

# Analytical Optimisation and Curvature Behaviour of CFST and Tubular Brace Truss for Bridge Structures

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**ABSTRACT:** As CFST trusses are the most recently emerged efficient system, many researchers are going all over the world to unveil every aspect related to it in terms of its properties, analysis etc. As a small contribution to this widely flourishing research area, this study considering the effect of various parameters such as angle in between the braces, Shape and size of chords, their positioning etc. Also change in the curvature of brace and chord element can cause variations in the response of structure under Static loading. Here, a small effort is made to consider these parameters and find out their effect on the flexural behaviour of CFST trusses.

**KEYWORDS:** Concrete filled steel tubes, hollow steel tubes, Curved concrete filled steel tubes, Single skinned concrete filled steel tubes, Double skinned concrete filled steel tubes, Radius of curvature.

## I. INTRODUCTION

The concrete-filled steel tubular (CFST) structures offer numerous structural benefits, such as high strength and fire resistances, favorable ductility and large energy absorption capacities. It also provides good confinement effect to the concrete and the need for shuttering during concrete construction can be avoid; hence, the construction cost and time are reduced. Concrete filled steel tubular truss is a kind of composite structure in which the top and bottom chords of the truss are filled with concrete and connected by hollow tubular braces.

The composite action of the truss enables it to take full advantage of the excellent axial behaviour of the CFST chords. The flexural and compression behaviour of the truss are improved greatly compared with the corresponding hollow tubular truss. In the construction the hollow tubular truss is usually fabricated and installed first and it serves as the formwork for pumping the concrete to form a CFST truss. The CFST trusses have now been widely used in large-scale structures due to the excellent mechanical and constructional advantages of the structure, especially in bridges. Due to the excellent performance in strength, stiffness and ductility, the CFST members have achieved extensive structural application. A large amount of experimental and analytical work has been carried out on the CFST members including columns, beams and in beam-column joints. Generally, the compressive strength of CFST can be greatly enhanced due to the existence of the confinement effect. As for the tensile behaviour the previous studies indicates that the contribution of concrete to the strength of the tensile chord may be limited, but it may significantly enhance the joints between the chords and braces.

Researchers, all over the world, gives more importance to the issue of steel tubular truss; however, some studies have been mainly focus on concrete-filled steel tube columns and steel truss connections, while the flexural behaviour of steel tubular truss has not been investigated in detail. Therefore, it is of great significance and prospects to study the flexural behaviour of concrete filled steel tubular truss under static loading. Also the behaviour of the CFST columns under different loading conditions is not studied fully. Thus, an intensive parametric study can be perform in order to fully understand the behaviour of CFST trusses.

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## II. RELATED WORK

**Wenbo Zhou et.al** [1] carried out an Experimental research on circular concrete filled stainless steel tubular truss. A total of four specimens were tested, including three circular concrete filled stainless steel tubular truss and one hollow circular stainless steel tubular truss. All specimens were tested under static load. The main parameter explored in the test included the location of concrete-filled. (Case 1: Concrete-filled top chord. Case 2: Concrete-filled bottom chord. Case 3: Concrete-filled top and bottom chord. Case 4: Hollow circular stainless steel tubular truss.) This paper presents the failure modes, overall deflections, load-strain curves, load versus displacement curves and load carrying capacity of all the tested specimens. It was found that the typical failure mode includes: the surface plasticity of the top chord, the weld fracture and crack around tubular joints at the bottom chord, and the bent of the top and bottom chords. The flexural rigidity, load carrying capacity and ductility of different types of circular concrete filled stainless steel tubular trusses are different due to the remarkable changes of the location of concrete-filled. It is demonstrated from the comparison that the truss of concrete filled in both top and bottom chord (CC100×2.0-BC76×2.0-C30A) has the best flexural rigidity and the greatest load carrying capacity per unit truss weight. Whereas, the truss of concrete filled in top chord (CC100×2.0-BC76×2.0-C30T) has the best ductility.

**Yong Hui Huang et.al** [2] conducted an experimental investigation of the flexural behavior of CFST trusses with interfacial imperfection. four experimental truss models with different interfacial imperfections are tested under four-point bending. Finite element models are also developed to conduct the corresponding mechanism and parametric analyses. The test results show that interfacial imperfections between the steel tube and concrete core have significant effects on the ultimate loading capacity of CFST trusses. The ultimate loading capacity of tested models with 100% interfacial separation, 10% depth separation and 20% depth separation are 9.2%, 18.0% and 37.7% lower than that of the model with fully bonded steel tube and concrete core. The finite element model is validated by the test results and is used to conduct further parametric studies for effects of interfacial imperfections such as friction coefficient, interfacial separation ratio and depth separation ratio on the ultimate load carrying capacity of CFST trusses. The finite element results show that the effect of depth separation on the ultimate load of CFST truss is more significant than other interfacial imperfections, and that the ultimate load of models with a depth separation ratio  $k_h=10\%$  and  $k_h=20\%$  are 13% and 33% lower than that of the model with no depth separation.

**Fei Gao et.al** [3] studied the Post-fire residual strength of steel tubular T-joint with concrete-filled chord. The post-fire behavior of steel tubular T-joints with a concrete-filled chord (CFC) was experimentally and numerically investigated. One specimen was tested at ambient temperature while the other two were tested after a heating and cooling process. The experimental results revealed that the failure mode was chord plastification, rather than local buckling of the chord wall, due to the support provided by the in-filled concrete. A finite element (FE) method was then developed to simulate the structural response of the post-fire joints under compressive load. The comparison between the FE simulation and experimental data illustrated that the FE method reliably and accurately predicted the failure modes, the measured load-displacement curves and the residual strength of the T-joints. The verified FE method was then used in a detailed parametric analysis, which systematically varied the geometric and material parameters including  $\alpha$ ,  $\beta$ ,  $\tau$ ,  $\gamma$ ,  $f_c$ ,  $f_y$  and the highest temperature of fire exposure- $T_{max}$ . The results indicated that filling concrete into the chord increased the fire resistance and bearing capacity of the joints, but had an appreciably negative impact on the post-fire behavior, as the damage to concrete in fire was irreparable. Moreover, the residual strength increased significantly with increasing  $f_y$ , but decreased with increasing  $\alpha$  and  $\gamma$ .  $\beta$  and  $f_c$  showed slight influence, while changing  $\tau$  had negligible effect. The effect of each parameter could be quantitatively simulated by a function. A parametric equation based on the effect was proposed, and its accuracy was verified through error analysis against the numerical and experimental results.

**Wu Xu et.al** [4] studied the flexural behaviour of curved concrete filled steel tubular trusses. A series of tests were conducted on curved concrete filled steel tubular (CCFST) trusses with curved CFST chords and hollow braces subjected to bending. A total of 8 specimens, including 4 CCFST trusses, 2 straight CFST trusses and 2 curved hollow tubular trusses were tested to study the effect of the rise-to span ratio and infill concrete on the flexural performance of CCFST trusses. Different failure modes were observed: bending failure for CFST trusses, bending-shear failure for CCFST trusses and local buckling failure for hollow tubular trusses. The experimental result showed that the stiffness

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and load-carrying capacity of CCFST trusses were larger than those of CFST trusses, but the CCFST trusses experienced a joint failure with relatively low ductility. Meanwhile, the infill concrete provided support to the steel tubular chords and increased the stiffness, load-carrying capacity and ductility. A finite element analysis (FEA) model of the CCFST trusses was developed and verified by the test results. The model was then used to investigate the mechanical behavior of the truss by full range analysis. A simplified model was proposed to predict the elastic stiffness considering both the flexural and the shear deformation. The load-carrying capacity of the CCFST structure was also discussed.

**Lin-Hai Han et.al** [5] presents a model to investigate the flexural behavior of concrete filled steel tubular (CFST) chord to hollow tubular brace truss under flexural loading. Concrete filled steel tubular (CFST) chord to hollow tubular brace truss (referred to as CFST truss for short) is a type of truss which uses CFST members as its chords and hollow tubes as its braces. The model uses a concrete slab that can be provided on the CFST truss to form a hybrid CFST truss. The new type of trusses can be used in bridge structures and other large span structures. This paper reports a series of bending tests on CFST trusses and hybrid CFST trusses. Hollow tubular trusses were also tested for comparison. The main parameters investigated were the shear span ratio, the angle between the brace and chord, profile of the bottom chord, the existence of the infill concrete and the concrete slab. The influences of these parameters on the flexural behaviour and failure modes of the trusses were investigated and compared. The results showed that both the infill concrete and concrete slab improved the flexural performance of the truss notably. The strain development of the truss and the strain distribution along the mid-span section were also presented and discussed. Based on existing design codes, simplified models for the flexural stiffness and flexural strength of the trusses were suggested and verified, respectively.

### III. SCOPE

The scope of this study is to make valuable changes in the flexural strength of the CFST trusses by various methods. It helps to determine the most efficient section for CFST trusses and to Study the curvature effect and the effect of angle between the diagonal braces on load carrying capacity. Also it will help in the practical applications of using CFST trusses in various structural works. The present study can be extended to include cases of other types of loading such as seismic and blasting loads. Also More complicated type of CFST truss specimens with various configuration can be tried.

### IV. MODEL

In this paper, 16 models were modelled and analysed in ANSYS software to determine the flexural load carrying capacity and failure modes. The dimensions of the truss sections used is taken similar to the dimension of section used in ganhaizi bridge which is reduced to the scale 1:6. For all the specimens, the grade of concrete used is  $M_{50}$  and steel is 250MPa. The boundary conditions are one end fixed and other end hinged. From IS 1161 – 2014 which deals with steel tubes for structural purposes, the various types of available steel tube sections are taken for modeling.

In first stage Modelling of CFST truss is done by using both single skinned concrete filled steel tubular (SSCFST) chord and double skinned concrete filled steel tubular (DSCFST) bottom chords and compared their results based on their load bearing capacity. The meshed model of SSCFST and DSCFST were shown in Fig. 1.

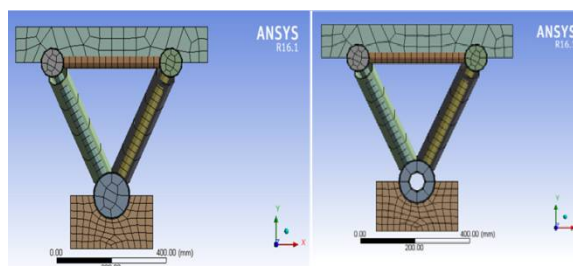


Fig. 1. Meshed model of SSCFST and DSCFST

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The results were showed that DSCFST shows greater load carrying capacity than SSCFST with a reduced dead load and economy.

The next step is finding the optimum angle between the diagonal braces in cross section which give greater load carrying capacity, Some angles such as  $45^\circ$ ,  $60^\circ$ ,  $75^\circ$  and  $90^\circ$  are used in modeling and analysis. Fig. 2 shows the angle between diagonal braces in cross section ( $\theta$ ).

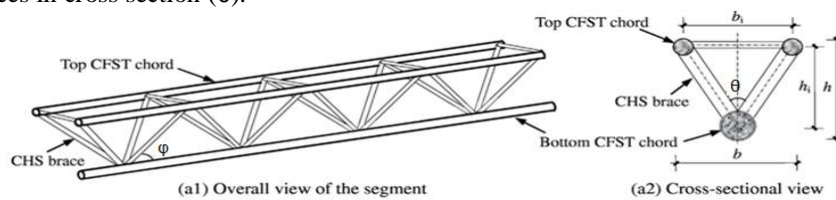


Fig. 2 Angle between diagonal braces in cross section ( $\theta$ )

From the analysis the truss section with an angle of  $60^\circ$  is found to be more suitable and further studies were carried out by fixing this angle.

After that the effect of plan and elevation wise curvature on the flexural strength of truss section is studied. 4 models with different radius of curvature such as 0, 10m, 15m, 20m in plan and elevation were taken for analysis. Fig.3 shows the radius of curvature.

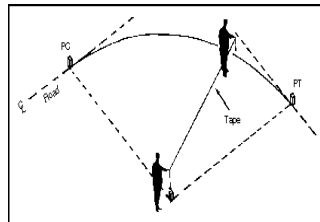


Fig. 3 Radius of curvature

Fig. 4 shows a model with plan wise curvature.

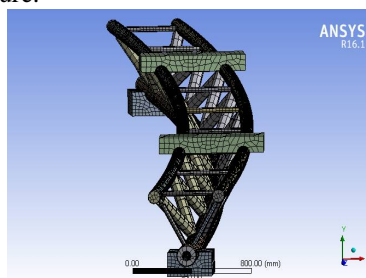


Fig. 4 plan wise curvature

Similarly the Fig. 5 shows a model with elevation wise curvature.

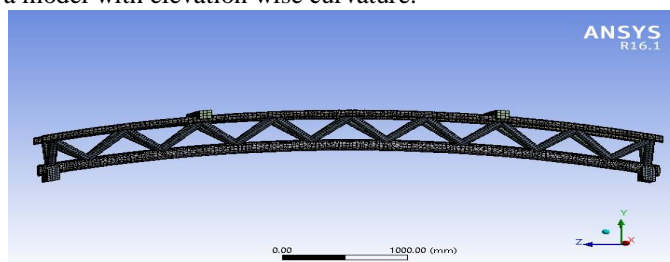


Fig. 5 Elevation wise curvature

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### V. ANALYTICAL RESULTS

Non-linear analysis were carried out for all specimens. Their corresponding figures and graphs are given below. The comparison of the ultimate load carrying capacity of various arrangements is discussed below. The summary of results obtained from the analysis is shown in Table 1.

S.NO	STUDY	NO.OF MODELS	MODEL	ULTIMATE LOAD CARRYING CAPACITY (kN)
1	Based on type of c/s of bottom chord	2	SSCFST	432.5
			DSCFST	452.7
2	With and without concrete fill in the top chord	2	DSCFST with hollow top chord	353.6
			DSCFST with concrete filled top chord	452.7
3	By varying angle between diagonal braces	4	45 <sup>0</sup>	437.7
			60 <sup>0</sup>	452.7
			75 <sup>0</sup>	457.2
			90 <sup>0</sup>	381.4
4	By varying radius of curvature in plan	4	0m	452.7
			10m	379.620
			15m	384.452
			20m	402.740
5	By varying radius of curvature in elevation	4	0m	452.7
			10m	623.70
			15m	587.82
			20m	574.82

Fig 6 shows the load deflection curve for varying angles between diagonal braces in cross section. Here the truss with included angle of 75<sup>0</sup> Shows greater load carrying capacity. But when we consider the overall performance, truss with 60<sup>0</sup> in cross section is chosen as the best.

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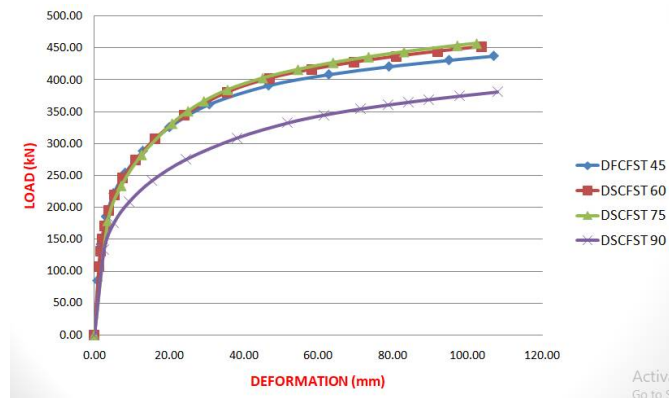


Fig 6. truss with varying angle between diagonal braces in c/s

### VI. CONCLUSIONS

CFST truss with double skinned bottom chord shows comparatively greater load carrying capacity than single skinned section. CFST truss with all chords filled with concrete shows greater load carrying capacity when compared with truss of hollow top chord.

The double skinned concrete filled steel tubular column with an angle ( $\theta$ ) of  $60^\circ$  is found to be most favorable section in terms of both load carrying capacity and economy.

The ultimate load carrying capacity of CFST truss highly depends on the radius of curvature.

Peak load decreased to 12.5% when the radius of curvature in plan increased from 0 to 10m. Peak load increased to 37.7% when the radius of curvature in elevation increased from 0 to 10m.

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