STRUCTURAL PERFORMANCE OF INNOVATIVE FABRICATED COUPLED COMPOSITE COLUMN IN MULTI STOREYD BUILDING.

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Abstract - *Tall buildings are now widely constructed in all over the world. The construction materials strength is the key factor to build the high rise structures. Concrete has compressive strength, stiffness and stability whereas steel has tensile strength, ductile behavior but both of those behaviors are not found in one material. As a result the composite materials are required to build tall buildings. The combined behavior of steel and concrete is reduced the member size and provide more strength for constructing tall buildings. Steel is widely used as reinforcement in reinforced concrete structure.*

Recently, concrete-filled steel tubular (CFST) columns have been widely used in tall buildings due to their significant advantages in structural performance and ease of construction. A new-type of fabricated coupled composite column (CCC) system composed of closely spaced double small- section concrete filled steel tubes (CFST) connected by steel connector beams. The infilled concrete prevents the inward local buckling of the steel tube, whilst the steel tube provides confinement to the concrete. Composite columns can have high strength for a relatively small cross-sectional area.By using this fabricated coupled composite column it gives an extra protection during earthquakes. If one column of the coupled composite column is failed during seismic action or some other high intensity force ,the other column of CCC withstand the structure. If the beam connector between the two composite column is failed during seismic action or some other forces ,it must be replaced by another beam *connector because of the usage of bling bolts. To analyse the steel members, three dimensional (3D) modeling, buckling and seismic action of building were applied, using ETAB software.*

Key Words: Fabricated coupled composite column, Concrete filled steel tubes, Fabricated structure, Connector beams, Seismic performance.

1. INTRODUCTION

A new-type of fabricated coupled composite column (CCC) system composed of closely spaced double small-section concrete filled steel tubes (CFST) connected by steel connector beams using blind bolts was proposed. The column limbs of the fabricated specimens performed well together combinedly and deformed as a whole without connection failure.Taking into account the current trend of industrialization of building structures and the beneficial structural performance of a combination of CFST members, In this type of frame systems, closely spaced double small-section CFST columns were used instead of single column members. This new type of columns denoted as coupled composite columns (CCC) were laterally connected by multiple H-shaped steel connector beams, which makes the main load-carrying components away from the central axis to obtain a larger moment of inertia. The CCC members have larger flexural rigidity about the open web axis (*x*-axis). Therefore, rigid connection was adopted in the strong axis direction (*y*-*y* direction), while pinned connection was adopted in the weak axis di- rection (*x*-*x* direction) In order to facilitate construction, blind bolts (Hollo-bolt) were used to connect the column limbs of CCC members as well as beam-to-column and column-to-column (along the height of building) connections. Blind bolts were found to be easy to install and tightened from one side of the connection.

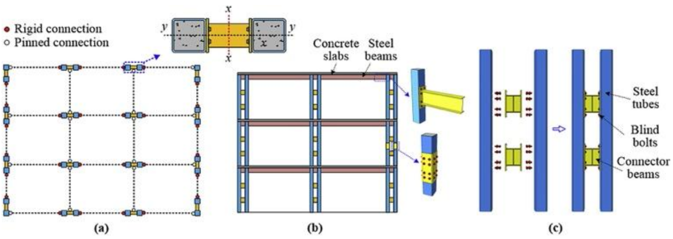

Fig. 1. Typical representation of CCC frame: (a) plan view; (b) elevation view; and (c) assembly of CCC.

1.1 OBJECTIVES

- This research work focusing on various parametric studies on investing the improvement of 10 storey 3D steel building using fabricated coupled composite column compared with steel column.
- To analyse the 10 storey 3D steel building using ETABS.The validation of building is done by using the journal "Investigation of

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the seismic behaviours of three-dimensional high-rise steel frame structures equipped with oil dampers with variable stiffness". Collect the earthquake records from PEER data base.

- To examine the horizontal ground motion records of the imperial Valley have been selected for performing the TH analysis. Modeling the fabricated coupled composite columns using ETABS.
- To Investigate buckling strength of an structure and load at which buckling takes place performance by varying parameters such as buckling load with varying link(2link, 3link, 4link and 5 link), buckling load with varying cross section(120mm, 140mm, 160mm, 180mm, 200mm) and buckling load with varying grade of concrete (M30 and M40).
- Examine the effective models from the buckling analysis,and implementing to the building.To estimate seismic structural deformations and seismic capacity of structures by placing the coupled columns in various conditions such as only at interior, only at exterior, only at corners, along with two interior sides, zigzag position, diagonal shape, two side exterior, four side centre exterior and alternative vertical. To perform various parametric study on 3D building by Replacing coupled composite column instead of conventional column.
- Comparing the seismic parameters such as base shear, storey displacement and compared with conventional structure.

1.2 SCOPE

- The work is limited to combining integrated composite steel buildings.
- The seismic analysis by means of time history analysis that we use and no other analysis is done.

2. METHODOLOGY

Examine the horizontal ground motion records of the imperial Valley have been selected for performing the TH analysis. Investigate buckling strength of an structure and load at which buckling takes place performance by varying parameters.Examine the effective models from the buckling analysis,and implementing to the building. To estimate seismic structural deformations and seismic capacity of structures by placing the coupled columns in various stories.Analysis is done by using ETABS.

3.MODELING OF BUILDING

Analyses are performed for the 10-story three-dimensional steel frame structures using Imperial valley ground motions analyzed using the ETAB software . The structure have three spans in the horizontal directions, the span length is 5 m, and the story height of the structure is 3.2 m. Arrangements of the beams and columns are shown in Table 1and Table2. Slab thickness is 130 mm. The concrete mix defined for the column, beam/slab is taken as M30 and M40 respectively. Fe-500 and Fe-415 grade rebar is use1 §d as a longitudinal and confinement bar.

Table -1: Types and sizes of beams and columns

BEAM	TOTAL DEPTH	WEB THICKNESS	TOP FLANGE WIDTH	TOP FLANGE THICKNESS	COLUMN	TOTAL DEPTH	FLANGE THICKNESS
b 1	0.45	0.01	0.225	0.02	c 1	0.45	0.03
b 2	0.4	0.01	0.225	0.02	c 2	0.4	0.025
b 3	0.35	0.0088	0.225	0.02	c 3	0.35	0.025
b 4	0.3	0.008	0.2	0.015	c 4	0.3	0.02
					c 5	0.25	0.015

Table -2: Beam and column type of structure

BUILDING	STORIES	BEAMS	COLUMNS
10-STOREY	1-4	b 2	c 3
	5 and 6	b 3	c 3
	7 and 8	b 3	c 4
	9 and 10	b 4	c 4

4. VALIDATION

For the validation of the model, "**Investigation of the seismic behaviours of three-dimensional high-rise steel frame structures equipped with oil dampers with variable stiffness"** journal paper is selected. Model is analysed by the software ETABS by using TIME HISTORY ANALYSIS. In this thesis, 10 story 3D steel building under time history analysis in ETABS 2019 for studying the effectiveness of seismic response in the form of base shear, story displacements . The horizontal ground motion records of RSN: 174, Imperial Valley-06 from PEER ground motion data base have been selected for performing the nonlinear dynamic TH analysis.

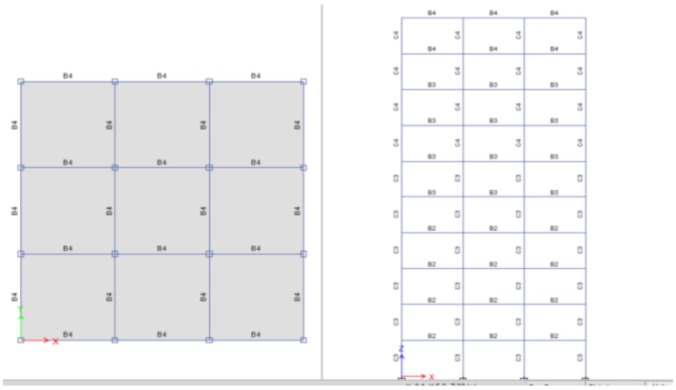

Fig -2: Plan and elevation view of building

Fig. 2and Fig 3 shows the dynamic displacement curves of the 10 story structure in the X and Y directions at the top of the structure with the Imperial Valley ground motion. The peak displacements of the 10-story structure in the X and Y directions are 0.313 m and 0.177 m respectively.

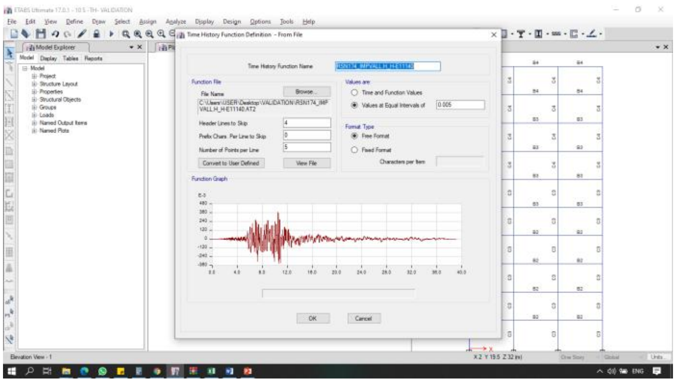

Fig -2: Time history load function in X- direction (PGA)

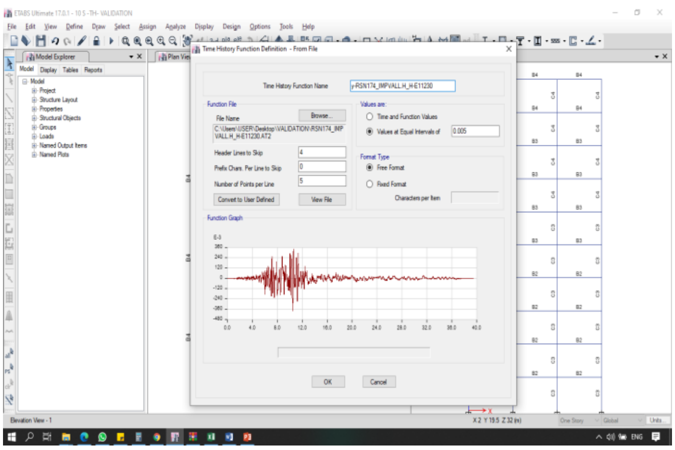

Fig -3: Time history load function in Y- direction (PGA)

4.1VALIDATION RESULT

The time taken for vibrating the building during earthquake in Y-direction is 1.877 seconds. The fig 5.7 and fig 5.8 shows the dynamic displacement curves of the 10 story structure in the X and Y directions at the top of the structure with the Imperial Valley ground motion using ETABS. The peak displacements of the 10-story structure in the X and Y directions are 338.99mm and 172.73mm respectively.

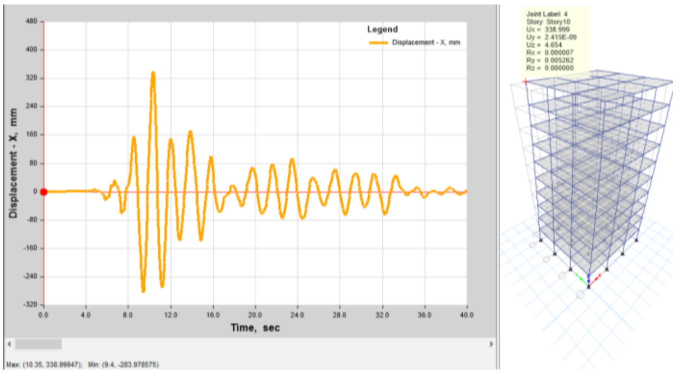

Fig -4: Time history analysis results for the displacement of top storey in X- direction

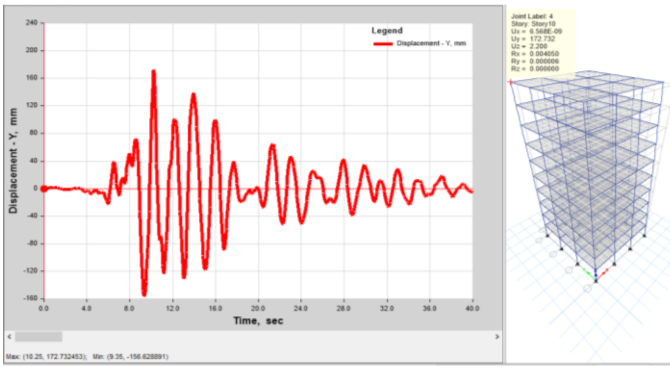

Fig -5: Time history analysis results for the displacement of top storey Y-direction

Table -3: Validation result comparison

	X	Y
JOURNAL	313	177
ETABS	338	172.3
DIFFERENCE (%)	7.99	2.66

Percentage of difference obtained is less than 10 percentage, hence validation is successful.

5. BUCKLING LOAD ANALYSIS WITH VARIOUS PARAMETERS

5.1ANALYSIS OF BUCKLING LOAD WITH VARYING LINK

Buckling load is analysed in coupled composite column with varying link such as 2link, 3link. 4link and 5 link. That is steel connector between the two composite column is changed by their number. Then comparing the CCC result with the conventional steel column under buckling load.The conventional steel column properties are taken from the beam column description from the base journal.

Table -4: Comparison of buckling load with varying link

MODEL	MAJOR AXIS (X-DIRECTION)	MINOR AXIS (Y-DIRECTION)
BOX SECTION	346115.42	346115.52
CCC-2(100mm)	33321.88	41356.29
CCC-3(100mm)	33167.99	43087.12
CCC-4(100mm)	33118.75	44876.22
CCC-5(100mm)	33098.47	46669.13

5.2 ANALYSIS OF BUCKLING LOAD WITH VARYING CROSS SECTION

Buckling load is analysed in coupled composite column with varying cross section such as 120mm, 140mm, 160mm, 180mm, 200mm. Then comparing the CCC result with the conventional steel column under buckling load. The conventional steel column properties are taken from the beam column description from the base journal. The coupled composite column consisting of concrete using M30 grade concrete.

Table -5: Comparison of buckling load with varying cross section

MODEL	MAJOR AXIS (X-DIRECTION)	MINOR AXIS (Y-DIRECTION)
BOX SECTION	346115.42	346115.52
CCC-120mm (M30)	61628.35	75441.42
CCC-140mm (M30)	103823.83	117721.69
CCC-160mm (M30)	162755.25	176652.02
CCC-180mm (M30)	241632.01	255474.97
CCC-200mm (M30)	343789.56	357538.22

5.3 ANALYSIS OF BUCKLING LOAD WITH VARYING GRADE OF CONCRETE

The conventional steel column properties are taken from the beam column description from the base journal. The coupled composite column consisting of concrete using M40 grade concrete and steel tube cross section is varying with 120mm, 140mm, 160mm,180mm and 200mm. Then comparing the CCC result with the conventional steel column under buckling load.

Table -6: Comparison of buckling load with varying grade of concrete

MODEL	MAJOR AXIS (X-DIRECTION)	MINOR AXIS (Y-DIRECTION)
BOX SECTION	346115.42	346115.52
CCC-120mm (M40)	62695.13	76544.95
CCC-140mm (M40)	106036.71	119975.36
CCC-160mm (M40)	166853.34	180795.49
CCC-180mm (M40)	248615.55	262508.96
CCC-200mm (M40)	354951	368760.55

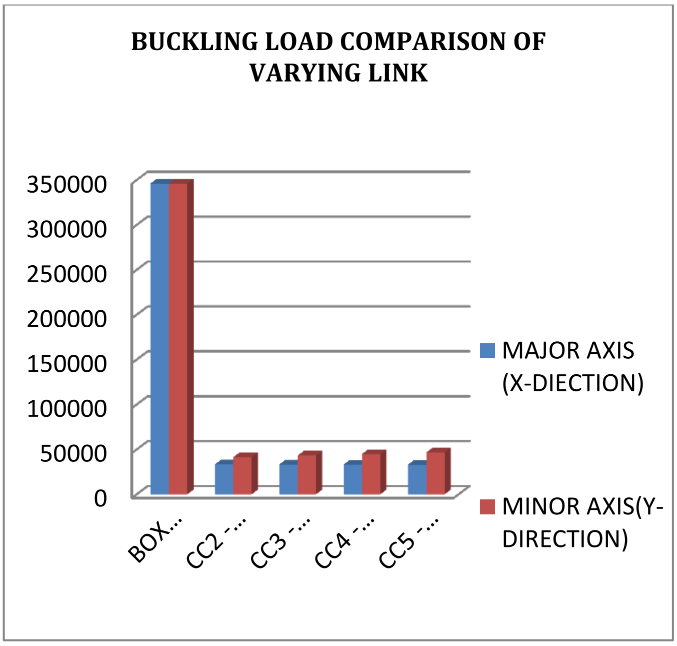

Fig -6: Bar chart of varying link

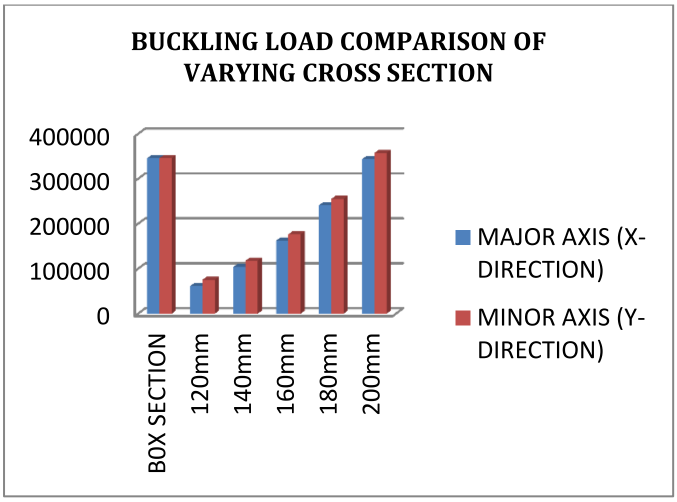

Fig -7: Bar chart of varying cross section

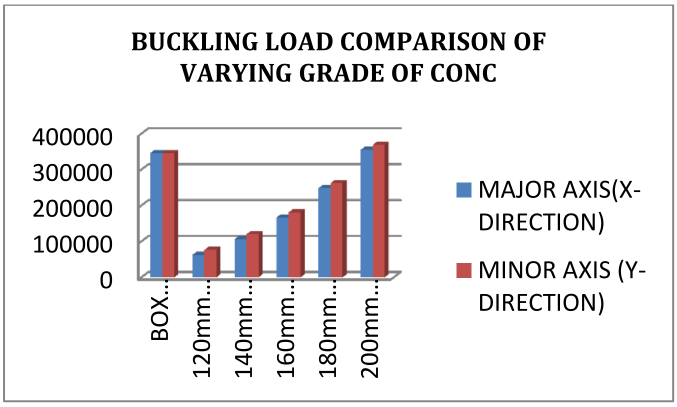

Fig -8: Bar chart of varying grade of concrete

From the analysis of buckling load, we have concluded that the value of displacement in X-direction and Y-direction of CCC200mm M40 is closer to the value of box section. From the analysis of buckling load with varying parametric condition taking the coupled composite column with 5 link and 200mm cross section using M40 grade concrete as effective model and implementing to the structure for seismic analysis .

6. SEISMIC ANALYSIS WITH DIFFERENT PARAMETRIC CONDITIONS

From the analysis of buckling load with various parameters, the effective model is taken and implementing to the structure for seismic analysis. In seismic analysis the effective model is implemented instead of some conventional steel columns according to the parametric conditions. Various parametric study are performed on 3D building by Replacing CCC instead of conventional columns by,

- CCC only at interior
- CCC only at exterior
- CCC only at corners
- CCC only at centre exterior
- CCC in zigzag position
- CCC at alternative vertical position
- CCC at diagonal shape
- CCC at horizontal length interior
- CCC at two side exterior

6.1 COMPARISON OF ALL MODELS BASED ON DISPLACEMENT,DRIFT AND BASE SHEAR

Effective models from the buckling analysis is implemented and it is a carried to estimate seismic structural deformations and seismic capacity of structures by placing the coupled columns in various stories Seismic parameters such as base shear, storey displacement and top storey acceleration are studied and compared with conventional structure. The following fig shows the comparison of storey displacement of all models in X and Y direction, comparison of base shear of all models in X and Y direction, comparison of storey drift of all models in X and Y direction and comparison of time period of all models in X and Y direction when building vibrates during earthquake.

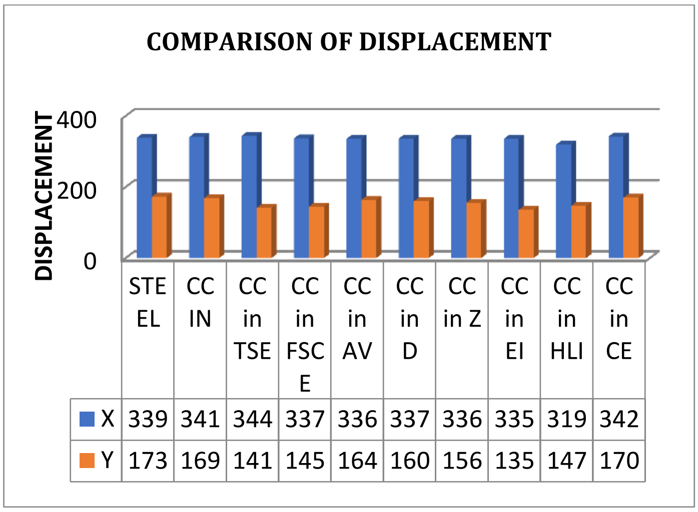

Fig -9: Comparison of displacement of all models in X and Y direction

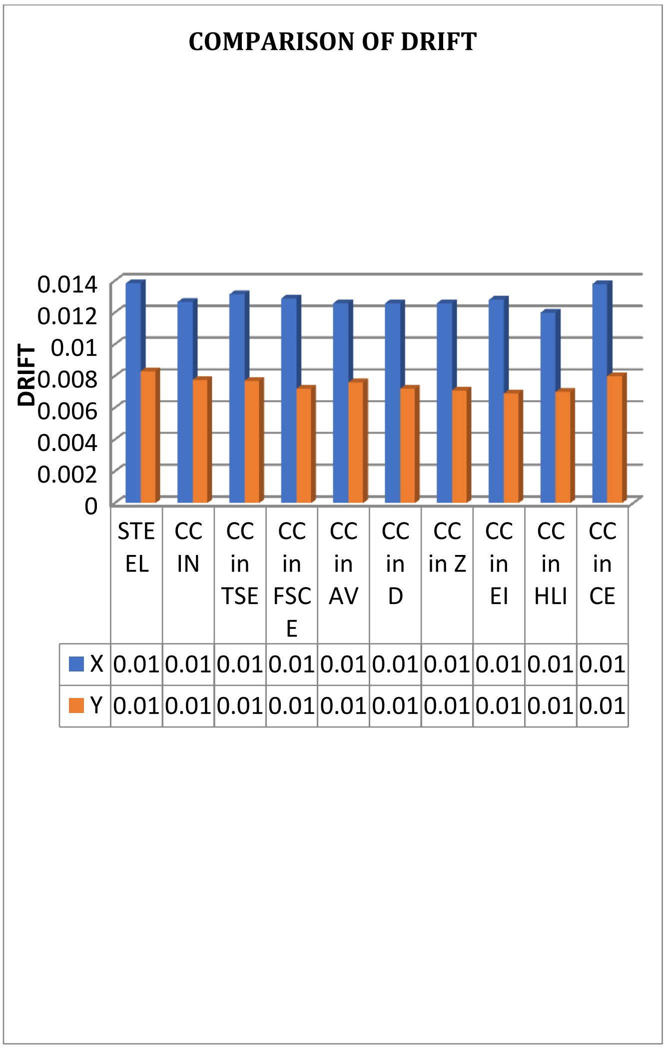

Fig -10: Comparison of drift of all models in X and Y direction

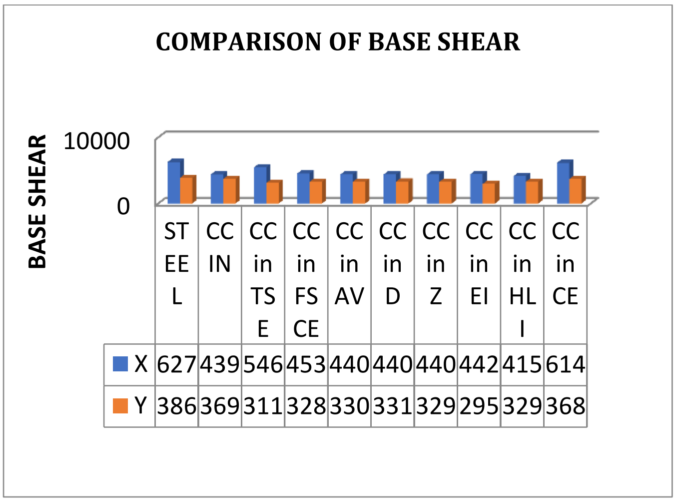

Fig -11: Comparison of base shear of all models in X and Y direction

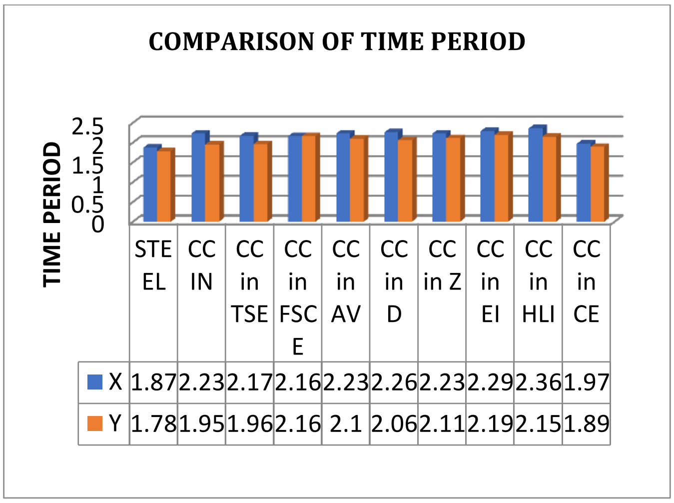

Fig -12: Comparison of time period of all models in X andY direction

From the modelling of various parametric study are performed on 3D building by Replacing coupled composite column instead of conventional columns according to the seismic parameters such as base shear, storey displacement and top storey acceleration are studied and compared with conventional structure we have concluded that coupled composite column placed in the two horizontal interior bays are considered as the perfect model for the seismic analysis.

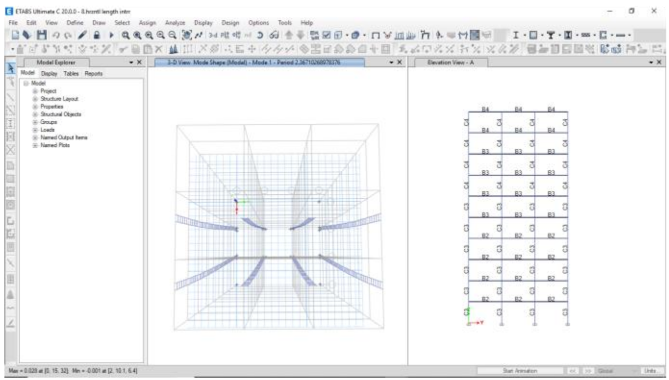

Fig -13: Finalized model

7. CONCLUSIONS

A steel with concrete composite column is fully compression type member, has mainly two type concrete encased in steel section and concrete infilled tube steel section and is normally used as a load-bearing member in a composite structural frame. Concrete infill steel column use the benefit of both material steel as well as concrete. This research work focusing on various parametric studies on investing the improvement of 10 storey 3D steel building using fabricated coupled composite column compared with steel column. To analyse the 10 storey 3D steel building using ETABS. The analysis was done in two parts.

- From the buckling analysis we have concluded that coupled composite column with 5 link,200mm thickness and m40 concrete taken for modelling.
- Modelling of various parametric study are performed on 3D building by Replacing coupled composite column instead of conventional columns.
- According to the seismic parameters such as base shear, storey displacement and top storey acceleration are studied and compared with conventional structure.
- From the study we have concluded that coupled composite column placed in the two horizontal interior bays are considered as the perfect model for the seismic analysis.
- From the seismic study result we have concluded that the coupled composite column implemented at horizontal lined interior model is better than other models.

The finalized modeling properties are:

- The displacement in X and Y direction of composite column placed horizontal length interior model is 5.79% and 14.91% respectively lower than that of steel model.
- The base shear in X and Y direction of composite column placed horizontal length interior model is 33.74% and 14.74% respectively lower than that of steel model.
- The drift in X and Y direction of composite column placed horizontal length interior model is 13.31% and 15.69% respectively lower than that of steel model.
- The weight of building reduced from 9241 to 9058.
- The percentage of material used during construction is reduced from 1 to 0.8.

REFERENCES

[1] L.H. Han, W. Li, R. Bjorhovde, Developments and advanced applications of concrete-filled steel tubular (CFST): member, J. Constr. Steel Res. 100 (2004) 211–228.

[2] H.S.Hu,Y.Liu,B.T.Zhuo,Z.X.Guo,B.M.Shahrooz,Axialcompressivebehaviorof square CFST columns through direct measurement of load components, J. Struct. Eng. 144 (11) (2018), 04018201.

[3]Y.Wei,C.Jiang,Y.F.Wu,Confinementeffectivenessofcircularconcrete-filledsteel tubular columns under axial compression, J. Constr. Steel Res. 158 (2019) 15–27.

[4] Z.C. Lai, A.H. Varma, K. Zhang, Noncompact and slender circular CFT members: experimental database, analysis, and design, J. Constr. Steel Res. 106 (2015) 220–233.

[5] L.L. Liu, Y.Q. Tu, Y.H. Ye, Experimental study of the properties of axially loaded multi-cell T-shaped concrete-filled steel tubular stub columns, China Civ. Eng. J. 44 (10) (2011) 9–16 (In Chinese).

[6] M.Y.Xu,T.Zhou,Z.H.Chen,Y.B.Li,L.Bisby,ExperimentalstudyofslenderLCFST columns connected by steel linking plates, J. Constr. Steel Res. 127 (2016) 231–241.

[7] Y.L. Yang, Y.Y. Wang, F. Fu, Static behavior of T-shaped concrete-filled steel tubular columns subjected to concentric and eccentric compressive loads, Thin-Walled Struct. 95 (2015) 374–388.