Seismic analysis of diagrid structures with concrete filled steel tubes under various parametric study

Sreelakshmi V S[1], Daniel Paul Thanaraj[2]

[1]*PG student, Dept. of Civil Engineering, KMEA Engineering College, Kerala, India*
[2]*Assistant Professor, Dept. of Civil Engineering, KMEA Engineering College, Kerala, India*

Abstract – *Diagrid structures have emerged as an innovative construction technique lately and has led to the advancement of tall and high-rise structures both in the engineering and architectural field. They have made structures stiffer and lighter when compared to conventional structures. Due to the inclined columns, a diagrid structural system for tall buildings produces axial force along the column direction under horizontal load which has the advantage of resisting horizontal wind and seismic load and gives more freedom to architectural design. The main aim of this paper is to study the optimum structural performance of CFST joints under various parameters by differing their diagrid angles and varying concrete property by infilling lightweight concrete (ULCC). This is to be done using the software ANSYS Workbench.*

***Key Words*: Diagrid Structures, CFST, ULCC Lightweight concrete, Diagrid angle, ANSYS Workbench.**

1. INTRODUCTION

The diagrid structural system has inclined columns and ring beams unlike vertical columns and horizontal beams of orthogonal or conventional structures. On applying horizontal load, the inclined columns of a diagrid structure mainly bear horizontal lateral force and produces axial force along the column direction thus eliminating second order bending moments and ensuring full use of the bearing capacity of the component. The beams and columns of conventional structures bear horizontal lateral force and produce significant bending moment and axial force, which can produce second order bending moments. The triangle formed by the intersection of ring beams and inclined columns are more stable than the quadrilateral formed by horizontal beams and vertical columns. A diagrid structure has more freedom of shape design, better internal space utilization and more material savings. So far there are no design specifications issued for diagrid structures. There are only design specifications for tall and super tall buildings which are nearly identical world-wide. In accordance with these specifications the conceptual design of tall buildings, should be paid special attention, which includes selecting uniform plane forms and structural forms, strengthening the construction measures, and selecting economic and reasonable structure systems for good resistance to earthquake and wind. Seismic design shall ensure the overall seismic performance of structure and the necessary carrying capacity, stiffness, and ductility.

2. OBJECTIVES

- To develop a full-scale model of a diagrid column using ANSYS Workbench.
- To study the seismic performance of CFST columns under 2 different parameters.
    1. Varying the diagrid angles.
    2. Varying concrete property by infilling lightweight concrete.

3. METHODOLOGY

In this paper the main aim was to study the seismic behavior of CFST as diagrid columns. The software used for modeling and analysis was ANSYS workbench. The seismic behavior was studied under two parameters. One by varying the diagrid angles and the other by varying the composition by infilling ULCC (ultra-lightweight cement composite).

4. MODELLING

This section deals with the various models used in the study. For fulfilling the first part of the objective, diagrid column specimens of varying diagrid angles were analyzed. For fulfilling the next objective, the specimens infilled with light weight concrete and varying diagrid angles were analyzed. The diagrid angles adopted in the analysis process are 20^0, 25^0, 30^0 and 35^0. The specimens used have same thickness of 5.5 mm as CFST-DIC-4 but have varying diagrid angles. They are subjected to cyclic loading with an alternate push and pull on each limb which imitates the excitations of seismic waves. ANSYS Workbench is the software used for modelling the joints. The journal "Developments and mechanical behaviors of steel fiber reinforced ultra-lightweight cement composite with different densities" was referred for the study of behavior of light weight concrete infilled CFST columns. The ultra-lightweight concrete of grade U1250 was selected. It has a density of 1257.6 kg/m^3 and compressive strength of 48.03 MPa. The CFST and CFST-LC (lightweight concrete infilled) columns of varying diagrid angles (20^0,25^0,30^0 and 35^0) were subjected to cyclic loading using ANSYS software and their seismic resistance was studied. Fig 1, 2, 3, 4, 5 shows the geometry, FEM model, boundary conditions, deformation, and stress distribution diagrams respectively of CFST 20 (20^0) obtained from ANSYS.

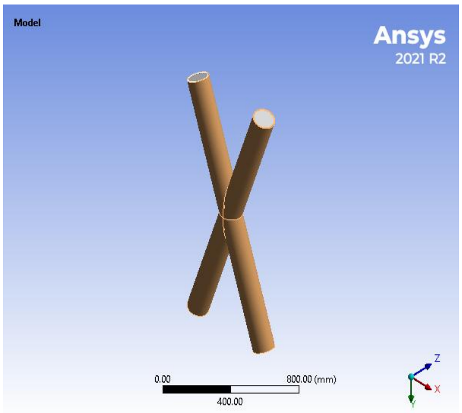

Fig-1 Geometry of CFST 20

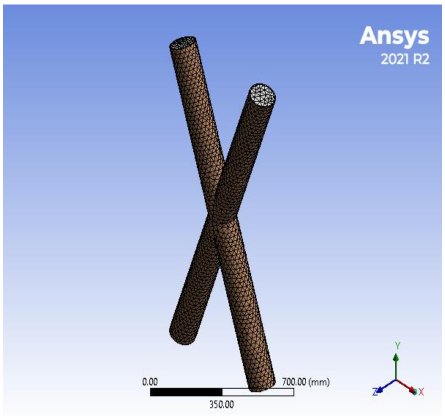

Fig-2 FEM model of CFST 20

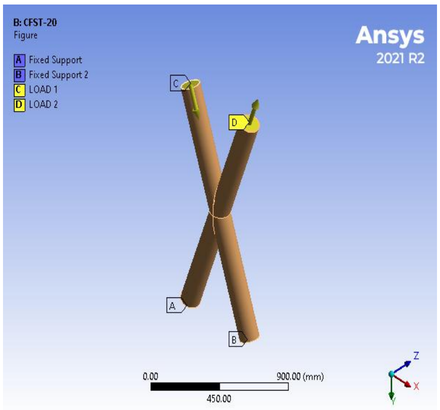

Fig-3 Loading diagram of CFST 20

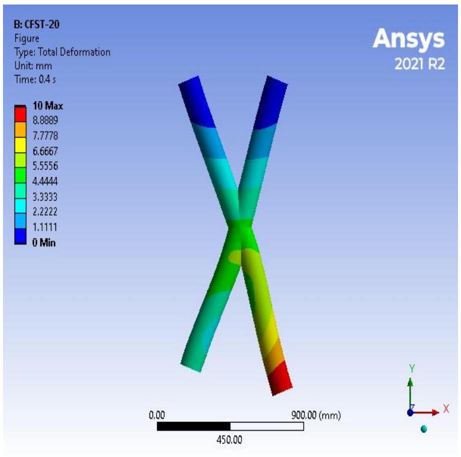

Fig-3 Total deformation of CFST 20

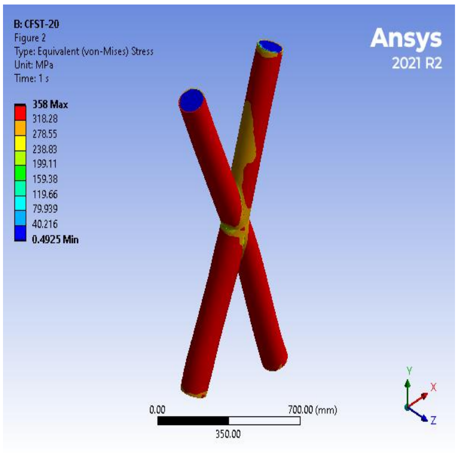

Fig-4 Total deformation of CFST 20

Similarly, all other CFST and CFST-LC column specimens were modelled and analyzed using ANSYS and the results were obtained.

5. RESULTS AND DISCUSSION

The load-deflection values from ANSYS were transferred to excel worksheet to obtain the load-deflection curves. The performance of above models under compressive and tensile loads were also obtained.

PERFORMNCE IN TENSION				
weight	MODEL	U-DEF(mm)	PU-LOAD (KN)	EFFECTIVE STIFFNESSKN/mm
140.1 kg	CFST-20	12.50	970.40	77.6
	CFST-25	12.50	957.79	76.6
	CFST-30	15.00	957.91	63.9
	CFST-35	15.00	952.58	63.5
99.238 kg	CFST-20-LC	9.05	901.78	99.7
	CFST-25-LC	16	919.03	57.4
	CFST-30-LC	14	913.98	65.3
	CFST-35-LC	12	908.2	75.7
PERFORMNCE IN COMPRESSION				
weight	MODEL	U-DEF(mm)	PU-LOAD (KN)	EFFECTIVE STIFFNESS KN/mm
140.1 kg	CFST-20	5.68	946.75	166.6
	CFST-25	6.06	887.26	146.4
	CFST-30	6.26	626.99	100.2
	CFST-35	4.98	437.83	88.0
99.238 kg	CFST-20-LC	9.05	880.09	97.3
	CFST-25-LC	10	774.3	77.4
	CFST-30-LC	6.467	749.8	115.9
	CFST-35-LC	10	419.45	41.9

Fig-5 Performance of all models

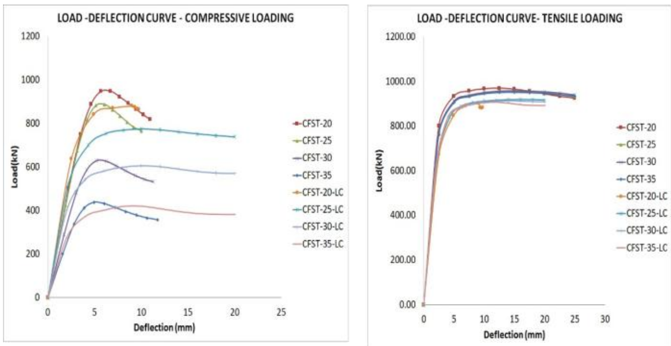

Chart -1: Load-deflection curves

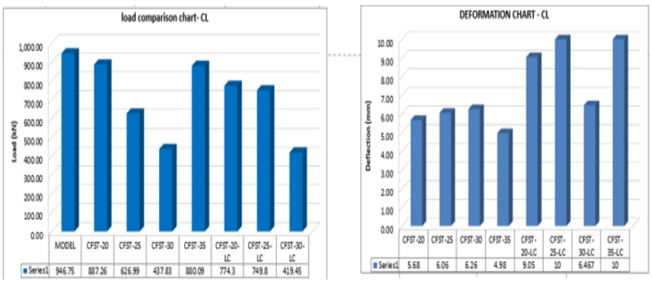

Chart -2: Load comparison and deformation under compressive loading

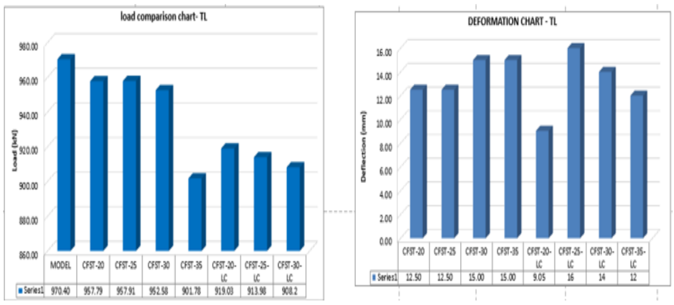

Chart -3: Load comparison and deformation under tensile loading

The observations can be summarized as below:

- The weight of the normal CFST column is 140.1 kg and that of ULCC infilled CFST column is 99.238 kg. The weight is reduced by almost 40 kg hence the weight of the entire structure will also be reduced to a great extent.
- The load carrying capacity of the columns follow a decreasing trend with increase in diagrid angles under compressive loads. Under tensile loads there are no significant changes with increase in angles.
- Under tensile loads the load carrying capacity of normal CFST columns and CFST-LC columns do not show much difference. This is basically because the tensile loads are taken up by the steel portion of the columns.
- The stiffness of the column joints is found to be reduced with increase in diagrid angles under both tensile and compressive loads and the maximum value is for CFST-20 (77.6 in tension and 166.6 in compression).
- For CFST-LC joints the load carrying capacity and stiffness values are found to be low, and they undergo large deflection. This proves improved ductility and results in better seismic resistance.

6. CONCLUSIONS

In this paper, the seismic performance of CFST columns in diagrid structures was studied. The study was based on two parameters, diagrid angle and concrete type. Apart from normal CFST columns CFST-LC columns were also used. This one had ULCC (ultra-lightweight cement composite) of grade U1250. The seismic behavior of CFST and CFST-LC columns of varying diagrid angles 20^0, 25^0, 30^0, 35^0 were studied and the results compared. It was concluded that the CFST-LC columns showed improved ductility which is an essential factor for determining seismic resistance. Improved ductility implies better seismic resistance.

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