Infill Effect on The Seismic Behaviour of L-Shaped Buildings With Confined Columns A Comparative Study Using RCC, CFST And Encased Columns

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Abstract—Poor detailing are one of the reasons for may failures of rreinforced concrete structures during earthquakes. Reinforced concrete structures are bulky and impart more seismic weight and less deflection whereas steel structures impart more deflections and ductility to the structure but uneconomical. Composite construction combines the better properties of both steel and concrete which gives better performance than RCC structures. The behaviour of composite columns in irregular shaped buildings, need to be studied. In buildings infill effect also have considerable impact on the seismic performance of the structure.

In the present study a G+14 building is considered with three different plans of L- shaped buildings with equal plan area to consider the plan irregularity. Three different types of columns RCC, CFST (Concrete Filled Steel Tubes) and Encased columns will be considered. Each structure is analyzed for seismic loading with and without infill walls. The behaviour of structure is to be discussed in terms of base shear, storey shear, storey drifts, mode shapes, time periods and also absolute maximum bending moment and absolute maximum shear force in columns. A finite element software ETABS is used for the analysis.

Index Terms: CFST column, ENCASED column, Infill walls, Irregular buildings, projection ratio

I. INTRODUCTION

In existing modern world, steel and concrete are the two building materials most commonly used for structures extending from pavements to high rises, these materials counter each other although they own different material properties and characteristics in various ways. Steel structures has lesser weight ratio but has excellent resistance to tensile loading. Steel structures impart more deflections and ductility to the structure but are uneconomical. Steel is prone to buckling phenomenon which can be resisted by concrete that is good in compression.

Corrosion prevention and thermal insulation can be done by concrete on the other hand steel may be used to impact ductility which is an important characteristic for high rise structures. Substantially, concrete has the capacity to resists buckling of steel. To get extreme benefits from both of the materials, composite construction is mostly preferred. In composite construction, three types of columns are used they are Reinforced Cement Concrete (RCC) Concrete filled steel tube column (CFST) and Encased column.

It is being progressively adopted due to their excellent static and earthquake resistant properties, such as large energy absorption capacity, bending stiffness, favourable construction, fire performance, corrosion resistance, favourable ductility, high strength and high ductility. CFST columns do not require shuttering as steel tube is provided for concrete. The steel tube wall buckling is prolonged by concrete. Concrete spalling, impact and abrasion is removed by the steel tube. It is economical as construction time and cost is reduced. Large part of the flexural rigidity of the column is imparted by the tubular section. It has lengthy service life. Under long term loading, the load carrying capacity of the CFST column is not affected. The steel tube within which concrete is confined has higher crushing strength. Lateral and longitudinal reinforcement is provided by the steel tube. CFST columns are more beneficial over reinforced concrete columns and thus are extensively adopted in civil engineering

Element Performance of Concrete Filled Steel Tubular columns:

The usual and most well-known characteristics of steel and concrete are taken advantage in concrete-filled steel tubular members. With the support of the concrete core, the local buckling of the steel tube is improved. The steel tube provides confinement to the concrete core. Fig:2, shows failure modes for the concrete-filled steel tubular column and the corresponding concrete and steel tube. It is shown that shear failure is found in plain concrete column and both inward and outward buckling is exhibited by the steel tube. The failure for the CFST column has only outward buckling in the outer steel tube and inner concrete fails in a ductile manner.

Encased Column : Encased Column is a steel-concrete composite column. It is a compression member, comprising either a concrete encased hot-rolled steel section and is generally used as a load-bearing member in a composite framed structure.

Typical cross-sections of composite columns with fully and partially concrete encased steel sections are illustrated in Figure 1(a). Concrete filled steel tube sections are shown in Figure 1(b). Combined concrete filled steel tube with encased with hot rolled sections are shown in Figure 1(c) and (e). Partially filled concrete (hallow concrete section) fill ed steel tube is shown in Figure 1(d).

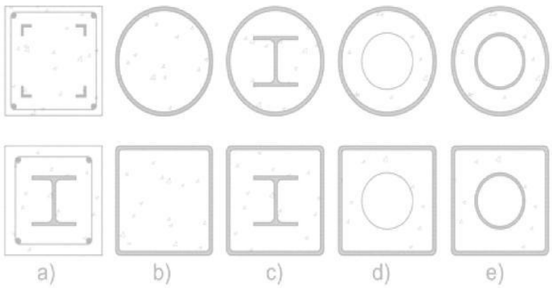


Figure 1: Various types of composite c olumns

In a composite column both the steel and concrete would resist the external loading by inte racting together by bond and friction. Supplementary reinforcement in the concrete may be provided and its encasement prevents excessive spalling of concr ete both under
normal load and fire conditions. In composite construction, the initial construction loads are bare by steel sections including the weight of structure during construction. Later concrete is cast around the steel section. The concrete and steel are com bined in such a fashion that the advantages of both th e materials are utilised effectively in composite colu mn. The lighter weight and higher strength of steel permit the use of smaller and lighter foundations. T he subsequent concrete addition enables the building frame to easily limit the sway and lateral deflections.

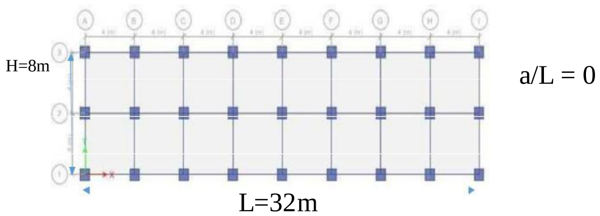
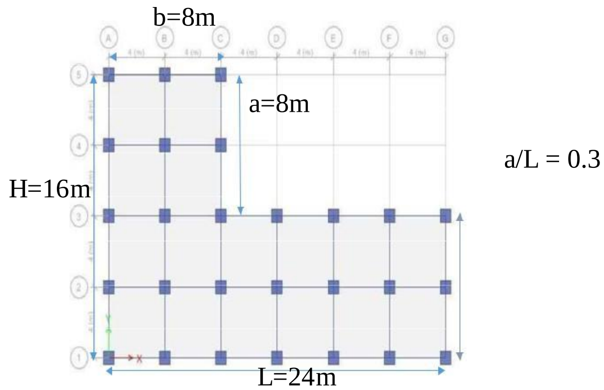
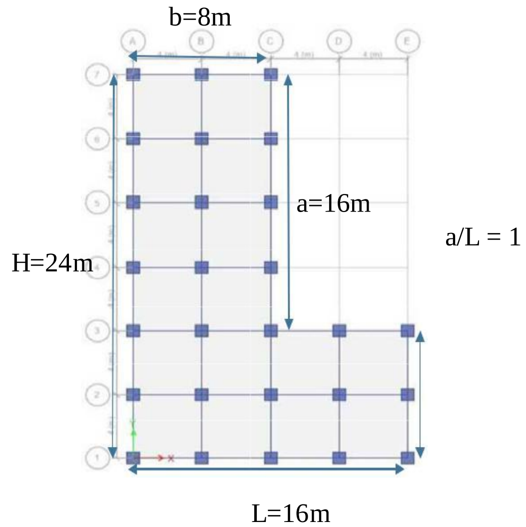


Figure 2: Failure modes for the hol low steel tube, concrete and concrete filled steel tu bular column

II. METHODOLGY

The present study focuses o n understanding seismic behaviour of irregular struct ures with RCC columns, CFST columns, and ENCASED columns with and without Infill walls. In CFST column three different columns sections of different steel tu be thicknesses. Plan irregularity is considered in the study. Three different plans are considered as shown in Figure 3. The first plan is a rectangular plan of no pro jections. Second plan is having a projection of three tim es less than the length of the building. Its projection ra tion is given as 0.3. Projection ratio in the study is defi ned as length of the projection to the length of the buildi ng. Third plan is having projection length is equal to th e length of the building, whose projection ratio is 1. Each bay length in both the direction is considered 4m . In all three buildings plan area is kept constant of 256 m^2. All three models number of floors are considered G+15 floors. In each building model the beam column system is considered along the slabs.





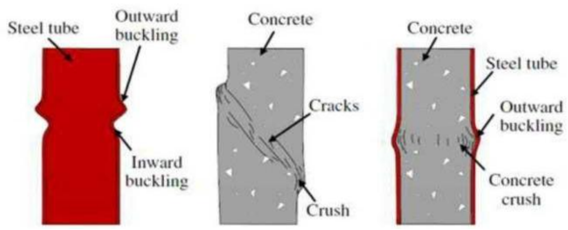


Figure 3: Plan of structures with different projectio n ratios

The beam sections and slab thicknesses are kept constant in all buildings. The equivalent column sections are considered in all buildings since the sections are concrete and steel composite. The different columns sections considered in the present study are shown in Figure 4. In CFST column sections three different thicknesses 6mm, 8mm and 10 mm and in Encased column section ISMB 150 are considered.. The above mentioned structures analyzed with and without infill walls. Infill is modeled as diagonal strut as shown is Figure 5. Equivalent diagonal strut method is to determine strut properties. Width of the strut depends on Elastic moduli of masonry and concrete, moment of inertia of the column, height of masonry etc.

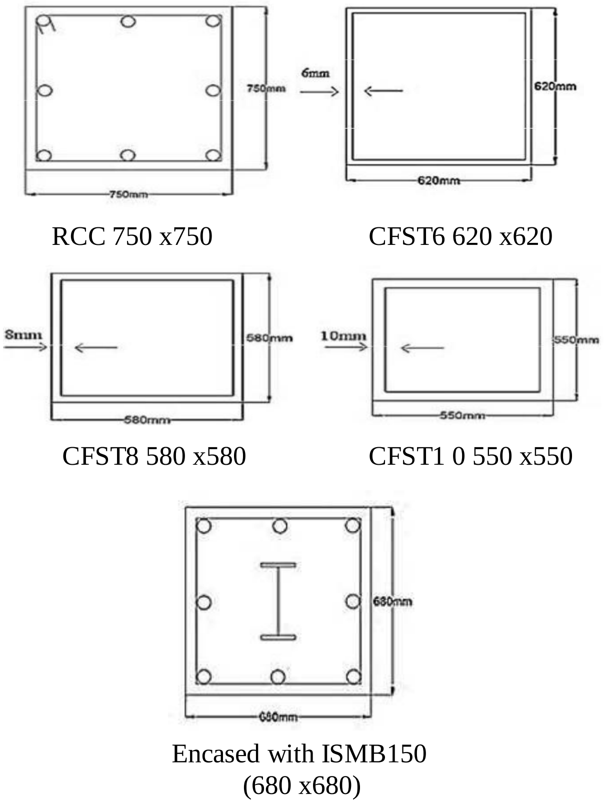


Figure 4: Composite columns dime nsions in RCC, CFST and Encased sectio ns

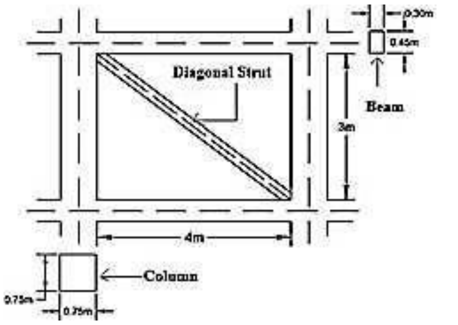


Figure 5: Equivalent strut model

In the present study the following equivalent strut details are obtained by using equivalent strut method. In RCC column structure, the width of diag onal strut is = 1.74m and area of diagonal strut is 1.74mX0.23m. In CFST column of steel thickness 6mm structure, width of diagonal strut is = 1.52m and area of diagonal strut is 1.5 2mX0.23m. In CFST column of steel thickness 8mm structure, width of diagonal strut is = 1.45m and a rea of diagonal strut is 1.45mX0.23m . In CFST column of steel thickness 10 mm structure, width of diagonal strut is = 1.40m and area of diagonal strut is 1.40mX0.23m. In Encased column structure, the width of diagonal strut is = 1 .62m and area of diagonal strut is 1.62mX0.23m.

The following parameters are considered in analysing all models.

Properties considered in all the models:

Number of Floors = 15flo ors (G+14)
Floor Height = 3m
Thickness of slab = 150m m
Size of Beam = 300x450 mm
Size of Column = Shown in Figure 4.
Thickness of Masonry wa ll = 230 mm
Spacing between frames: 4m along X-direction and 4m along Y-direction
Materials: M30 (Concrete) and Fe415 (Steel)
Unit weight of Concrete: 24kN/m^3
Unit weight of RCC: 25k N/m^3
Loadings:

The loads taken into cons ideration are as per IS 875 (P-1) for dead loads and IS 8 75 (P-2) for live loads.

Live load: 3kN/m
Wall load: 12kN/m
Floor Finish: 1kN/m
Seismic Parameters:
Seismic zone: V
Seismic zone factor(Z): 0.36
Soil Type: 3 (Soft Soil)
Importance factor(I):1 (Or dinary building)
Response reduction factor (R): 3 (OMRF)
Damping for concrete: 5%
Damping for steel: 2%

A finite element software ETABS is used to analyse the models. A response sp ectrum method is used for seismic analysis. The resu lt parameters base shear, storey shear, storey drift, ti me periods and maximum roof displacements are studie d.

III. RESULTS AND DISC USSION

The variations in the results for the models of RCC, CFST columns of different t hicknesses and ENCASED columns along with difference in projection ratio are taken for comparative st udy and tabulated. The comparative study is also carried out by considering the structures with and without Infill walls. The seismic effect is considered along the X-direction and Y-direction of the model plan to note the variation of irregularities in the structure .

1. ***Base Shear***

Base shear in X-direction without Infills

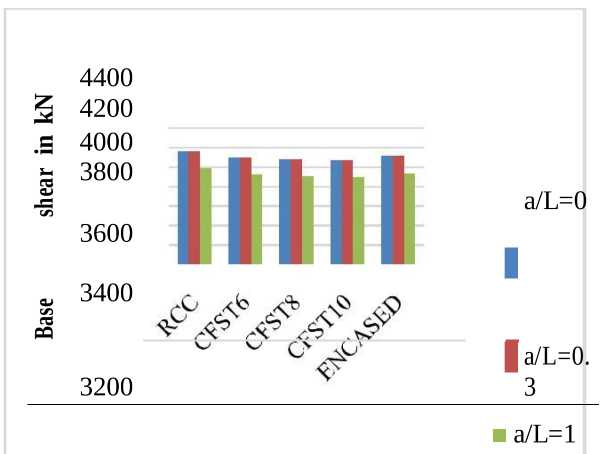


Figure 6: Base shear in X-direction without Infills

Type of building

Base shear in X-direction with Infills

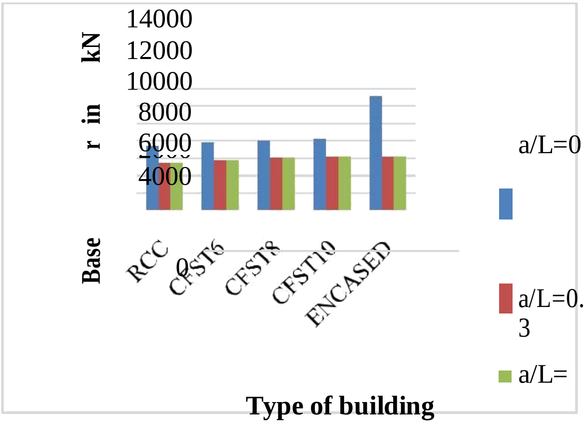


Figure 7: Base shear in X-direction with Infills

From Figure 6, the base shear decreases as the projection ratio increases. The decrement when compared to projection ratio a/L=0 is about 8.6% in RCC structure, 9.3% in CFST6, 9.5% in CFST8, 9.5% in CFST10, and 5% in ENCASED. The thickness of steel tube does not have influence on base shear in X-direction. The base shear depends on the plan of the structure that is affected by irregularity of the buildings.

From Figure 7, the base shear remains same in projection ratio a/L = 0.3 as in a/L = 0 but, decreases in projection ratio a/L = 1. The decrement when compared to projection ratio a/L=0 is about 15% in RCC structure, 15.9% in CFST6, 16.3% in CFST8, 16.5% in CFST10, and 16.3% in ENCASED. The thickness of steel tube does not have influence on base shear in X-direction. The base shear depends on Infill walls and the plan of the structure that is affected by irregularity of the buildings.

From Figure 8, the base shear increases as the projection ratio increases. The increment when compared to projection ratio a/L=0, is about 7.6% in RCC structure, 7.5% in CFST6, 7.4% in CFST8, 7.4% in CFST10 and 14% in ENCASED.

Base shear in Y-direction without Infills

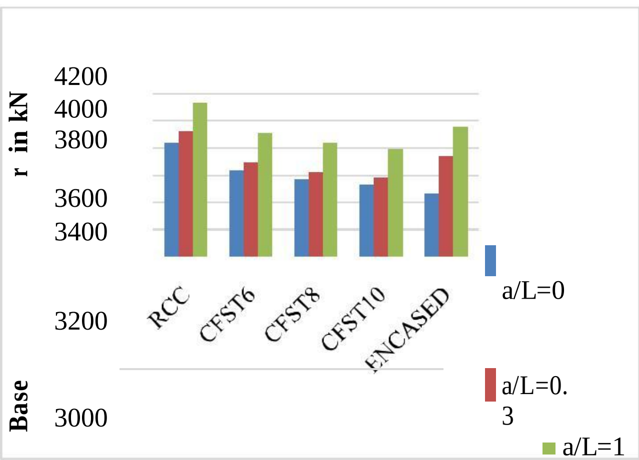


Figure 8: Base shear in X-direction without Infills

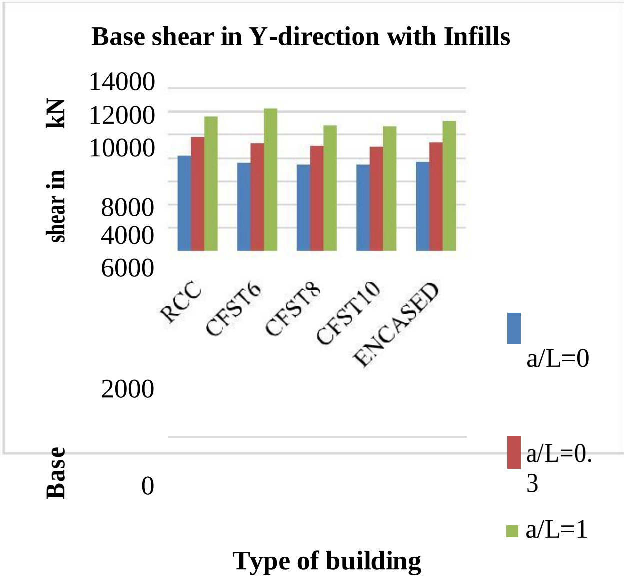


Figure 9: Base shear in X-direction with Infills

The thickness of steel tube of does not have influence on base shear in Y-direction. The base shear depends on the plan of the structure that is affected by irregularity of the buildings.

From Figure 9, the base shear increases as the projection ratio increases. The increment when compared to projection ratio a/L=0, is about 7.6% in RCC structure, 7.5% in CFST6, 7.4% in CFST8, 7.4% in CFST10 and 14% in ENCASED. The thickness of steel tube of does not have influence on base shear in Y-direction. The base shear depends on the plan of the structure that is affected by irregularity of the buildings.

2. *Time Period:*

From Figure 10, the time period decreases as the projection ratio increases. The decrement when compared to projection ratio a/L=0 is about 4.8% for RCC, 4.9% for CFST6, 4.8% for CFST8, 4.9% for CFST10and 17.1% for ENCASED. The time period for projection ratio a/L=0.3 and a/L=1 is same for respective type of building. As the thickness of steel tube increases time period also increases. ENCASED has maximum time period of 2.359sec for the projection ratio a/L=0. The regular building of projection ratio a/L=0 has greater time period compared to irregular L shaped -building.

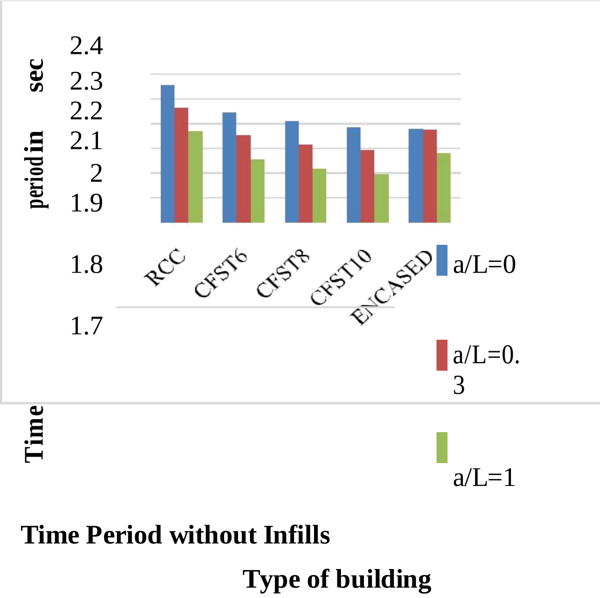


Figure 10: Time Period in seconds without Infills

From Figure 11, the time period decreases as the projection ratio increases. The decrement when compared to projection ratio a/L=0 is about 19.7% for RCC, 21.2% for CFST6, 21.7% for CFST8, 20.1% for CFST10 and 21.7% for ENCASED. The time period for projection ratio a/L=0.3 and a/L=1 is same for respective type of building. As the thickness of steel tube increases time period also increases. CFST8 and ENCASED has maximum time period of 0.97sec for the projection ratio a/L=0. The regular building of projection ratio a/L=0 has greater time period compared to irregular L shaped-building and the building with Infill walls has lesser time period.

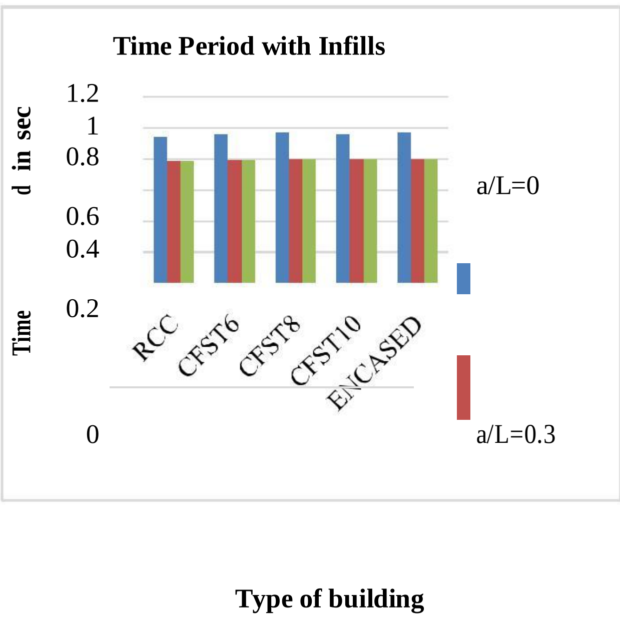


Figure 11: Time Period in seconds with Infills

3. Maximum Roof Displacements :

From Figure 12, the maximum displacement increases as the projection ratio increases. The increment when compared to projection ratio a/L=0 is about 38.3% in RCC structure, 39.9% in CFST6, 40.4% in CFST8, 40.6% in CFST10 and 34.2% in ENCASED. The thickness of steel tube is not influencing the maximum deflection in X-direction. The maximum displacement depends on the plan of the structure that is affected by irregularity of the buildings.

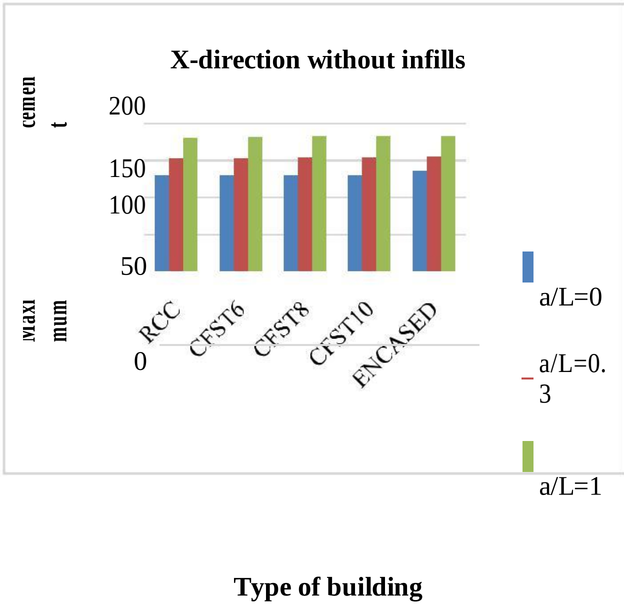
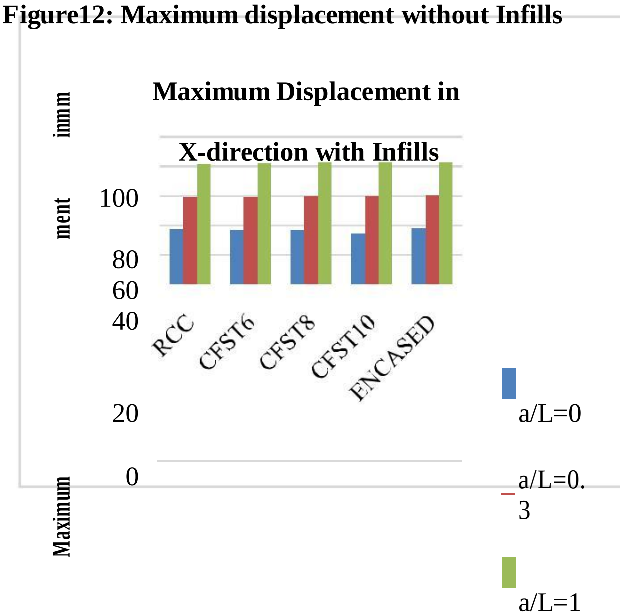


Figure12: Maximum displacement without Infills



From Figure 13, the maximum displacement increases as the projection ratio increases. The increment when compared to projection ratio a/L=0 is about 17 times greater in RCC structure, 23 times greater in CFST6, 24 times greater in CFST8, 41 times greater in CFST10 and 18 times greater in ENCASED. The thickness of steel tube is not influencing the maximum deflection in X-direction. The maximum displacement depends on the plan of the structure and presence of Infill walls that is affected by irregularity of the buildings.

From Figure 14, the maximum displacement decreases as the projection ratio increases. The decrement when compared to projection ratio a/L=0 is about 16.5% in RCC structure, 16.9% in CFST6, 17.01% in CFST8, 17.05% in CFST10 and 19.9% in ENCASED. The thickness of steel tube is not influencing the maximum deflection in Y-direction. The maximum displacement depends on the plan of the structure that is affected by irregularity of the buildings.

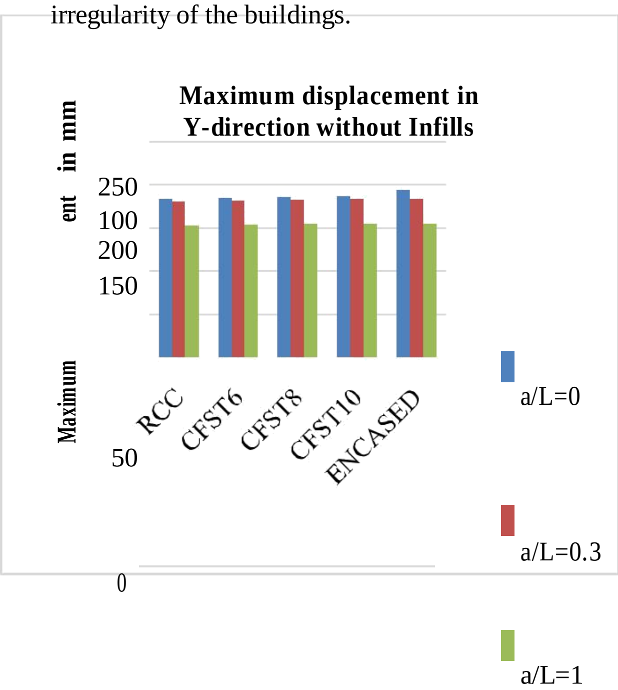


Figure 14: Maximum displacement without Infills

From Figure 15, the maximum displacement decreases as the projection ratio increases. The decrement when compared to projection ratio a/L=0 is about 33.3% in RCC structure, 34.6% in CFST6, 35% in CFST8, 34.2% in CFST10 and 34.1% in ENCASED. The thickness of steel tube is not influencing the maximum deflection in Y-direction. The maximum displacement depends on presence of Infill walls and the plan of the structure that is affected by irregularity of the buildings

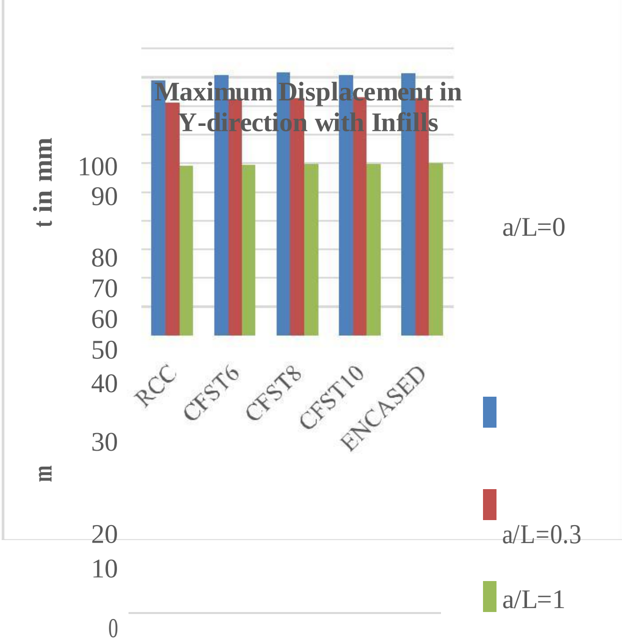
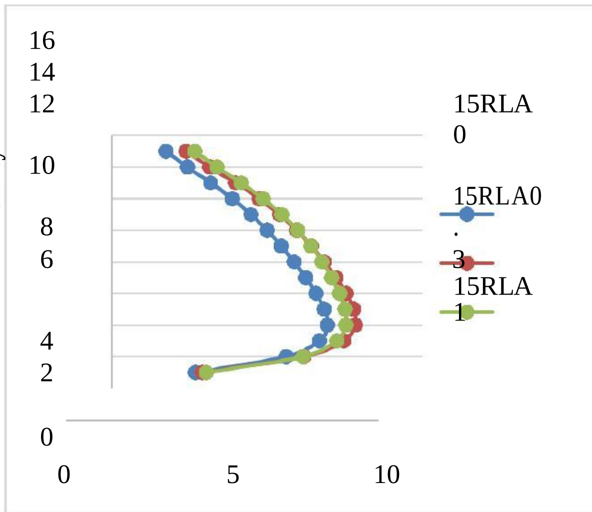


Figure 15: Maximum displacement with Infills

4. Storey Drifts

From Figure 16, difference of lateral displacements of two storeys known as storey drift is varying as an inverse parabola. For RCC structure of projection ratio a/L=1 has maximum storey drift in X-direction compared to the other projection ratios



Maximum Storey Drift without Infills for RCC

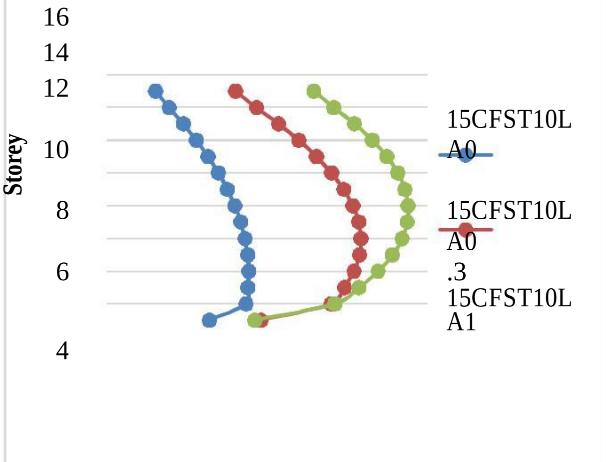
Maximum Storey Drift

Figure 16: Maximum Storey Drift in X-dir

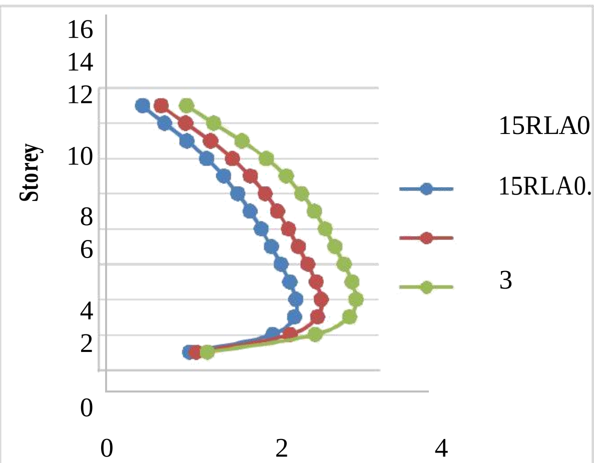
From Figure 17, difference of lateral displacements of two storeys known as storey drift is varying as an inverse parabola. For RCC structure of projection ratio a/L=1 has maximum storey drift in X-direction compared to the other projection ratios. By

considering Infill walls the maximum storey drift is much greater in RCC structure with projection ratio a/L = 1 compared with other projection ratios.

Maximum Storey Drift without Infills for CFST



Maximum Storey drift with Infills for RCC



Maximum Storey Drift

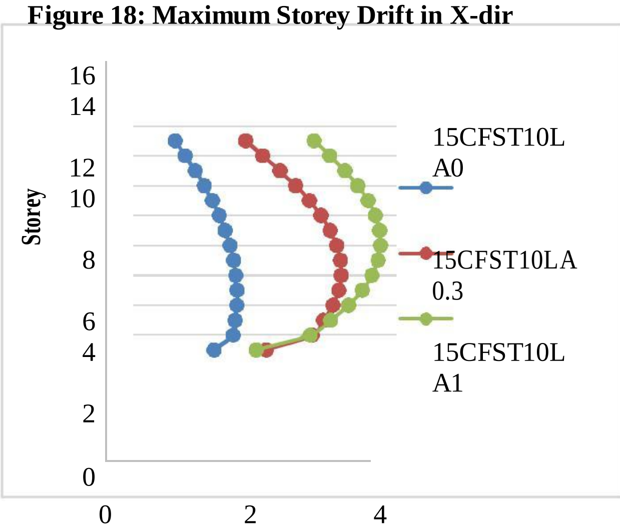
Figure 17: Maximum Storey Drift in X-dir

From Figure 18, difference of lateral displacements of two storeys known as storey drift is varying as an inverse parabola. For CFST10 structure of projection ratio a/L=1 has maximum storey drift in X-direction compared to the other projection ratios.

From Figure 19, difference of lateral displacements of two storeys known as storey drift is varying as an inverse parabola. For CFST10 structure of projection ratio a/L=1 has maximum storey drift in X-direction compared to the other projection ratios. By considering Infill walls the maximum storey drift is much greater in CFST10 structure with projection ratio a/L = 1 compared with other projection ratios.

Maximum Storey Drift

Figure 18: Maximum Storey Drift in X-dir



Maximum Storey Drift with Infills for CFST

Maximum Storey Drift

Figure 19: Maximum Storey Drift in X-dir

IV CONCLUSIONS

From the above discussion, the following conclusions are made.

1. The base shear of structure with Infill walls is about 1.8 times greater than the base shear of structure without Infill walls.

2. The time period of structure with Infill walls is about 1.2 times lesser than the time period of structure without Infill walls.
3. The maximum displacement of structure with Infill walls is about 1.2 times lesser than the maximum displacement of structure without Infill walls.
4. As the base shear increases the time period decreases.

Maximum deflection of structure with Infill walls is about 1.4 times lesser than the maximum deflection of structure without Infill walls

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