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Parametric Study of CFST Chord in Tubular Brace Truss to Full Scale Model Using FEA

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Abstract— *Concrete filled steel tubular truss (CFST truss) structures is a composite structures composed of CFST members as chords and steel tube members as braces are having expanded utilization in large-scale infrastructure constructions such as bridges, electricity towers, buildings etc. This CFST sections are formed by filling concrete into a hollow steel tube section and offers resistance to applied load through the composite action of steel and concrete. A concrete slab is usually provided on top of the CFST truss to form a hybrid CFST truss bridge structures. This paper thus presents a finite element analysis (FEA) modelling on CFST truss without concrete slab as well as hybrid CFST truss with concrete slab subjected to flexural loading, and then modelling a full scale Concrete filled double skin steel tubular (CFDST) truss bridge and analyse the structural response of the bridge. Before this the important parameters which influences the strength of the composite truss are also investigated, including effect of core concrete, behaviour of angle, type of chords, effect of shear span ,effect of plan curvature and effect of elevation curvature. A CFDST truss with 60^0 brace angle is best suited for the analysis of full scale model. A comparison on seismic performance of CFST and CFDST truss bridge are also investigated.*

Keywords— *ANSYS software, CFST, CFDST, deformation, equivalent stress, shear span ratio.*

I. INTRODUCTION

Concrete filled steel tubular (CFST) chord to hollow tubular brace truss is a kind of composite structure formed by filling the hollow tubular truss chords with concrete. It is one of the best composite sections which have many advantages over conventional steel and RC sections and hence these CFST sections are becoming more popular in recent year due to their shape from structural, architectural and economical point of view. As well as they take the advantages both steel and concrete.

The hollow truss is usually fabricated and installed first. Then it serves as the formwork and then the concrete is pumped into the chords to form a CFST truss. Due to the excellent mechanical and constructional advantages of the structure, the CFST trusses have now been widely used in large-scale structures, especially in bridges used as girders in bending, piers in compression and arch ribs in combined bending and compression. The steel tube in CFST section lies at the outer perimeter, which effectively resist tension and bending moments and also increases stiffness of CFST section as steel has a high modulus of elasticity. The inner concrete core of CFST section also plays an important role in delaying the inward buckling of steel tube and improves the behaviour of CFST section.

Among these the development of concrete filled double skin steel tubular (CFDST) structures has drawn the attention of researchers and designers in recent years. CFDST member consists of inner and outer steel tubes with sandwiched concrete in between. Due to its particular geometrical characteristics, CFDST could effectively reduce the structure self-weight, which maintaining a series of advantages of CFST, such as high strength, ductility, high rigidity and large energy absorption capacity, which are very important for a structure located in earthquake prone areas. Similar to traditional CFST members, CFDST also has feasibility to be used as chords in composite trusses to strengthen the strength, stiffness, and fatigue life of the connections whilst gain extra benefit from the light self-weight.

The objectives of the study are to analyse the CFST truss and hybrid CFST truss subjected to flexural loading. To find the best model by conducting parametric analysis using the FEA modelling to evaluate the effects of core concrete ,types of chords, brace angle, shear span ratio as well as material properties. To perform finite element analysis on CFST bridge model and to find the seismic behavior.

II. MODELLING AND ANALYSIS

The model in this paper were chosen to represent the trusses of the Ganhaizi Bridge in China It had a scale of 1:6. The gross length of the truss (5000 mm), the dimension of the truss section (432 × 375 mm),

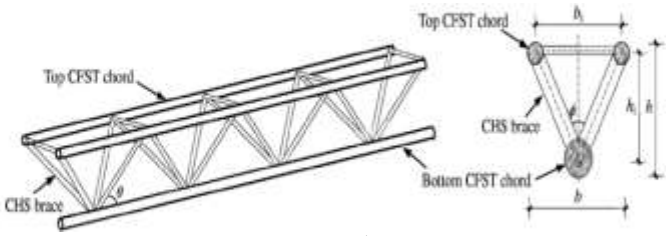

Fig. 1. Schematic view of FEA modelling.

The core concrete in the chords was high strength self-consolidating concrete with
$(f_{cu}) = 69.9$ N/mm^2
Elastic Moduli $(E_c) = 36400$ N/mm^2

TABLE I. Material properties.

Profile	D (mm)	t (mm)	f_y (MPa)	E_s (N/mm2)	μ_s
Bottom chord	139.7	4.5	316	2.14×10^5	0.283
Top chord	88.9	3.2	324	1.92×10^5	0.289
Diagonal braces	76.1	3.2	360	2.15×10^5	0.294
Vertical braces	33.7	2.6	325	2.02×10^5	0.302

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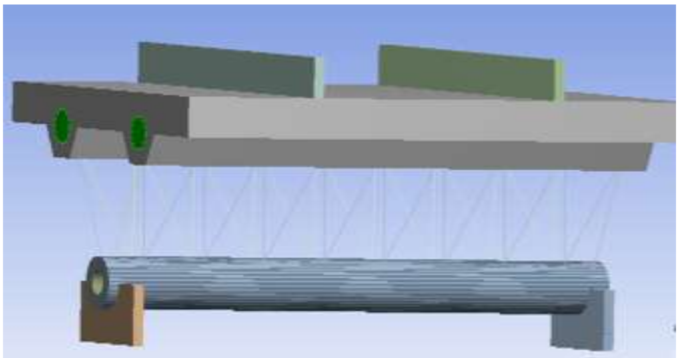

Fig. 2. Perspective view of hybrid CFDST truss.

A. *Time History Analysis*

Time history analysis is used for the analysis of CFDST truss bridge. To investigate the modal characteristics of the structure, a modal analysis is done first. A modal analysis calculate the frequency modes or natural frequencies of a given system. The natural frequency of a system is dependent only on the stiffness of the structure and the mass which participates with the structure. A full time history will give the response of a structure over time during and after the application of load. This is a numerical step by step integration of equations of motion. It is usually required for critical or geometrically complex bridges. Acceleration time history of the 1940 EI Centro earthquake commonly referred to as the Imperical Valley earthquake, which had a Ritcher magnitude of 6.9 is considered for the study.

III. RESULTS AND DISCUSSIONS

The trusses with different parameters were modelled and analysed by using ANSYS Workbench 16.1. The material properties were assigned, simply support and four point loadings were provided. After meshing of the structure analysis is done.

A. *Type of Chord*

TABLE II. Force reaction of different models.

Model		Deformation (mm)	Force Reaction (kN)
Hollow Tube		111.8	233
Bottom Hollow Top Filled		100.54	282
CFST	**45^0**	105.59	423
	60^0	103.89	434
CFDST	**45^0**	107	437
	60^0	103.7	452

From the table it is clear that CFST truss system has the highest load carrying capacity when compared with both CHS and CFST top chord combined with CHS bottom chord. The chords filled with concrete, the load carrying capacity of the truss are greatly enhanced due to the contribution of compressive strength by concrete. Then comparing the brace angle, the chord with 60^0 has the highest strength. From the comparison of CFST and CFDST .It is found that concrete filled double-skin steel tubular (CFDST), truss with angle 60^0 has the highest load carrying capacity than the CFST truss. So for further parametric studies, CFDST truss with 60^0 is taken.

B. *Shear Span*

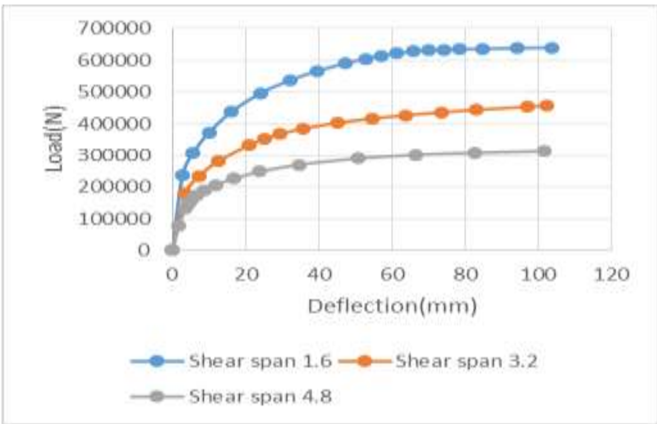

Fig. 3. Load verses deflection curve.

Concrete filled double-skin steel tubular (CFDST) truss with different shear span as shown above. It is found that the truss with shear span 1.6 has the highest load carrying capacity. It is helpful to find out the behaviour of concrete filled double-skin steel tubular (CFDST) truss under uneven distribution loads acting on the truss.

C. *Effect of Curvature*

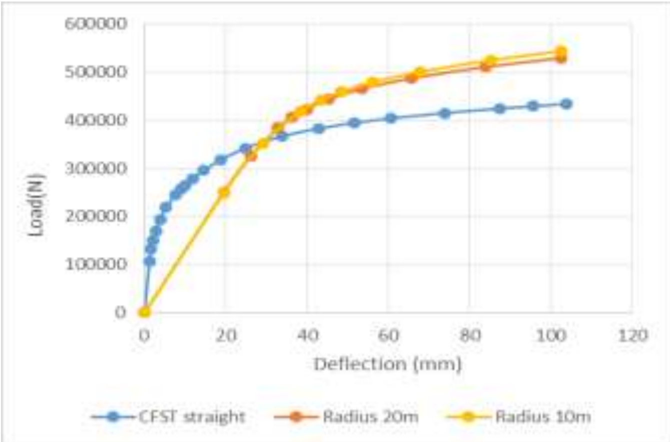

Fig. 4. Straight and curved truss comparision.

It is found that curved concrete filled double-skin steel tubular (CFDST) truss has the highest load carrying capacity than the straight truss. There is an increase of load carrying capacity about 24.4% for the curved truss than straight truss.

D. *Hybrid CFDST Truss*

A Concrete slab is to be provided on the CFDST truss to form a hybrid CFDST truss as shown in Fig 2. The new type of trusses can be used in bridge structures and other large span structures. All the hybrid CFST trusses performed in a ductile manner due to the support of the concrete slab attached to the top chord and joints. Due to the presence of concrete slab both stiffness and load varying capacity are improved.

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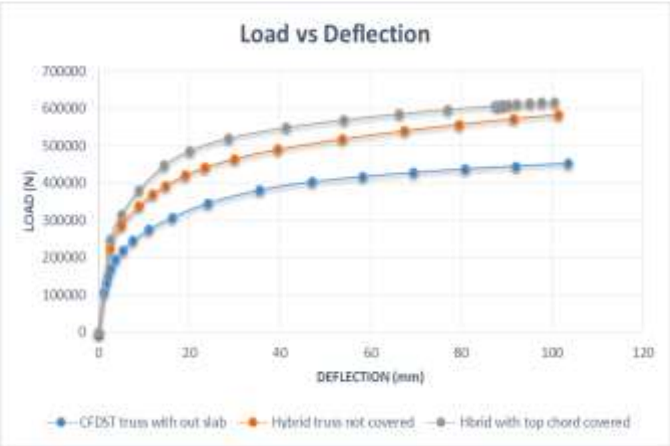

Fig. 5. Effect of concrete slab.

It can be found that the CFDST truss with concrete slab (Hybrid) top chord embedded in concrete, both stiffness and load carrying capacity are improved due to the existence of the concrete slab. Compared with the CFDST truss the maximum load of the hybrid truss is increased by 36.64%.

IV. Full Scale Model

From the previous results the hybrid concrete filled double skin steel tubular trusses with 60^0 brace angle are selected for the full scale bridge model, which has the higher value of stiffness and load carrying capacity than other models. Typical parameters from a real bridge construction are adopted, detailed profile of the hybrid CFDST truss bridge segment is listed in below table.

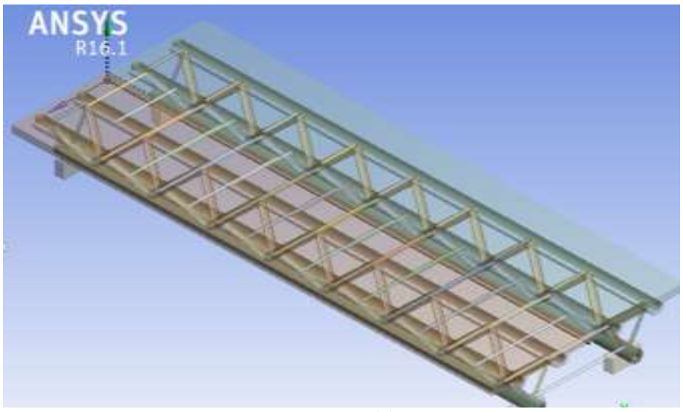

Fig. 5. Perspective view of full scale bridge.

TABLE III. Full scale model diamensions.

Length (mm)	**Height (mm)**	**Bottom Chord (dia)**	**Top Chord (dia)**	**Brace (dia)**	**Width**
30,000	2250	840	534	456	12000

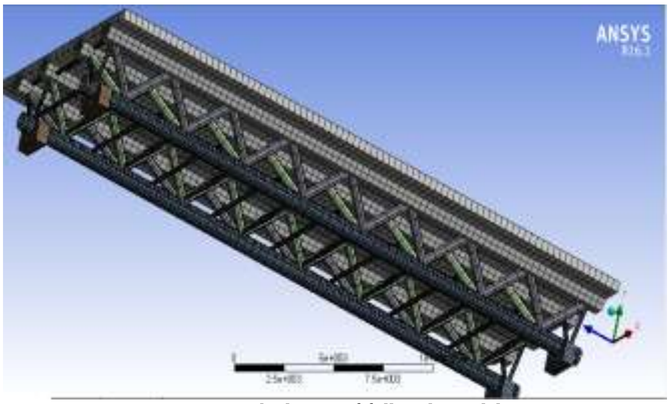

Fig. 6. Meshed view of full scale model.

The load is taken as per IRC 6 class A loading and applied on the girder to find out the displacements

Total dead load = 3.328×10^6 N

Live load = 18.46 kN/m

Impact load = 2.30 kN/m

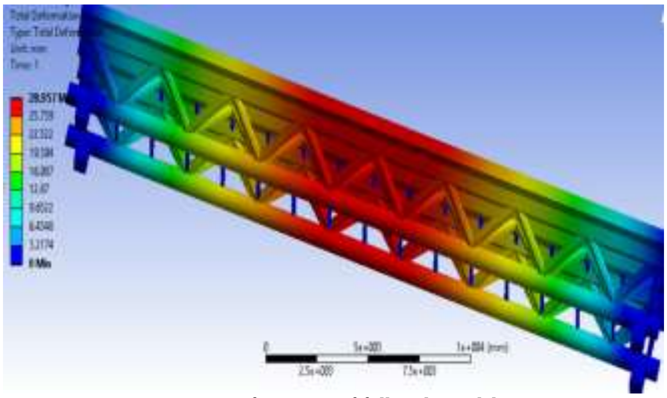

Fig. 7. Deformation of full scale model.

The total deformation of the truss bridge is 28.95mm.Which is within the limit.

V. Seismic Performance

Time history analysis is used for the analysis of CFDST truss bridge. To investigate the modal characteristics of the structure, a modal analysis is done first.

A. Time-History Analysis

A full time history will give the response of a structure over time during and after the application of load. This is a numerical step by step integration of equations of motion. It is usually required for critical/important or geometrically complex bridges. Inelastic analysis provides a more realistic measure of structural behavior when compared with an elastic analysis. When the structures enters the nonlinear range, or has non classical damping properties, modal analysis cannot be used. A numerical integration method, sometimes referred to as time history analysis, is required to get more accurate responses of the structure.

Acceleration time history of the 1940 EI Centro earthquake commonly referred to as the Imperical Valley earthquake, which had a Ritcher magnitude of 6.9 is considered for the study.

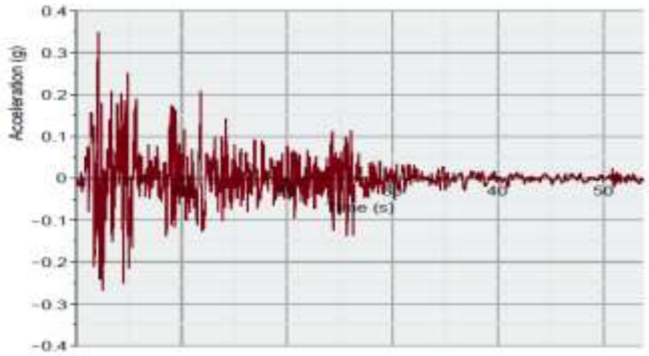

Fig. 8. El-Centro earthquake time history.

B. Results and Discussions

The fifty modes are incorporated in the analysis. These modes are not excited in the same manner. The extent to which dynamic loading excites a specific vibration modes depends on the spatial distribution and the frequency content of the load. It is necessary to include at least six modes in the analysis in order to obtain the most fundamental movements. It might be sufficient to consider only these modes in a preliminary analysis. From the file obtained that the CFDST truss bridge has less mode frequencies compared to CFST truss. For these two bridge systems, the frequency is increasing proportional to the mode number.

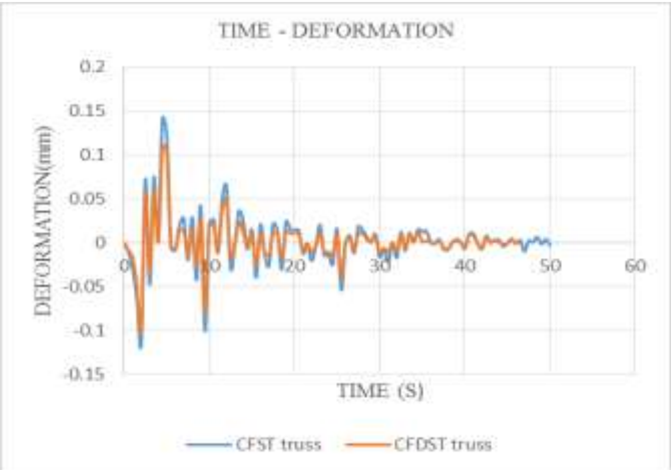

Fig. 9. Time – displacement curve.

From this analysis it is clear that there is not much difference in value of deformation in between CFST and CFDST truss bridge. When compared both of them, the CFDST truss bridge has a slight lesser difference in deformation when compared to CFST truss bridge. So we can say the CFDST truss has slight better seismic performance.

VI. CONCLUSION

- CFST truss system has the highest load carrying capacity when compared with both CHS and CFST top chord combined with CHS bottom chord
- In the case of angle, both single skin (CFST) and double skin (CFDST) trusses with 60^0 brace angle has the highest load carrying capacity than the other.
- It is found that concrete filled double-skin steel tubular (CFDST) truss has the highest load carrying capacity than the single skin CFST truss.
- From the study of shear span the truss with shear span 1.6 has the highest load carrying capacity.
- The curved concrete filled double-skin steel tubular (CFDST) truss has the highest load carrying capacity than the straight truss.
- It can be found that the CFDST truss with concrete slab (Hybrid) top chord embedded in concrete, both stiffness and load carrying capacity are improved due to the existence of the concrete slab.
- When compare the seismic performance, the CFDST truss bridge has a slight lesser difference in deformation when compared to CFST truss bridge. So the CFDST truss has better seismic performance.

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