Finite element analysis of concrete filled steel tubular truss girder

Rusna K.P

Abstract— Concrete filled steel tubes (CFST) are becoming increasingly popular and used in various structures throughout the world due to the excellent composite interaction between the steel tube and concrete. CFST truss is a type of truss which uses CFST members as its chords and hollow tubes as its braces. The new type of trusses can be used in bridge structures and other large span structure. Due to the excellent performance in strength, stiffness and ductility, the CFST members have achieved extensive structural application. This project mainly focuses on analysis and behavioral characteristics of CFST Pratt truss using ANSYS. The concrete infill increases the compressive strength of the top chord and the tensile strength of the bottom chord. Filling the chord with concrete will greatly increase both the static and fatigue strength of the joint. The various parameters considered are diameter of chord, diameter of brace, thickness of chord and strength of concrete infill, truss height and span length

Index Terms CFST, Pratt truss, finite element analysis, girders, ANSYS

1 INTRODUCTION

Concrete filled steel tubes (CFST) are becoming increasingly popular and used in various structures throughout the world due to the excellent composite interaction between the steel tube and concrete. Concrete filled steel tubular (CFST) truss is a type of truss in which the both top and bottom chord are filled with concrete and the braces are hollow tubes.

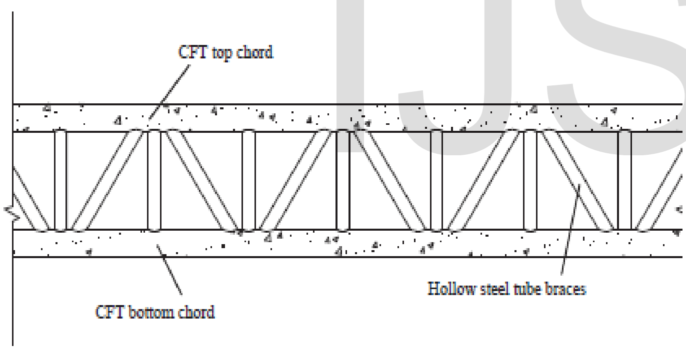


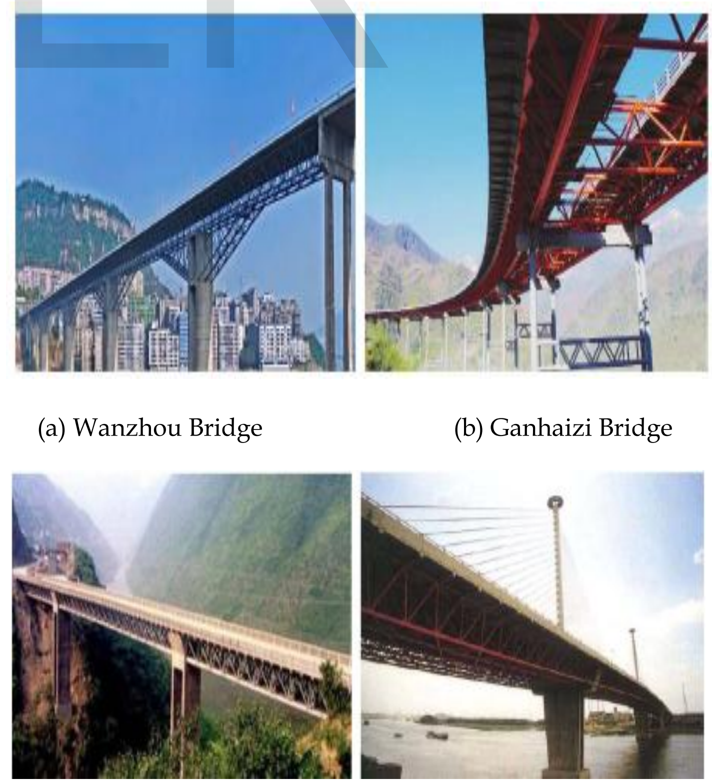
Fig.1. Typical CFST truss girder

The new type of trusses can be used in bridge structures and other large span structure. Due to the excellent performance in strength, stiffness and ductility, the CFST members have achieved extensive structural application. In CFSTs the steel section reinforces the concrete to resist any bending moments, tensile and shear forces. The concrete in a composite truss reduces the potential for buckling of the steel section in addition to resisting compressive loading. The concrete infill helps to increase the compressive strength of top chord and tensile strength of bottom chord. The strength of brace to chord joint also can be increased by concrete infill and thereby increases the overall flexural stiffness of the truss. The concrete infill prevents the inward buckling of top chord and restrains steel tube of the bottom chord from inward contraction due to Poisson's effect. The steel tube in CFSTs also serves as a formwork for placing the concrete and thereby facilitates the construction and also reduces the labor cost too.

The behavior and strength of CFST trusses are greatly improved as compared to hollow steel tubular trusses. The failure modes of CFST truss girders are the tensile fracture of bottom chord and shear failure (local buckling of braces or weld fracture).

Main applications of CFST trusses

- Used as girders in roof systems
- Used as main girders in cable-stayed bridges



(a) Wanzhou Bridge (b) Ganhaizi Bridge

(c) Xiangjiaba Bridge (d) Zidong Bridge

Fig.2. Typical applications of CFT truss girders in bridges

2 ANALYTICAL STUDIES

2.1 Material Selection

The materials used for the analysis of CFST truss girders are steel and concrete. The CFST chords are of 150mm diameter and 5mm thickness. The diameter of brace is fixed as 50mm and its thickness is 3mm.

Table 1: Properties of steel

Density	7860 kg/m^3
Yield strength	2x10^5 MPa
Poisson's ratio	0.3

Table 2: Properties of steel

Density	2400 kg/m^3
Grade	M40
Poisson's ratio	0.15

2.2 Loading Condition

Mid- point loading is applied

2.3 Modelling

The second stage in ANSYS is modeling. Both the chord and braces are modeled as of circular cross section. The overall span of the girder is fixed as 2m. The chord members, loading and supports are modeled as solid element. The braces are modeled as line body

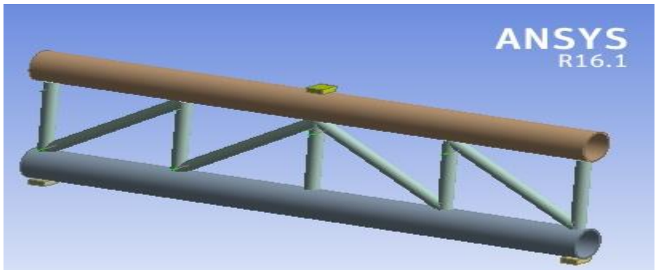


Fig 3. Geometry of hollow tubular truss model

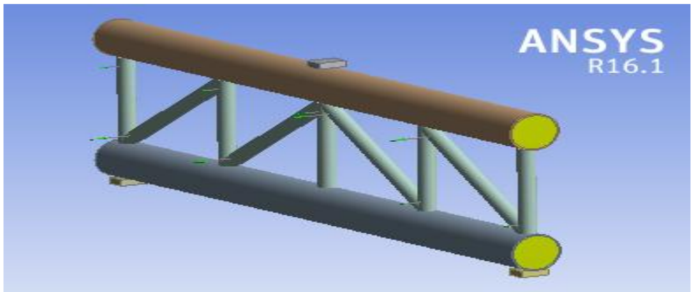


Fig 4: Geometry of concrete infilled steel tube truss

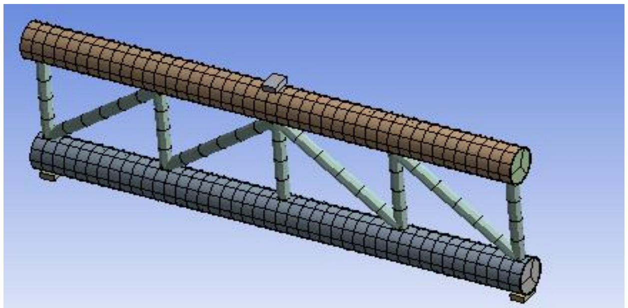


Fig 5 Meshed view of CFST specimen

3 RESULT AND DISCUSSIONS

3.1 Parametric Study

The parametric study is done by varying grade of concrete infill, by varying diameter of chord, diameter of brace, thickness of chord wall, truss height, span length etc.

3.1.1 Varying concrete grade

Table 3: Varying concrete grade

Concrete grade	Deflection (mm)	Load (kN)
Hollow	10.713	117.76
M25	18.913	394.63
M30	18.934	403.6
M40	19.47	432.62

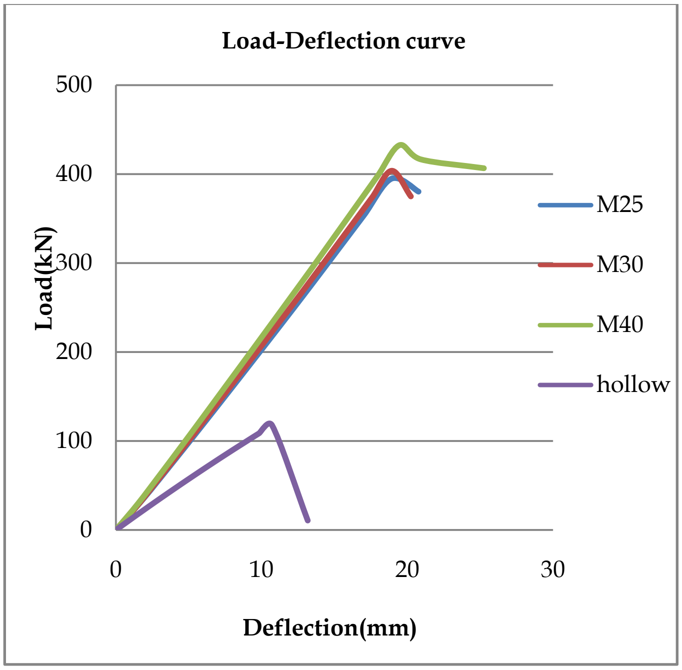


Fig 6: Load Vs deflection curve

The load carrying capacity of concrete filled steel tubular truss girder is very much higher than that of hollow steel tubular truss girder. By filling the hollow steel tubular truss by M25 grade concrete the load carrying capacity is increased by about 70%. As the grade of concrete infill increased the load carrying capacity also increased. But the percentage of increase in strength is small. As the grade of concrete infill is increased as M30 and M40, the load carrying capacity also increased by 2.3% and 6.7% respectively.

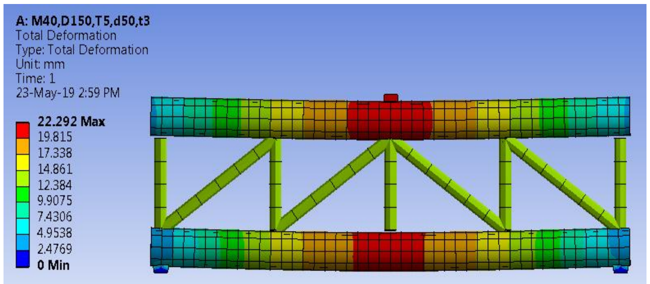


Fig 7. Total deformation diagram of CFST specimen for M40 grade concrete infill

3.1.2 Effect of brace diameter

Table 4: Varying brace diameter

Brace diameter(mm)	Deflection (mm)	Load (kN)
32	18.94	419.87
40	19.34	430
50	19.47	432.62
65	19.602	436.2
75	19.78	440.11

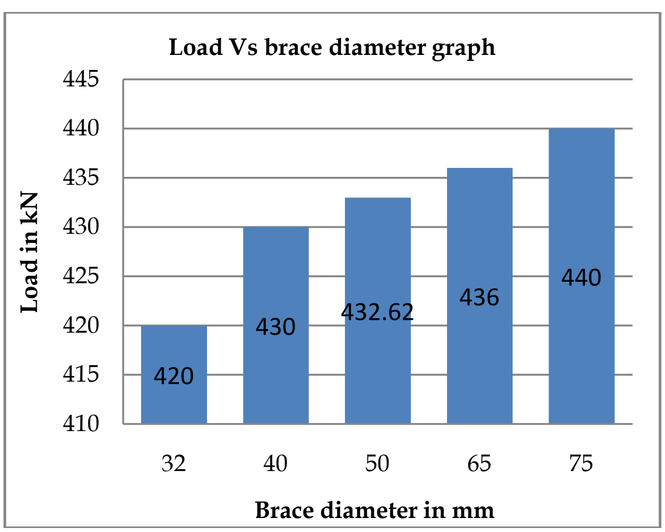


Fig 8: Load Vs diameter of brace graph

The load carrying capacity of CFST truss girder is influenced by the diameter of the brace members. As the brace diameter increased the load carrying capacity also increased. Brace diameter is changed as 32mm, 40mm, 50mm, 65mm and 75mm. It is found that as the brace diameter increases there is slight increment in load carrying capacity.

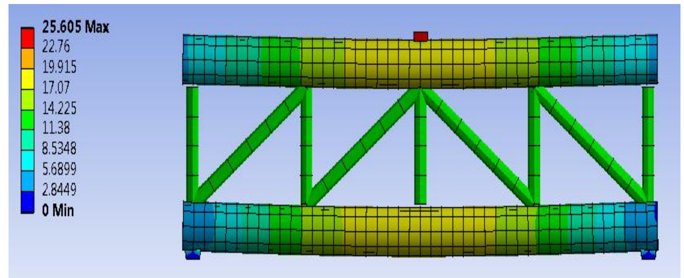


Fig 9. Total deformation diagram of CFST specimen for 75mm brace diameter

3.1.3 Effect of chord diameter

Table 5: Varying chord diameter

Chord diameter(mm)	Deflection (mm)	Load (kN)
100	18.589	402.66
150	19.47	432.62
200	19.74	458.69

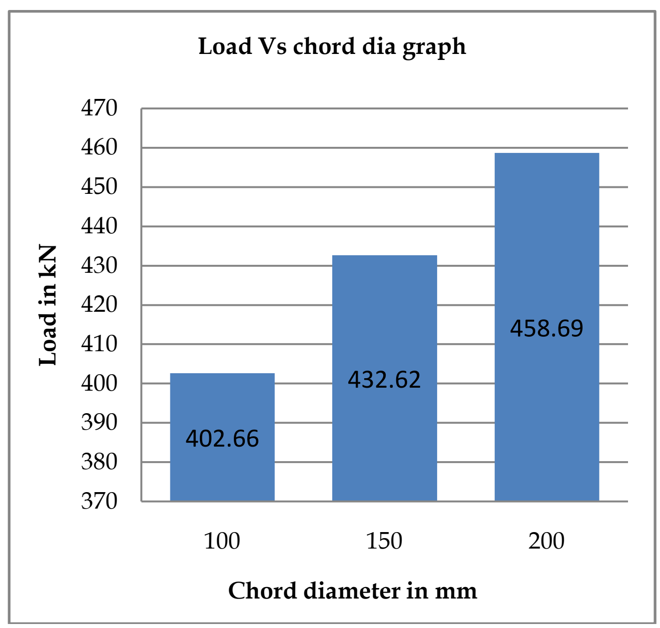


Fig 10: Load Vs chord diameter curve

The load carrying capacity of CFST truss girder is influenced by the diameter of the chord members. As the chord diameter increased the load carrying capacity also increased.

Chord diameter is changed as 100mm, 150mm and 200mm. For each 50mm increment in chord diameter, there is about 6% increment in load carrying capacity.

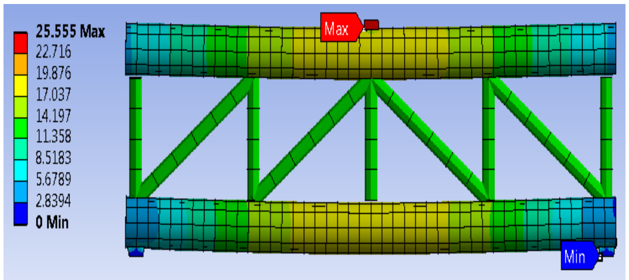


Fig 11. Total deformation diagram of CFST specimen for 200mm chord diameter

3.1.4 Effect of chord thickness

Table 6: Effect of chord thickness

Chord thickness(mm)	Deflection (mm)	Load (kN)
3	16.237	358
4	19.278	395
5	19.47	433
6	19.264	475

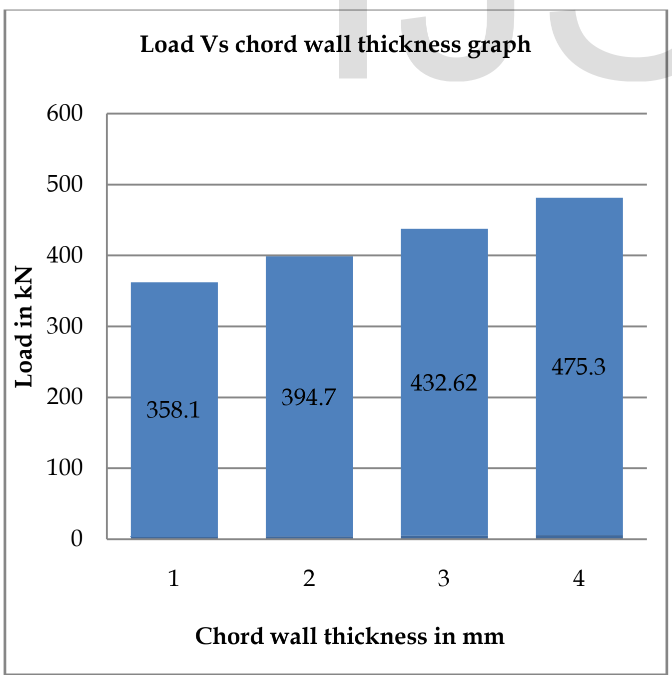


Fig 12: Load Vs chord wall thickness curve

The load carrying capacity of CFST truss girder is influenced by the thickness of chord members. As the chord thickness increased the load carrying capacity also increased. Chord thickness is changed as 3mm, 4mm, 5mm, and 6mm. It is found that for each 1mm increment in thickness of chord wall there is about 9% increment in load carrying capacity

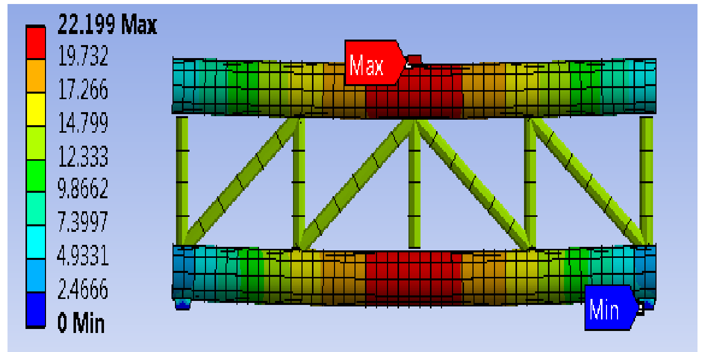


Fig 13. Total deformation diagram of CFST specimen for 6mm chord thickness

3.1.5 Effect of truss height

Table 7: Effect of truss height

Chord thickness(mm)	Deflection (mm)	Load (kN)
400	18.821	418.23
500	19.47	432.62
600	19.713	446.7
700	19.87	464

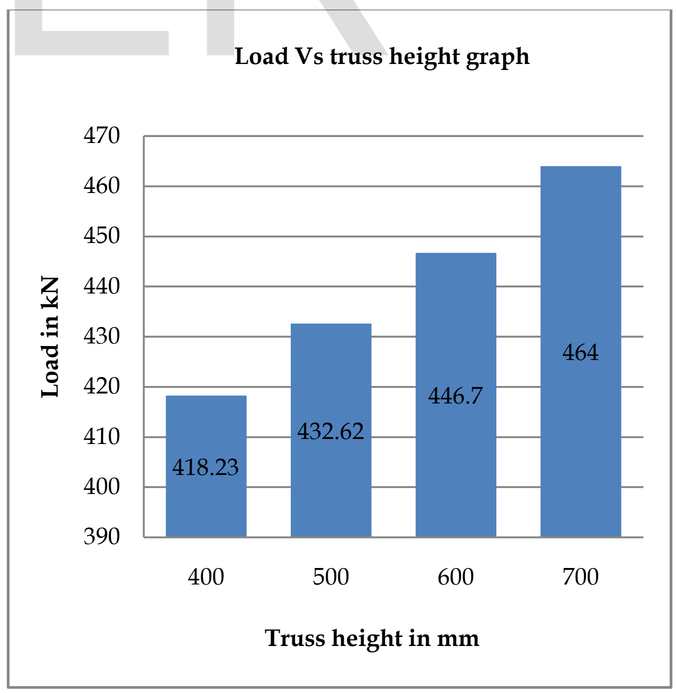


Fig 14: Load truss height curve

The load carrying capacity of CFST truss girder is influenced by the truss height. As the truss height increased the load carrying capacity also increased. Truss height is changed as

400mm, 500mm, 600mm, and 700mm. It is found that for each 100mm increment in height of truss there is about 3.5% increment in load carrying capacity.

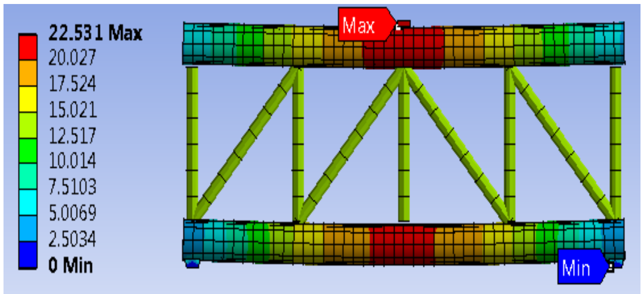


Fig 15. Total deformation diagram of CFST specimen for 700mm truss height

The load carrying capacity of CFST truss girder is influenced by the truss height. As the truss height increased the load carrying capacity also increased. Truss height is changed as 400mm, 500mm, 600mm, and 700mm. It is found that for each 100mm increment in height of truss there is about 3.5% increment in load carrying capacity.

3.1.6 Effect of span length

Table 7: Effect of span length

Chord thickness(mm)	Deflection (mm)	Load (kN)
384	18.625	495.96
480	19.47	432.62
576	24.407	341.84
672	25.293	253.48

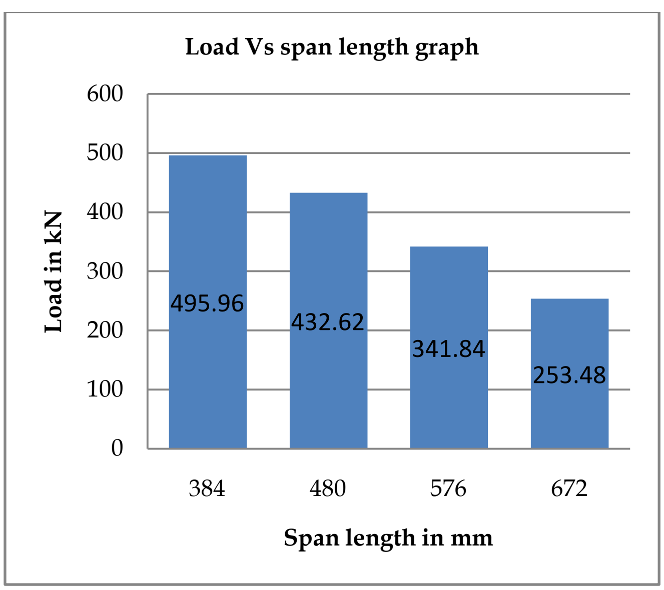


Fig 6: Load Vs deflection curve

The load carrying capacity of CFST truss girder is influenced by the span length. As the span length increased the load carrying capacity is decreased. Span length is changed as 384mm, 480mm, 576mm, and 672mm. It is found that for each 96mm increment in span length, the percentage decrease in load carrying capacity increased

4 CONCLUSIONS

From this work it is understood that the concrete filled steel tubular truss has good load carrying capacity and better ductility. On the parametric study is conducted by varying diameter of brace, chord, thickness of chord, and grade of concrete infill, truss height and span length.

- By filling the hollow steel tubular truss by M25 grade concrete the load carrying capacity is increased by about 70%. As the grade of concrete infill increased the load carrying capacity also increased. But the percentage of increase in strength is small. As the grade of concrete infill is increased as M30 and M40, the load carrying capacity also increased by 2.3% and 6.7% respectively.
- As the brace diameter increased the load carrying capacity also increased. Brace diameter is changed as 32mm, 40mm, 50mm, 65mm and 75mm. It is found that as the brace diameter increases there is slight increment in load carrying capacity.
- As the chord diameter increased the load carrying capacity also increased. Chord diameter is changed as 100mm, 150mm and 200mm. For each 50mm increment in chord diameter, there is about 6% increment in load carrying capacity.
- As the chord thickness increased the load carrying capacity also increased. Chord thickness is changed as 3mm, 4mm, 5mm, and 6mm. It is found that for each 1mm increment in thickness of chord wall there is about 9% increment in load carrying capacity
- As the truss height increased the load carrying capacity also increased. Truss height is changed as 400mm, 500mm, 600mm, and 700mm. It is found that for each 100mm increment in height of truss there is about 3.5% increment in load carrying capacity.
- As the span length increased the load carrying capacity is decreased. Span length is changed as 384mm, 480mm, 576mm, and 672mm. It is found that for each 96mm increment in span length, the percentage decrease in load carrying capacity increased

REFERENCES

1. Zhang et al (2000): "Concrete-filled steel tube truss girders", Beijing, China (Press in Chinese): China Communications Press; 2000.

2. Mr. Artiomas Kuranovas, Audronis Kazimieras Kvedaras(2007), "Behaviour of composite steel-concrete elements in various loading stages",journal of civil engineering and management,,pp.131-141

3. Chen B, Huang W (2007): "Experimental research on ultimate load carrying capacity of truss girders made with circular tubes" (press in Chinese). J Build Struct; 28: 31–8.

4. Zhong Tao et al 2013: "Flexural behavior of curved concrete filled steel tubular trusses", *Journal of constructional steel research, Elsevier Journal*, 2014, pp.119-134

5. Mr. Bhushan H. Patil, P. M. Mohite (2014) , "Square concrete filled steel tube columns subjected to concentric loading", *journal of engineering research and applications, vol 4*

6. Ms.Shilpa Jain, Prof. Anubhav Rai,and Prof. Yogesh Bajpai (2014) , "Comparision of concrete with marble dust and clay", *International journal of engineering technology and advanced engineering,vol 4*

7. Lin-Hai Han et al (2014): "Flexural behavior of concrete filled steel tubular (CFST) chord to hollow tubular brace truss: experiments", *Journal of constructional steel research, Elsevier Journal*, 2015, pp.137-151

8. M.Pragna and Partheepan Ganesan (2015) : "Analysis of Concrete Filled Steel Tubes using Ansys",, *International Journal of Latest Engineering Research and Applications* 2015, pp.71-79

9. Wenjin Huang et al 2017: "Concrete-filled steel tube (CFT) truss girders: Experimental tests, analysis, and design", *Engineering structures, Elsevier Journal*, 2018, pp. 118-129.