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Performance of a Multi-Storey Complex Building with CFST Columns.

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Abstract: Due to rapid on-going horizontal development and restricted vertical development of buildings has resulted in congestion of cities and shrinkage of agricultural land, particularly in high seismic zones. For vertical development, there is a need for the construction of buildings as high as possible. The restriction to the vertical development is due to the reason that high rise structures are more vulnerable to lateral loads acting on the building resulting from the seismic events. With a background in view, the current work studies the seismic responses of a multi-storey complex building with concrete-filled steel tube columns (CFST). In present work, CFST columns of different sizes were used for the study of a Ground+12 storey building with plan dimensions 35m x 30m, situated in seismic Zone-V and medium soil type as per IS 1893-2016 classification. The Response spectrum analysis was carried out for different building models as per IS 1893:2016 provisions. E-TABS software was used for three-dimensional modelling and analysis of buildings. Several response parameters like fundamental time period, maximum storey displacement, maximum storey drift, storey shear and overturning moment are considered in this study to evaluate the performance of the building. It was concluded that CFST columns perform well for high seismic zones even at smaller cross-sectional dimensions.

Keywords: CFST, E-TABS.

I. INTRODUCTION

Due to a large amount of deficiency of Urban land and enormous population growth in developing countries, especially in urban areas, have made it necessary for the civil engineers to go for multi-storey building construction. The design of a high multi-storey building is mainly governed by lateral force-induced due to wind and seismic actions. The building that is designed to withstand the vertical loads acting on it may not have the ability to survive lateral loads or even if it will stand against the lateral loads would significantly increase the construction cost as the number of stories is increased. Earlier the choice with the engineers was normally between concrete and steel structures. Nowadays, to meet the demands of the construction industry, Concrete Filled Steel Tube (CFST) sections are highly popular with a lot of advantages over conservative steel and RC sections, so CFST sections have been suitably adapted and embraced particularly in high seismic areas from past few decades.

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These columns can be used at places where there is a need to increase the available area of the floor with the given strength. In the case of reinforced concrete-filled tubular sections, no need to have additional reinforcement steel and even formwork have not required this results in speedy, economical and easy construction. With the increasing use of composite structure worldwide, the interest and demands are also increasing for using concrete-filled steel tubes (CFST) columns. Concrete filled steel tubes (CFST) are primarily used as columns for the tremendous design of high-rise multi-storey structures. These CFST columns are constructed by filling hot rolled steel tubular sections with concrete. As all of us know, that concrete is good in compression but weak in tension on the other hand steel is good in tension but weak in compression. These materials are combined due to which compressive strength of concrete is accompanied by the tensile strength of steel thus providing the most efficient sections. Many types of research have been carried out in past to check the behaviour of composite structures, some of them are mentioned in this paper.

Han Thi Thuy Hang (2019) conducted a study to check the seismic response of G+15 storied buildings with square composite columns having plan dimension of 35mx25m with soil type B and peak acceleration as 0.0928 ag/g. The height of each storey ways was taken as 3m. The beam and column size was taken as 250mmx500mm and 450mmx450mm respectively. Different models with various irregularities in their plan and elevation were modelled and analyzed using the response spectrum method as per TCVN 9386:2012 for the Vietnamese seismic area, using ETABS 2016 software program. They found out there was 11.4% reduction of the time period in case of a rectangular building with CFST columns, the displacement reduced by 3% (X direction) and 9.4% (Y direction) and the storey drift reduced by 5.3% (X direction) and 12% (Y direction), the base shear increased by 3.88% (X direction) and 7.8% (Y direction) compared to CES column.

Deepak M Jirage and V.G. Sayagavi (2017) conducted a study to compare steel-concrete composite frame structure with RCC frame structure having G+15 storey, plan dimension of 20m x 20m situated in earthquake zone-IV and medium soil type as per IS 1893-2016 classification. The total height of the building was taken as 52.4m with the height of each floor as 3.2m. The size of the beam was taken 230mm x 700mm, size of the column as 300mm x1100mm for RCC frame and ISWB400 for the composite frame. All the buildings were modelled and then analyzed for response spectrum and Equivalent Static Method using ETABS software program. Parameters like self-weight, base shear, storey drift, deflection and time period were studied.

It was found that the self-weight of Composite structure was reduced by 33%,

base shear was reduced by 15%, axial forces were reduced by 15%, displacements and time period was more as compared with RCC Structure.
Asha B.R and Sowjanya G.V (2015) conducted a study to compare of Seismic Behavior of a Typical Multi-Storey Structure with Composite Columns and Steel Columns". The plan dimension of the building was taken 40m x 30m with G+12 storey, situated in seismic zone III and V. The height of the building was taken as 40.2m with the height of each floor as 3m. Two buildings with different types of columns i.e. CFST and steel were modelled and the equivalent static method was used to analyze the building using the E-TABS software program as per IS 1893:2002. Parameters like storey drifts, base shear, storey overturning and roof displacements for both zones were studied. It was found that, 22%-28% reduction in Base shear and overturning moment, 26.6% reduction in Roof displacement, 25%-28.5% reduction in storey drifts in case of the CFST column on comparison with the steel. Thus, it was concluded that the performance of building with composite columns is better than building with steel columns for high seismic zones.

Composite Columns.

A concrete composite column is a full compression type member, that is classified into two types, one with encasement of steel section in concrete and another with concrete-filled in tubular steel sections, and is generally used as a member that transport load in a structural frame to the foundation. Typical cross-sections of composite members with wholly and partly concrete encased and concrete-filled steel members are shown in fig (1) and fig (2) respectively. These composite members consist of two materials i.e. steel and concrete which are joined together to stand the subjected load by bond and friction between these materials. Nowadays, due to the fact of massive constructions and multi-storey structure of 10 and above, the dimensions of columns increase due to the fact of the revised IS – codes. In such cases, the dimensions of Columns exceed 1m which results in a reduction of the available area of the floor and also makes the structure uneconomical. Composite columns are the solution to this type of problem. Moreover, CFST columns have various benefits compared to pure steel columns and reinforced concrete columns. The infilled concrete provides steadiness and enhances compressive strength to the steel tubular column to limit the ability of buckling.

Composite column types.

A concrete-filled steel tubular column makes use of both materials steel as well as concrete. Generally, steel tubular section of square, rectangular or circular shapes are filled with reinforced concrete or plain concrete. it is normally used in high-rise frame structures and multi-storey buildings frames as columns, and in case of a low-rise building, these composite members are used as beam mostly in industrial buildings where an effective and advantageous structural system is required. There are more than a few benefits for utilizing such structural systems in places were both construction order and structural performance is required along with economical benefits. Thin-walled steel tubular sections undergo buckling when subjected to heavy loading, so their use has been limited. This problem can be solved by the use of concrete as infill material in these tubular sections. Due to the confinement effect of steel shell on a concrete core, its performance of these members is improved and also the presence of concrete core improves the resistance against buckling, thus helps the whole structural system to perform efficiently. Because the steel is furnished on the outer side i.e. on its surface, it behaves in an efficient way towards tensional forces and buckling. It additionally offers the ultimate stiffness because of the core material present inside it i.e. concrete. This concrete core offers a larger contribution to resisting axial compression

1) Concrete-Filled Column members.

- Circular concrete-filled steel tube (CCFST).
- Square concrete-filled steel tube (SCFST).
- Rectangular concrete-filled steel tube (RCFST).

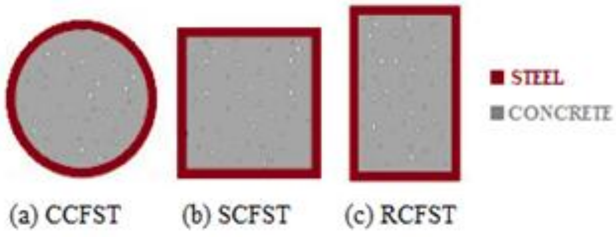


Fig. 1 Concrete Filled Column Sections.

2) Wholly or Partly Encased Column members.

- Wholly encased sections.
- Partly encased sections.

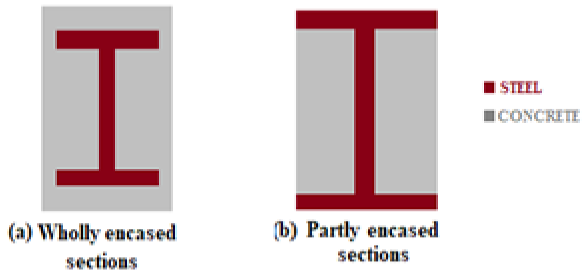


Fig. 2 Wholly or Partly Encased Column Sections.

Fig. 1.1 shows the cross-sections in which concrete is filled inside the hot rolled steel tubular section i.e. hollow circle, hollow square or hollow rectangular tubes. Fig. 1.2 shows the cross-sections in which structural steel is embedded in concrete i.e. I-Section is fully encased with concrete or partially encased with concrete without reinforcement bars.

Objectives of the Study

1. Comparison of seismic behaviour of three types of multi-storey framed structures consisting of:
   - Concrete-Filled Steel Tubular Column with RC beam.
   - Concrete-Filled Steel Tubular Column with ISWB550 Beam.
   - Reinforced Concrete Column with RC beam.
2. To compare the parameters like Time period, Storey displacement, Storey drifts, Storey shear, Storey overturning moments of a multi-storey building with CFST column and RC column using ETABS.
3. To compare the seismic behaviour by varying the size of CFST columns.
4. To find out which building type will be more effective against lateral loads.

II. MODELLING AND ANALYSIS.

Three buildings of same plan dimensions as 35m x 30m with G+12 storey is modelled for analysis with setbacks at different levels, one with CFST columns and another with RC columns. In both, these buildings RC beams were used. The 3rd building was modelled with CFST columns and ISWB550 beam section. To examine the effect of irregularity at different levels and change in design parameters of a building, the size of the CFST columns was reduced. The loading on all the buildings is kept the same. Table-1 shows the building model along with the different types and sizes of columns being utilized. Table-2 shows the details required for the modelling and analysis of all buildings. The structures are modelled and analyzed using E-tabs 2017 and the usual modelling procedure is carried out. Fig 3 shows the plan view of all buildings. Fig (4) and (5) show the elevation for irregular and regular buildings respectively.

Table-1: Shows the building models along with the type and size of columns

Building Model ID	Description
B1-CFST	Concrete Filled Steel Tube Column (CFST) of size 700x450mm with RC beam.
B2-RCC	Reinforced Concrete Column (RCC) of size 700x450mm with RC beam.
B3-CFST	CFST Column of size 400x300mm with RC beam.
B4-CFST	CFST Column of size 300x300mm with RC beam.
B5-CFST	CFST Column 700x450mm with ISWB5-CFST50 Beam.

The details mentioned in Table (1) and (2) are used to design and analyze the building frames using E-tabs. The buildings were analyzed using Equivalent Static Method and response spectrum method as per IS 1893-2016. Various parameters like Deadweight, base shear, maximum storey displacement, maximum storey drift, time period, maximum storey shear, maximum overturning moment are studied.

Table-2: Geometrical and material properties of buildings

Description	Specification
The total height of the building	42 m
Storey height	3.5 m
No. of bays in X-direction	7
No. of bays in Y-direction	5
Width of a bay in X-direction	5
Width of a bay in Y-direction	6
Type of column	Rectangular
Size of beam	400x350 mm
Thickness of slab	150 mm
Grade of concrete for beams	M30
Grade of concrete for columns	M35
Grade of reinforcing bars	Fe 415
Grade of structural steel	Fe 345
Live load on all floors	3 kN/m^2
Imposed load on all floors	2 kN/m^2
Density of concrete	25 kN/m^3
Seismic zone	V
Soil type	Medium
Importance factor	1
Response reduction factor	5

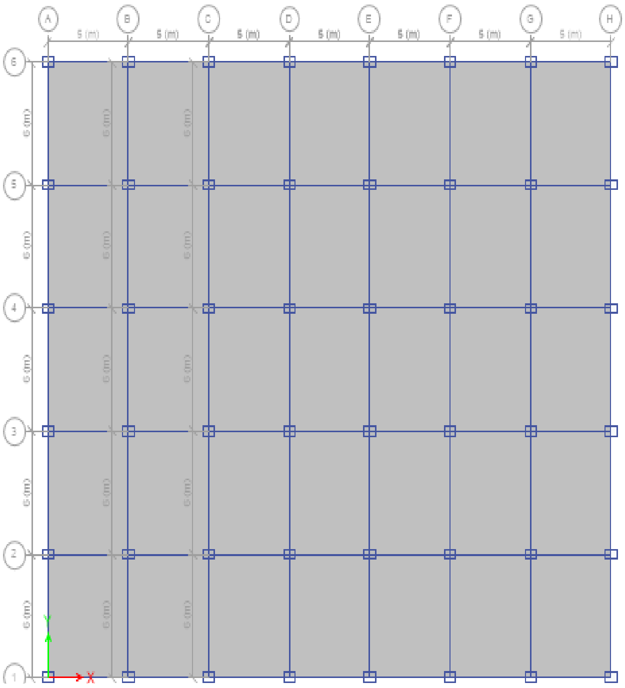


Fig. 3. Floor plan of the building

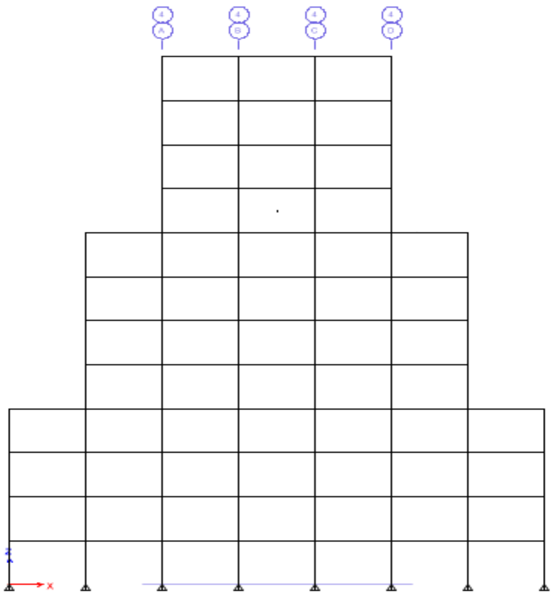
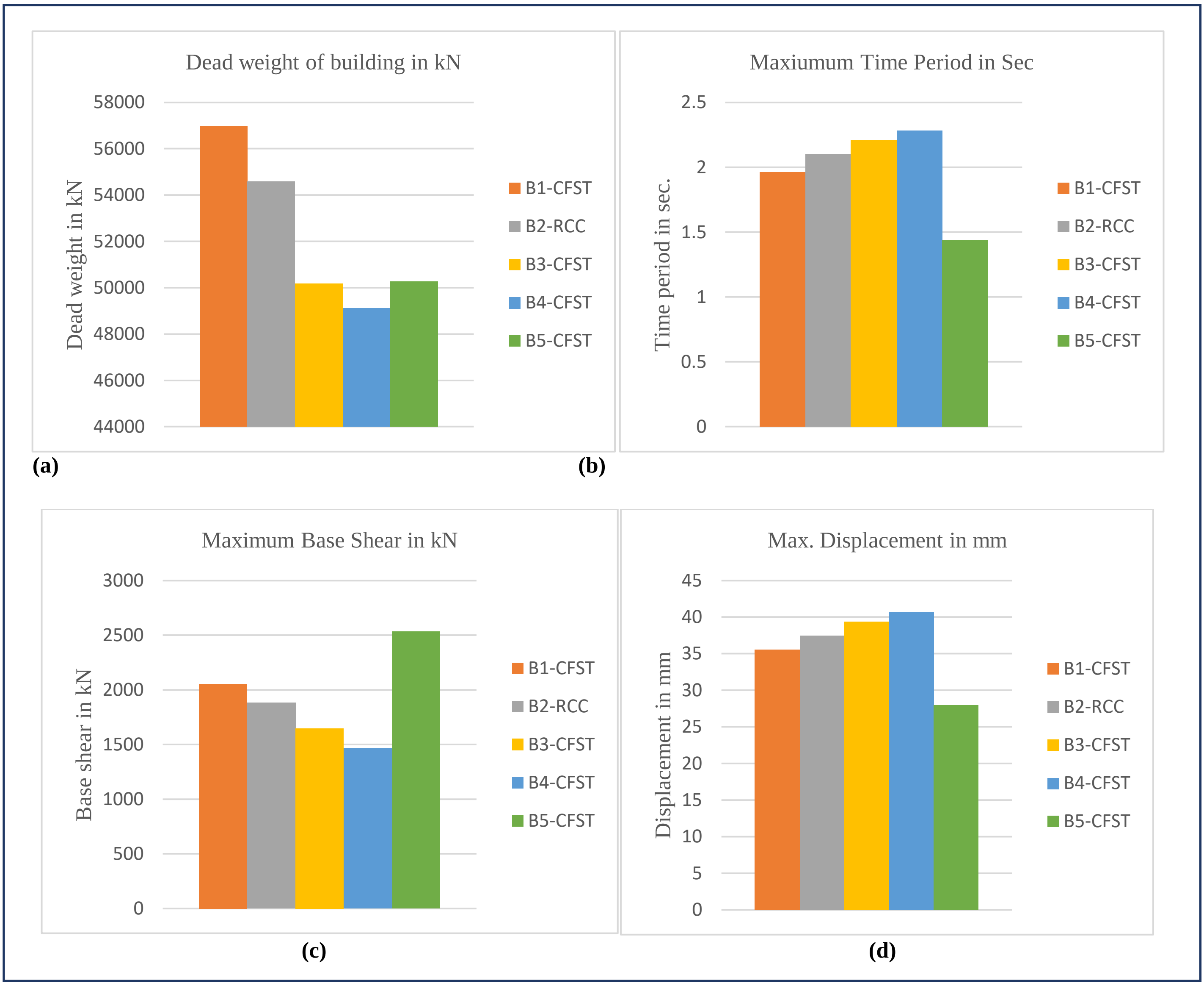


Fig. 4. Elevation of the irregular building

III. RESULTS AND DISCUSSION.

Models ID	Deadweight of building in kN	Max. Time Period in Sec.	Base Shear in kN	Max. Displacement in mm	Max. Drift	Max. Overturning moment kN-m
B1-CFST	56987.979	1.962	2053.8271	35.513	0.001336	32594.231
B2-RCC	54577.879	2.103	1882.2817	37.504	0.001426	30287.562
B3-CFST	50187.625	2.21	1647.8173	39.402	0.001501	27263.687
B4-CFST	49108.308	2.283	1466.8056	40.657	0.001551	24998.226
B5-CFST	50264.433	1.434	2533.308	27.984	0.001068	43769.046

Table-3: Results obtained for different response parameters



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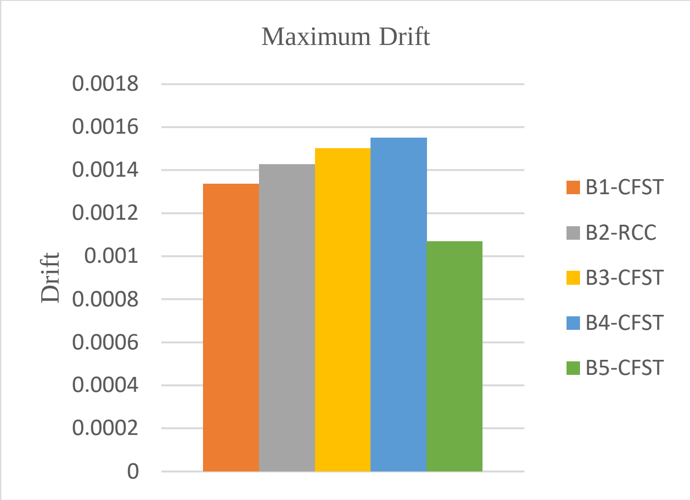
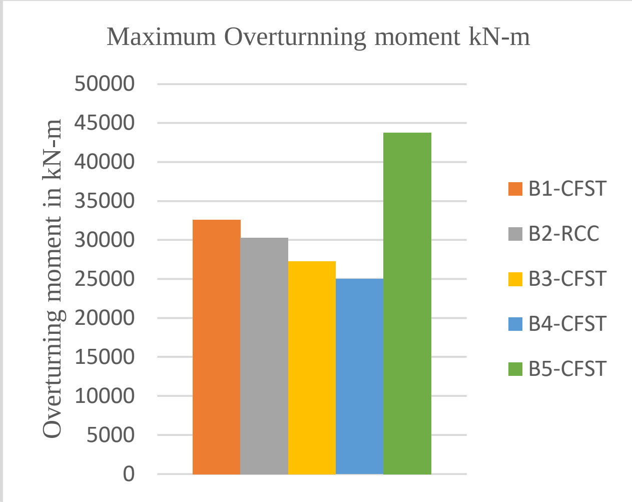


(e)



(f)

Fig. 5. Shows variation of (a) Dead load (b) Max. Displacement (c) Max. Time period (d) Max. Drift (e) Max. overturning moment (f) Max. Base shear.

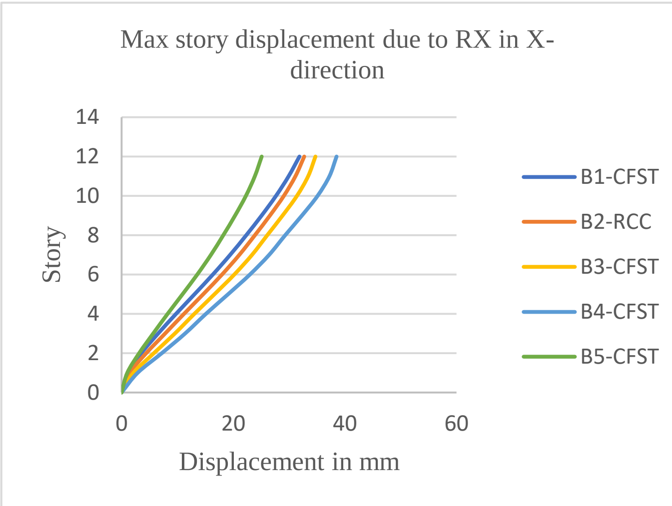


Fig. 6. shows the variation of displacement in X-direction.

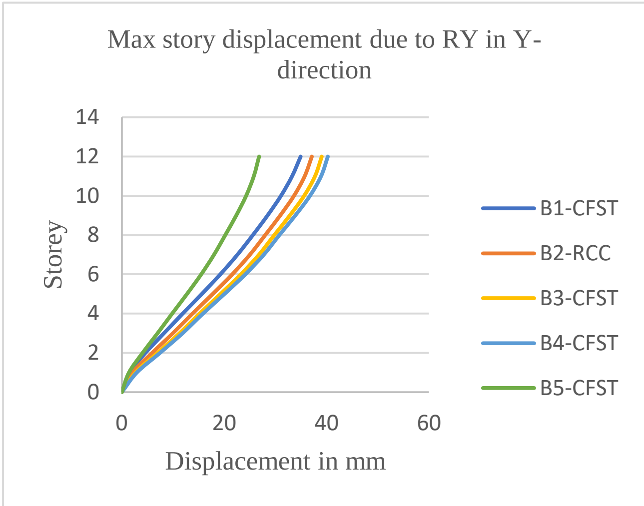


Fig. 7. Shows the variation of displacement in Y-direction.

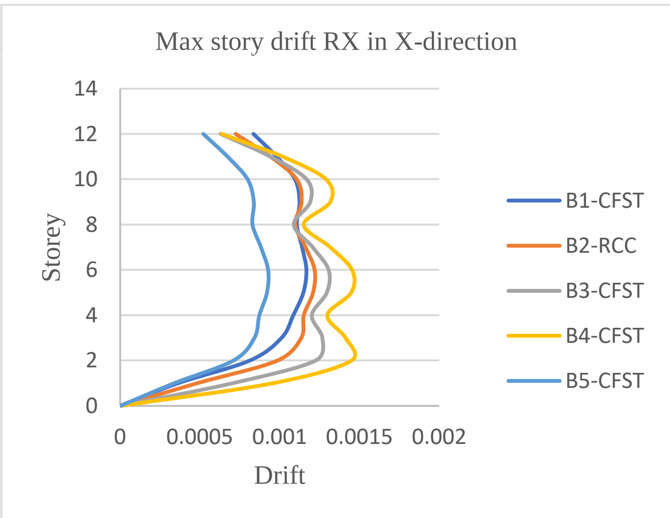


Fig. 8. shows the variation of drift in X-direction.

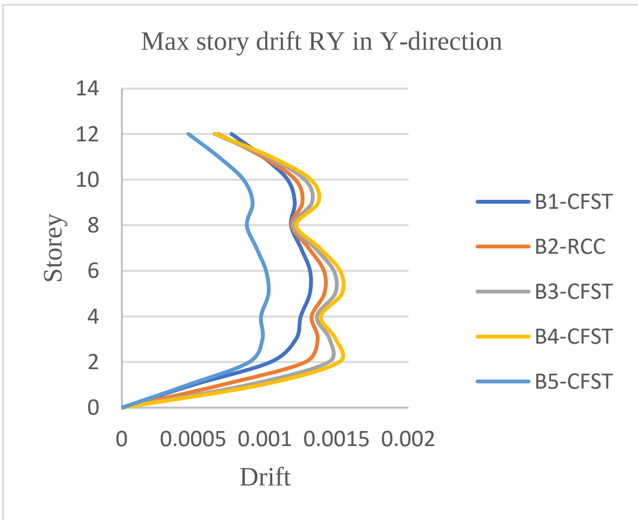


Fig. 9. shows the variation of drift in Y-direction.

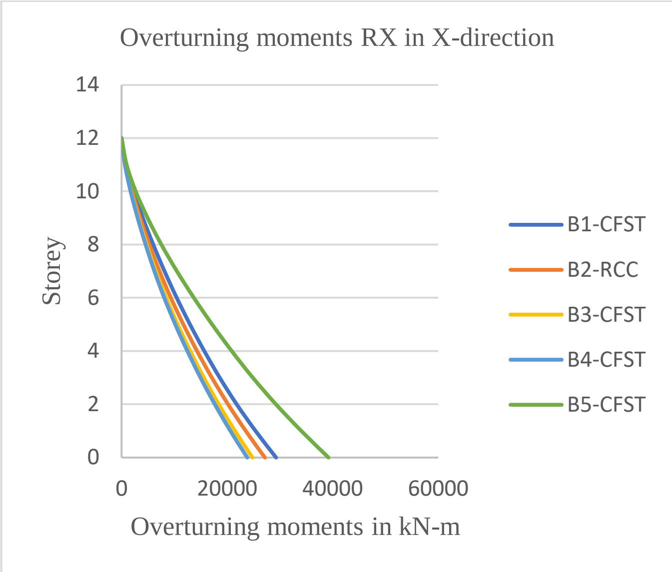


Fig. 10. shows the variation of overturning moment in X-direction.

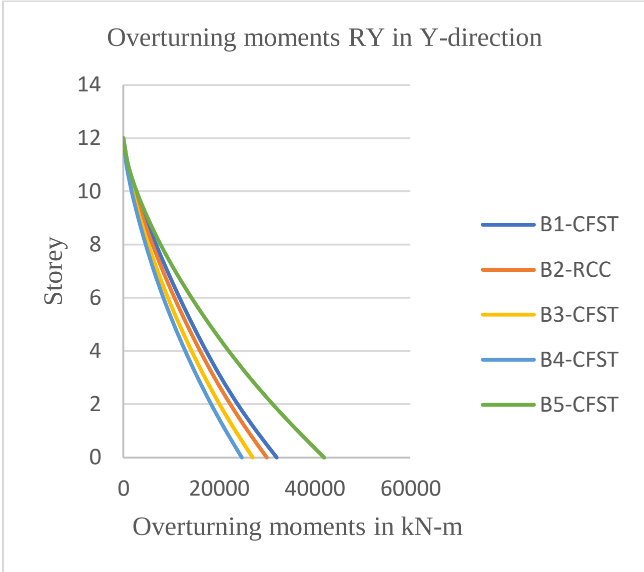


Fig. 11. Shows the variation of overturning moment in Y-direction.

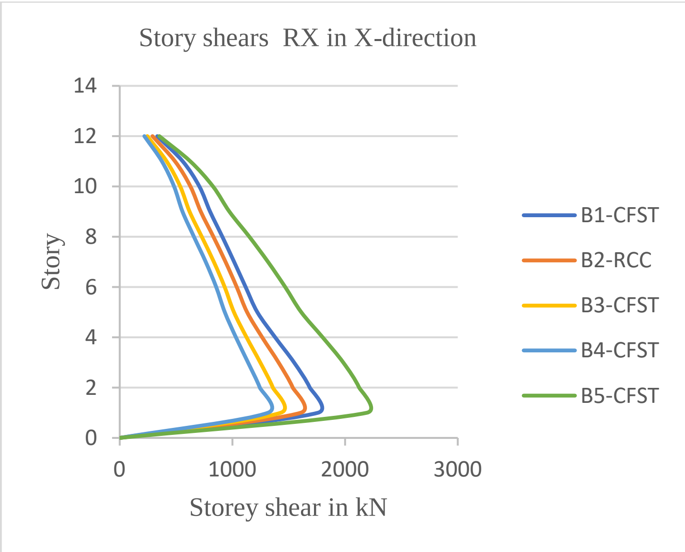


Fig. 12. Shows the variation of Story shears in X-direction.

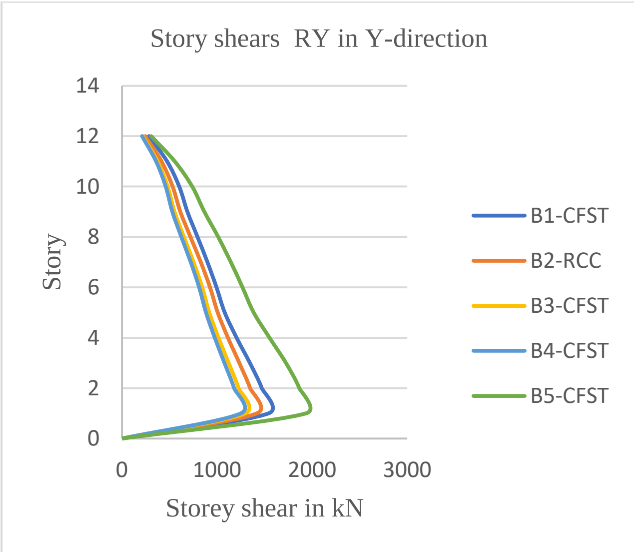


Fig. 13. shows the variation of Story shears in Y-direction.

The dead load building B1-CFST is more than B2-RCC and building B5-CFST and has very little weight compared to B1-CFST and B2-RCC. It is seen that as the size of CFST columns is reduced the dead load of the building is reduced which are represented by building B3-CFST and B4-CFST. The time period in building B1-CFST is found to be less than B2-RCC. The Time period is found least in B5-CFST and it is found that as the size of the CFST column in building B3-CFST and B4-CFST is reduced the time period increases which results in a decrease in stiffness. Displacement in B1-CFST is found to be less than B2-RCC.

The Displacement is found least in B5-CFST and it is found that as the size of the CFST column in building B3-CFST and B4-CFST is reduced the Displacement of building increases. An overturning moment in B1-CFST is found to be greater than B2-RCC. The Overturning moment is found highest in B5-CFST and it is found that as the size of the CFST column is reduced in building B3-CFST and B4-CFST the Overturning moment of building decreases. The overturning moment in B1-CFST is found to be greater than B2-RCC.

The Overturning moment is found highest in B5-CFST and it is found that as the size of the CFST column is reduced in building B3-CFST and B4-CFST the Overturning moment of building decreases. Storey drifts in B1-CFST are found to be less than B2-RCC. The Storey drifts is found least in B5-CFSTand it was found that as the size of the CFST column is reduced in building B3-CFST and B4-CFST the Storey drifts of building increases.

IV. CONCLUSION

1. The dead load of the building (B1-CFST) with CFST columns and RC beams is increased by 4% than RCC building (B2-RCC) for the same column dimensions and the dead weight of building (B5-CFST) with CFST columns and ISWB550 beam is reduced by 7.9% than RCC buildings.

2. It is observed that the time period of building B1-CFST is decreased by 6.7% than building B2-RCC and the time period of B5-CFST is decreased by 31.8% compared to B2-RCC, thus resulting in an increase of stiffness building with CFST columns.
3. The base shear of building B1-CFST is increased by 8.3% than building B2-RCC and the base shear of building B5-CFST is increased by 25.6% compared to B2-RCC.
4. The displacement of building B1-CFST is decreased by 5.3% than building B2-RCC and the displacement of building B5-CFST is decreased by 25.35% compared to B2-RCC.
5. The drift of building B1-CFST is decreased by 6.3% than building B2-RCC and the drift of building B5-CFST is decreased by 25.35% compared to building B2-RCC.
6. The overturning moment of building B1-CFST is increased by 7.07% than building B2-RCC and the overturning moment of building B5-CFST is increased by 30.8% compared to building B2-RCC.
7. The performance of the building with CFST columns is found to more as compared to conventional RCC columns in terms of drift and displacement of the buildings.

From the above observations, it is concluded that the required size of CFST columns to pass the design check is less than that of RCC columns thus the dead load of the structure is reduced to a greater extent. This makes these columns more suitable for high seismic zones. The overall response of building with CFST columns is much better than RCC columns i.e. less displacement, more resistance to structural forces/actions.

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