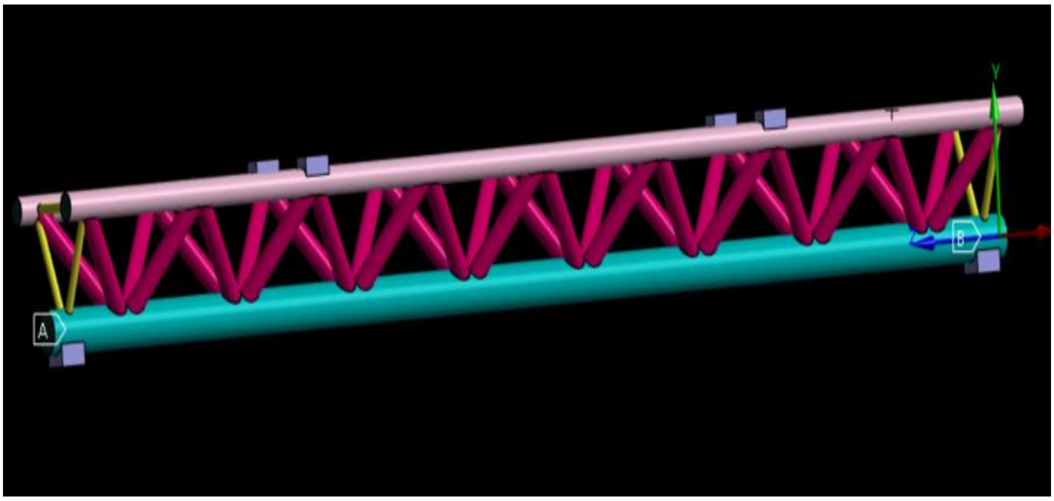


Fig.2.3: Shows Boundary Conditions

3. Design Table

A design table is a tabular representation used to organize and present different design parameters, the calculations, and findings for a particular project or structural element in civil engineering. In order to make sure that the intended structure complies with safety, functionality, and legal requirements, these tables are frequently utilized during the design process.

3.1 Determining the depth of neutral axis

The Working Stress Method assumes that both concrete and steel behave linearly elastic, meaning that their stresses are proportional to their strains. The depth of neutral axis is calculated as below,

Depth of Neutral axis (x) is calculated by,

$$A_C \ x \ (A_{sc}m) \ x = (mAst) \ (d - x) \quad ..(1)$$

$$10826\ x\ (1621.71X10.98)\ x = (10.98X1709.71)\ (375 - x)$$

$$\boldsymbol{x = 148\ mm}$$

3.2 Determining Moment of Resistance

Moment of Resistance is calculated by,

$$M_R = \mathrm{T}\ Ast\ \ d$$

Where.

$$\mathrm{T} = \frac{\sigma_{cbc}}{5000\sqrt{fck}}\left(\frac{d\text{-}x}{x}\right)\ \mathrm{E}_S$$

And

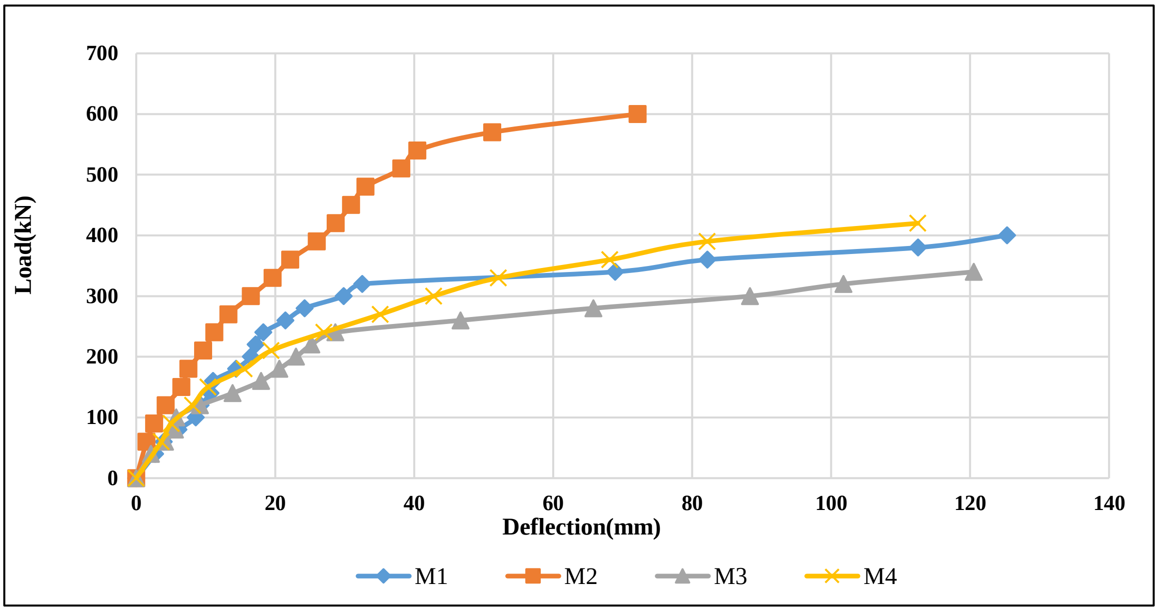
$$M_R = \frac{\sigma_{cbc}}{5000\sqrt{fck}}\left(\frac{d\text{-}x}{x}\right)\ \mathrm{E}_S\ \ Ast\ \ d \qquad \dots (2)$$

$$\mathbf{M_R = 66.86KN\text{-}m}$$

4. Results And Discussion

4.1 Comparison of load v/s deflection curve of all four models

Linear elastic analysis is the most common type of FEA analysis. A linear static analysis is one in which a linear relationship between applied forces and displacements is maintained. A static structural analysis computes the effect of constant loading conditions on a structure while ignoring the effects of inertia and damping caused by time-varying loads. Constant inertia loads, rotational velocity and time variable loads, and static equivalent loads can all be included in a linear static analysis. In actuality, this only applies to structural stresses that are within the linear elastic range of the material used.



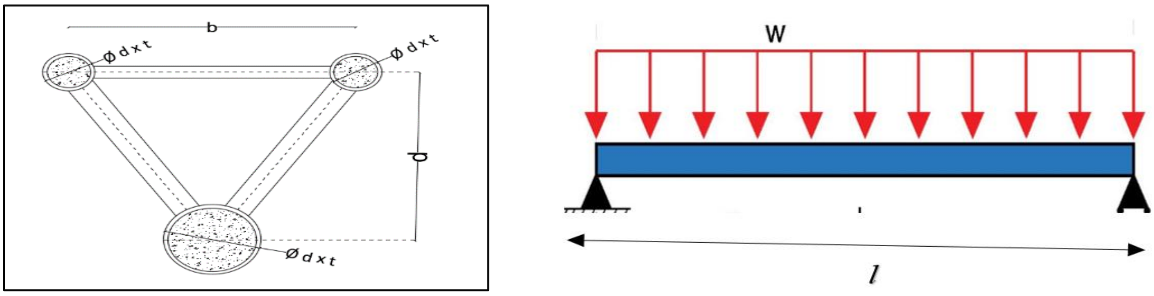


Fig4.1.Load v/s deflection

From the above graph we can conclude that M-2 has more load carrying capacity when compared to M-1, M-3 and M-4.

4.2 Typical calculation of Design Table

The depth of Neutral axis, x =105mm

Moment of Resistance, M_R =113.71 kN-m

- $M_R = \frac{wl^2}{8} = (\frac{w_{DL}+w_{LL}}{8})\, l^2$
- W= WLL + WDL
- WLL= 99.57 kN/m

4.3 Tabulated Design Table

Top chord outer dia(mm)	Thickness (mm)	Bottom chord outer dia(mm)	Thickness (mm)	Length *l* (mm)	*x* *(mm)*	d *(mm)*	M_R (kN-m)	W (kN/m)	WLL (kN/m^2)
60.3	2.9	101.6	3.6	3000	104	375	37.49	33.33	12.12
	3.6		4	3000	102	375	42.71	37.97	13.81
	4.5		4.8	3000	104	375	49.69	44.18	16.06
76.1	3.2	114.3	3.6	3000	85	375	55.34	49.2	17.89
	3.6		4.5	3000	95	375	59.52	52.91	19.24
	4.5		5.4	3000	98	375	68.22	60.65	22.05
88.9	3.2	127	4.5	3000	92	375	69.16	61.48	22.36
	4		4.8	3000	88	375	78.13	69.45	25.25
	4.8		5.4	3000	88	375	87.68	77.94	28.34
89	6	140	8	3000	148	375	66.84	59.42	21.61
60.3	2.9	101.6	3.6	6000	104	375	37.49	8.33	3.03
	3.6		4	6000	102	375	42.71	9.49	3.45
	4.5		4.8	6000	104	375	49.69	11.04	4.02
76.1	3.2	114.3	3.6	6000	85	375	55.34	12.3	4.47
	3.6		4.5	6000	95	375	59.52	13.23	4.81
	4.5		5.4	6000	98	375	68.22	15.16	5.51
	3.2	127	4.5	6000	92	375	69.16	15.37	5.59

88.9	4		4.8	6000	88	375	78.13	17.36	6.31
	4.8		5.4	6000	88	375	87.68	19.49	7.09
89	6	140	8	6000	148	375	66.84	14.85	5.4
60.3	2.9	101.6	3.6	9000	104	375	37.49	3.7	1.35
	3.6		4	9000	102	375	42.71	4.22	1.53
	4.5		4.8	9000	104	375	49.69	4.91	1.78
76.1	3.2	114.3	3.6	9000	85	375	55.34	5.47	1.99
	3.6		4.5	9000	95	375	59.52	5.88	2.14
	4.5		5.4	9000	98	375	68.22	6.74	2.45
88.9	3.2	127	4.5	9000	92	375	69.16	6.83	2.48
	4		4.8	9000	88	375	78.13	7.72	2.81
	4.8		5.4	9000	88	375	87.68	8.66	3.15
89	6	140	8	9000	148	375	66.84	6.6	2.4

5. Conclusions

- The result of CFST chord -CHS braces with shear span ratio of 1/8Lo and 45° is compared with CHS chord-CFST braces with shear span ratio of 1/8Lo and 45°. It was found that the load bearing capacity of CFST chord-CHS braces with shear span ratio of 1/8Lo and 45° is more than CFST braces with CHS chords with shear span ratio of 1/8Lo and 45° because of presence of infilled concrete braces which might cause joint failure.
- The shear span ratio shows significant effect on flexural strength of the truss the effect of concrete on the CFST trusses is dominated by the tensile yielding of the bottom chord, whereas hollow tubular braces failed due to the buckling or joint failure.
- By using working stress method depth of neutral axis and moment of resistance of CFST chord and brace bridge girder is calculated.
- Design table has been generated for different cross sections by considering spans such as 3m, 6m and 9m.

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