JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

# A Comparative Study of T-shaped Multi-storey Building using Rectangular and Special Shaped Columns

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## ABSTRACT

Architects frequently impose size restrictions on columns in order to maximize available space and maintain the building's good aesthetics by preventing columns from projecting past walls and corners. This is typically neither economically or structurally practical, hence an alternative approach is needed to get over this challenge that faces all structural design engineers. Because non-rectangular unique shaped columns outperform traditional rectangular columns structurally, they have been researched and identified as a potential solution to the aforementioned issue. The T-shaped building plan, with a total width of 46.5 m and 21 m (Y-direction) and a total length of 84 m (X-direction), is the subject of this study

Using E-Tabs software, trial and error is used to establish the economically viable sizes of columns in a 20-story building model that is analyzed using special-shaped (L, T,+ Plus) columns. Once more, the identical building model is examined using traditional rectangular columns. In order to get all columns to pass the design criteria and satisfy building drift/deflection and design requirements in line with IS 16700-2023, IS456-2000, IS875-2015, and IS1893-2016, the most cost-effective section sizes are acquired using a trial and error process. The T-shaped building with specially designed columns outperforms the building with traditional rectangular columns under seismic and wind stress conditions, according to a thorough analysis and comparison. The study's conclusion is that, if special-shaped columns are taken into consideration, the cost of building multi-story buildings, such as apartments, hotels, offices, etc., would be lower with more open space and a column-free appearance because, in comparison, smaller columns are needed for the same amount of beams and spans. This also benefits the environment because using fewer construction materials means emitting fewer carbon emissions.

**Keywords:** E-TABS, special shaped columns (SSC), seismic load, wind load, displacement, storey shear, storey drift and base shear, overturning moment.

## I. INTRODUCTION

Rapid development and drastic changeof urban construction and various design requirements of architects, different methods of structural design of buildings came into existence. The customers need more than basic housing function from the building as day after day the living standards of people improve greatly. They need their dwelling places to be perfect in terms of aesthetics. So frame structure with special shaped columns is suitable especially for villa and multi-storey buildings. This type of structure satisfies area requirements of corners and intersection of the wall and intersection of corners so that no edges or prominent columns would appear in the buildings and so the actual usable floor area is increased and more furniture can be placed in the rooms and thus increasing the utility of the buildings.

## SPECIAL SHAPED COLUMNS

In RCC buildings, columns are structural members which are basically subjected to axial compressive forces, moments, and transfers total load from the super structure to sub-structure. The columns of different shapes are used. Some common shapes are square, rectangular, circular columns and some special shapes of columns are L-shaped, T- shaped and Plus (+) shaped columns as shown in Fig. 1 which are not used very often but gives more usable space than commonly used shapes of columns. Special shaped columns (SCC) avoid columns protruding at corners in a room as columns are flushed with walls

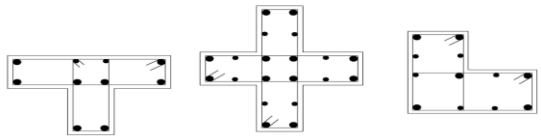


Fig. 1 Special shaped (T,+,L) columns with longitudinal and shear reinforcement

Concrete structures with special shaped columns have many advantages such as:

- Stiffness in both the axes
- Usable floor area is increased

- Avoiding visible corners in the rooms
- Dead load of the structure is lowered etc.

The better performance of the buildings in seismic and wind loads conditions can be achieved by using high strength steel bars and high strength concrete in construction. The present study is performed using M30 grade of concrete. The reinforced cement concrete (RCC) structure system with special shaped columns can be a system widely adopted in residential structures due to no exposed beams and columns in the room.

Frame structures with few RCC special shaped columns have been used in multi-storey dwelling buildings over recent decades in China. The thickness of special shaped column leg is the same as a wall, so the edges of columns are invisible and the structure with special shaped columns is beautiful in aesthetics and appearance. But the section of special shaped column is irregular and its behavior is different from that of rectangular column. Sometimes, the special shaped columns with different limb lengths may be adopted in actual engineering, but in present study similar limb lengths of the shaped columns are used.

In this study comparison of building model using all special shaped RCC columns is done with building model using conventional rectangular shaped RCC columns.

## II. MODEL DATA

Grade of steel used is Fe500.
Grade of concrete used for beams is M30 and columns is M40.
($f_{ck}$ = 30 N/mm$^2$)
Young's modulus

M30 concrete, $E$ = 27.386x10$^3$kN/m$^2$ (5000x$\sqrt{f_{ck}}$)

M40 concrete, $E$ = 31.623x10$^3$kN/m$^2$ (5000x$\sqrt{f_{ck}}$)

Density of reinforced concrete = 25 kN/m$^3$

**Building model details:**

The model details are given below:

| | |
|---|---|
| Number of storeys | = G+20 storeys |
| Floor to floor height | = 3.2 m (typical) |
| Longitudinal beam size | = 230 mm x 600mm |
| Transverse beam size | = 230 mm x 450mm |
| Transverse Edge beam size | = 300 mm x 900mm |
| Thickness of slab | = 150 mm |
| Thickness of external walls | = 230 mm |
| Thickness of internal walls | = 150 mm |

## III.LOADING

**Dead Loads (DL):**

Dead loads are taken from IS 875 (Part-1)-1987 Table2.

| | |
|---|---|
| Self-weight of slab (150 mm thick slab) | = 3.75kN/m$^2$ |
| Suspended metal lath and gypsum plaster | = 0.50 kN/m$^2$ |

**Wall Loads:**

Taking density of brick wall = 18 kN/m$^2$

External walls are considered 230mm thick, and internal walls are considered 150mm thick

| | |
|---|---|
| Floor finishes | = 2.0 kN/m$^2$ |
| Roof finishes | = 2.0 kN/m$^2$ |

**Live Loads (LL):**

Live loads taken from IS 875 (Part-2)-1987 Table 1.
Flat roof with access provided, imposed load = 1.5 kN/m$^2$
Considering residential building i.e., dwelling houses

| | |
|---|---|
| Live load for all rooms and kitchen | = 2.0 kN/m$^2$ |
| Live load for toilet and bathrooms | = 2.0 kN/m$^2$ |
| Live load for passage and staircase | = 3.0 kN/m$^2$ |
| Live load for balconies | = 3.0 kN/m$^2$ |

**Seismic Loads (EQ):**

Seismic loads are calculated as per IS 1893 (Part-1) 2016.
**Note:** With reference to Annex-E of IS 1893, building is considered in Zone-V with Z = 0.36.Hence, this building evaluation study is applicable to buildings in all severe seismic zones.
In seismic analysis, three factors are to be considered, they are:
1. Response reduction factor (R)
2. Zone factor (Z)
3. Importance factor (I)

The eccentricity of the loads is considered as 5%.
The response reduction factor is taken from Table 7 of IS 1893. Considering the building as RC moment resisting frame, R = 5.0.
Consider the soil as Type-II medium soil as per Table 1of IS 1893.
The importance factor (I) is taken from Table 6 of IS 1893. Considering the building as residential with occupancy more than 200 people, the importance factor I = 1.2 is considered for structural design.
The seismic load is calculated by the software itself from the above given input data.
For various zones, zone factors are given from Table 2 of IS 1893.
Dynamic loads (response spectrum method) are represented by Spec-1, Spec-2, Spec-3.
Where;
Spec-1 = Dynamic Loads in X direction.
Spec-2 = Dynamic Loads in Y direction.
Spec-3 = Dynamic Loads in Z direction.

**Wind Loads (WL):**

Wind loads are taken from IS 875(Part-3)-2015.
Basic wind speed considered $V_b$ = 50 m/s as per Clause 6.2, Annexure-A (considered maximum wind speed available in the list for worst case scenario).
Design wind speed $V_z = V_b K_1 K_2 K_3 K_4$
$K_1$ = risk coefficient obtained from Table 1
$K_2$ = terrain height and structure size factor is obtained from Table 2 of IS 875 Part 3- 2015.
$K_3$ = topography factor from Clause 6.3.3
$K_4$ = importance factor in cyclone zone from Clause 6.3.4.
$K_1$ = 1.0, $K_2$ = 1.0, $K_3$ = 1.0, $K_4$= 1.0
Assume the terrain category as 3 and class B.

## IV. OBJECTIVES OF THE STUDY

The present study is aimed at evaluating existing RCC framed buildings with the following objectives:

- Generation of 3D building models with conventional rectangular columns and special shaped (L, T, + Plus) columns.
- Determination of deflections, storey drifts, base shear and overturning moments of the buildings under wind and seismic conditions.
- To find whether special shaped columns are suitable and economical compared to conventional rectangular columns for the given loads.
- To study the behavior of the building under lateral loads like seismic (static and dynamic) and wind loads.

**Parametric Studies:**

The different parameters like displacement, storey drift, base shear and the overall behavior of the structures when subjected to different loads is studied and compared with reference to the columns.

**Tall Building consideration:**

Since the building height is more than 50 m, it comes under the category of tall building structure.

All the parameters have been considered in the analysis and design of the building models in compliance with IS 16700-2023. Cracked section properties of RC members has been considered as per Table 5 and moment of inertia of the columns and beams sections has been reduced to 70% and 35% respectively for limit state of design of the section and 90% and 70% for limit state of serviceability.

## V. CASE STUDY AND METHODOLOGY

For this study, a T-shaped building plan is considered with total width of 46.5m and 21m (Y-direction) and total length of 84 m (X-direction). The span (column to column distance) in X-direction is taken as 6 m and in Y-direction as 4.5 m with a corridor of width 3m in between. The same building is analyzed with special shaped (L, T, + Plus) columns. Building models with 20 storeys are taken and the economical sizes of columns are determined by trial and error with E-TABS software.

Again the same building model with conventional rectangular columns of model of 20 storeys is generated and analyzed for the study.

The height of each floor is taken as 3.2m and the buildings are designed in compliance with the relevant Indian Codes of Practice. The buildings are assumed to be fixed at base and floor slabs act as rigid diaphragms. The columns are rectangular, L, T, + Plus) shaped and their sizes varies.

The foundation depth is taken as 2.5 m and all other storey heights are taken 3.2m as constant including ground floor. All external walls are assumed to be of 230 mm thickness and all internal walls as150 mm thick. Beams in X-direction are 230 mm x 600 mm size and beams in Y-direction are 230 mm x 450 mm size. Slab thickness is taken as 150mm thick.

The buildings are modeled using E-TABS. Seismic zone is Zone-V and the type of buildings considered as residential apartment. In seismic analysis only 25% of the floor live load is considered as per IS1893-2016 for live load ≤ 3 kN/m$^2$.Ground floor has been considered as stilt floor to use as car parking area with slab on grade without any infill brick walls, hence no slab or wall load has been modeled at ground floor level.E-TABS software has been used for the analysis and design of building models. Multi-storey building models are analyzed and designed using conventional rectangular columns and special shaped (L, T and Plus + shape) columns and a comparative study of both type of buildings has been performed. The buildings are modeled and analysed for static wind load and dynamic seismic load using response spectrum method.

Buildings are designed based on forces obtained by static and dynamic analysis and detailed comparison of the results have been performed. A span of nearly 4.5m to 6m c/c between columns has been chosen for the present study. Lateral loads like wind and seismic loads have also been applied as per requirements of IS 875 (Part 3)-2015 and IS 1893-2016 and comparative study of storey displacement, storey shear, storey drift, base shear, overturning moment has been done using static and dynamic seismic analysis. Fig.3 shows isometrics view, Fig-4 shows front elevation, Fig. 5 shows SSC column layout foundation to 10$^{th}$ floor, Fig. 6 indicates SSC column layout 10$^{th}$ floor to Roof, Fig. 7 shows rectangular column layout foundation to 10$^{th}$ floor and Fig. 8 indicates rectangular column layout 10$^{th}$ floor to roof and Fig-9 is for side elevation.

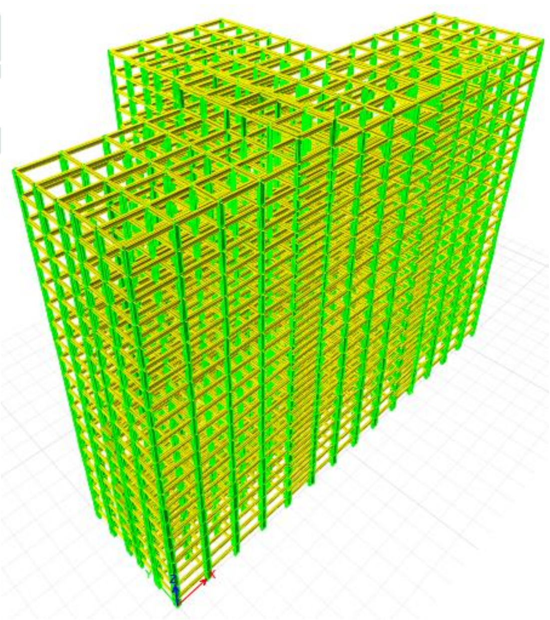


**Fig. 2: Isometric view**

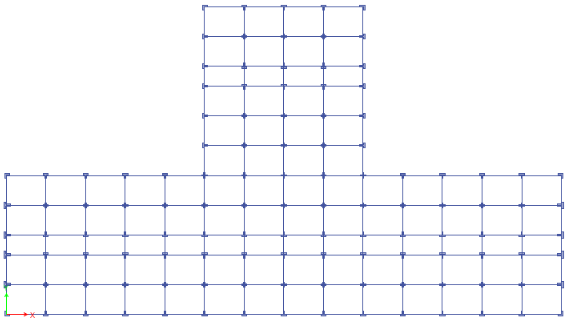


Fig. 3: Framing Plan

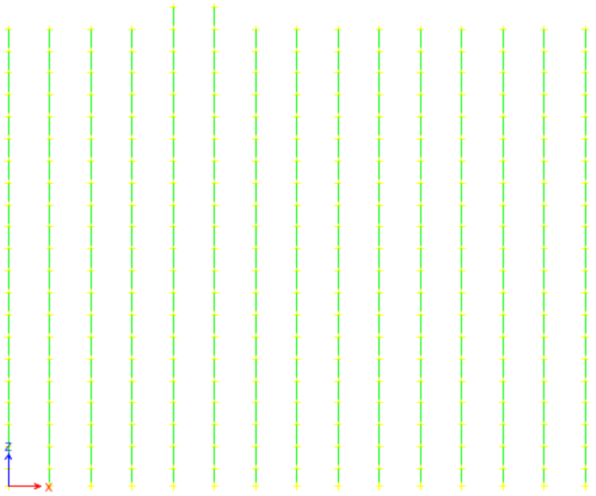


Fig. 4: Front Elevation

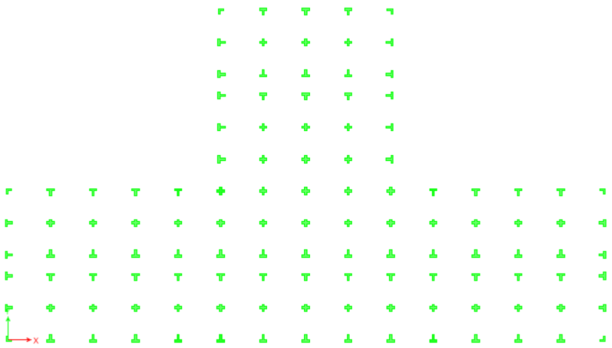


Fig. 5: SSC column layout foundation to 10th floor

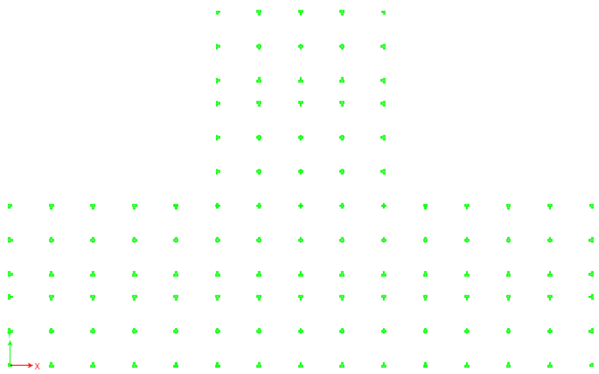


Fig. 6: SSC column layout 10th floor to Roof

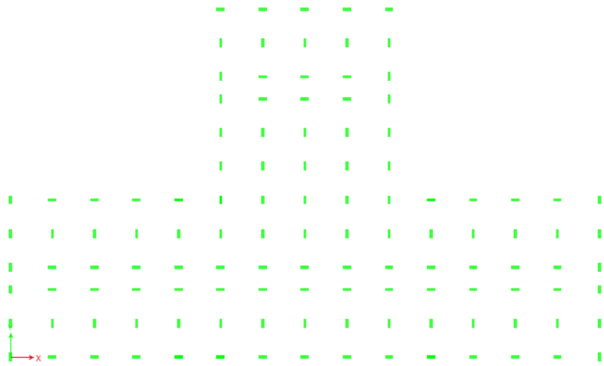


Fig. 7: Rectangular column layout foundation to 10th floor

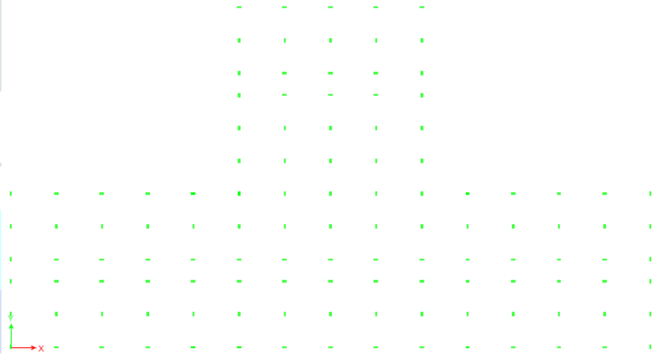


Fig. 8: Rectangular column layout 10th floor to roof

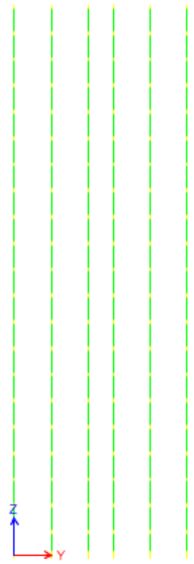


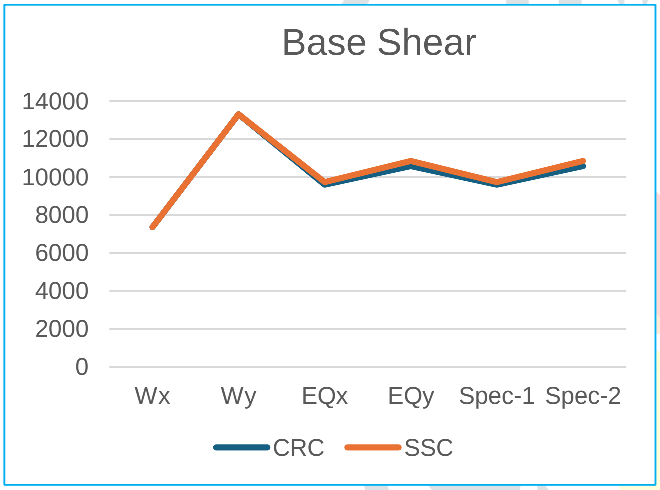
Fig. 9: Side Elevation

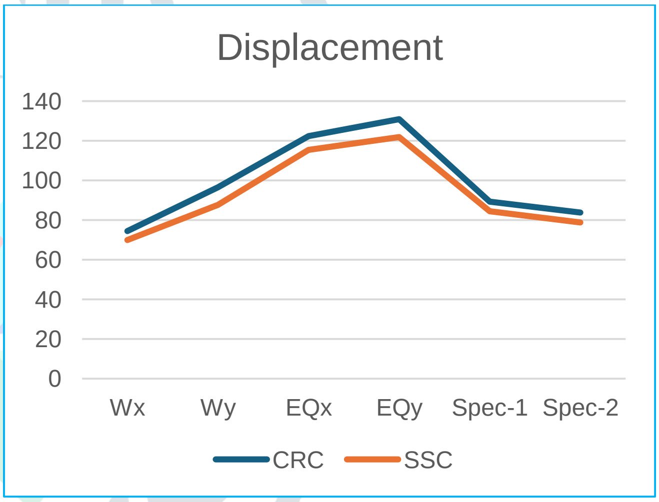
## VI. RESULTS AND DISCUSSION

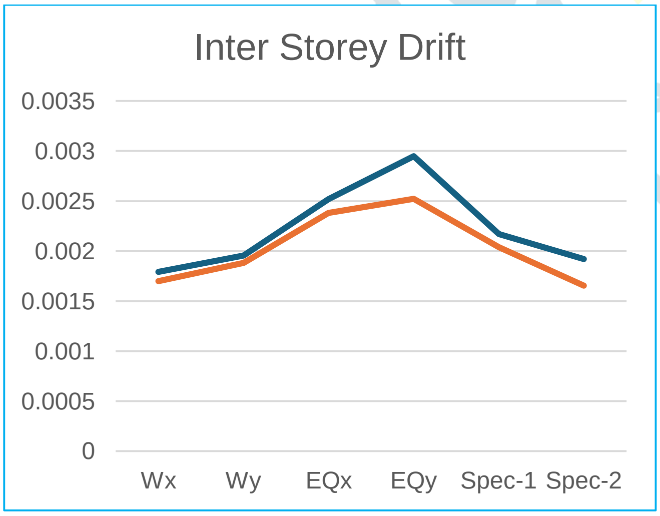
Table 1 gives shows the ETABS analysis results for special shaped and rectangular columns

**Table-1: Column structural analysis (ETABS results)**

| Rectangular shaped column (Rect.) section analysis | | | | | | | Special Shaped column (SSC) section analysis | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sl. No. | Load | Base shear (kN) | Max. storey displacement (mm) | Max. storey drift ratio | Overturning moment (kN-m) | | Base shear (kN) | Max. storey displacement (mm) | Max. storey drift ratio | Overturning moment (kN-m) |
| 1 | Wx | 7357 | 74.44 | 0.001792 | 320324 | | 7357 | 69.91 | 0.001698 | 317492 |
| 2 | Wy | 13294 | 96.52 | 0.001954 | 559538 | | 13294 | 87.63 | 0.001881 | 554292 |
| 3 | EQx | 9600 | 122.28 | 0.00252 | 533870 | | 9727 | 115.36 | 0.002382 | 520899 |
| 4 | EQy | 10566 | 130.98 | 0.00295 | 518687 | | 10840 | 121.80 | 0.002523 | 504874 |
| 5 | Spec-1 | 9600 | 89.31 | 0.00217 | 435348 | | 9727 | 84.48 | 0.002040 | 424770 |
| 6 | Spec-2 | 10566 | 83.86 | 0.00192 | 408325 | | 10840 | 78.84 | 0.001653 | 401243 |
| 7 | Spec-3 | 0.002 | 0.05 | 0.000002 | 150 | | 4.40 | 0.021 | 0.000001 | 59 |



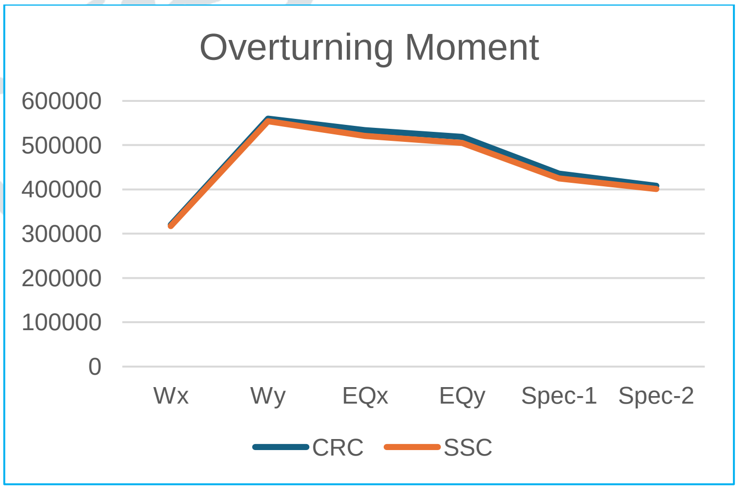



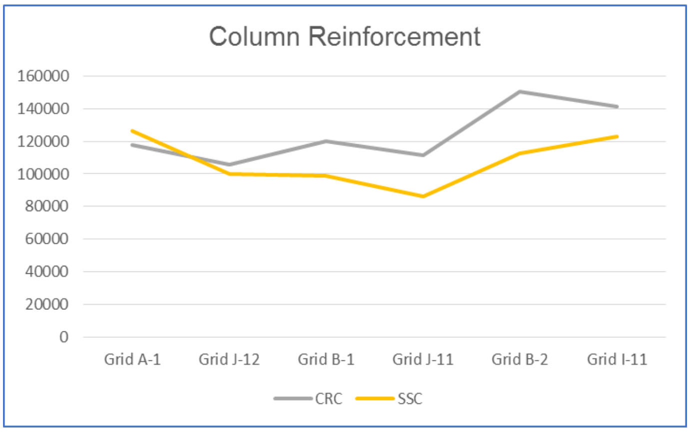
Table-2 shows Column design results.

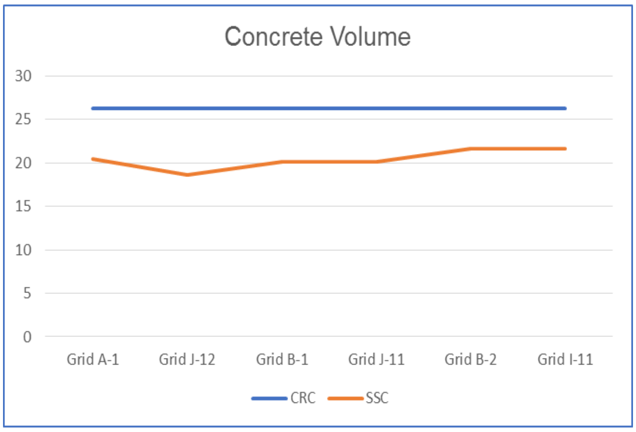
| Table-2:Column Section Design (ETABS Results) Representative Columns | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Rectangular Column (Rect.) Section Design** | | | | | | **Specially Shaped Column (SSC) Section Design** | | | |
| Column at grid A-1 | | | | | | | | | |
| LEVELS | Long. Reinf. | Shear Reinf. | Column Size | Conc. Qty | | Long. Reinf. | Shear Reinf. | Column Size | Conc. Qty |
| | mm$^2$ | mm$^2$ | mm | CuM | | mm$^2$ | mm$^2$ | mm | CuM |
| 19F-20F | 3395 | 831.33 | C2-300X750 | 0.72 | | 3497 | 498.80 | L-230x450 | 0.83 |
| 18F-19F | 2053 | 831.33 | C2-300X750 | 0.72 | | 2057 | 498.80 | L-230x450 | 0.83 |
| 17F-18F | 2235 | 831.33 | C2-300X750 | 0.72 | | 2386 | 498.80 | L-230x450 | 0.83 |
| 16F-17F | 2487 | 831.33 | C2-300X750 | 0.72 | | 2543 | 498.80 | L-230x450 | 0.83 |
| 15F-16F | 2402 | 831.33 | C2-300X750 | 0.72 | | 2689 | 498.80 | L-230x450 | 0.83 |
| 14F-15F | 2507 | 831.33 | C2-300X750 | 0.72 | | 3113 | 498.80 | L-230x450 | 0.83 |
| 13F-14F | 2687 | 831.33 | C2-300X750 | 0.72 | | 3862 | 498.80 | L-230x450 | 0.83 |
| 12F-13F | 2928 | 831.33 | C2-300X750 | 0.72 | | 4513 | 498.80 | L-230x450 | 0.83 |
| 11F-12F | 3007 | 831.33 | C2-300X750 | 0.72 | | 4455 | 498.80 | L-230x450 | 0.83 |
| 10F-11F | 4616 | 831.33 | C2-300X750 | 0.72 | | 3065 | 498.80 | L-230x450 | 0.83 |
| 9F-10F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 2913 | 831.33 | L-230x750 | 1.27 |
| 8F-9F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4083 | 831.33 | L-230x750 | 1.27 |
| 7F-8F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4912 | 831.33 | L-230x750 | 1.27 |
| 6F-7F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 5478 | 831.33 | L-230x750 | 1.27 |
| 5F-6F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 8962 | 831.33 | L-230x750 | 1.27 |
| 4F-5F | 4362 | 1330.12 | C1-450X1200 | 1.728 | | 5148 | 831.33 | C-400x750 | 0.96 |
| 3F-4F | 4831 | 1330.12 | C1-450X1200 | 1.728 | | 6718 | 831.33 | C-400x750 | 0.96 |
| 2F-3F | 7106 | 1330.12 | C1-450X1200 | 1.728 | | 8520 | 831.33 | C-400x750 | 0.96 |
| 1F-2F | 8534 | 1330.12 | C1-450X1200 | 1.728 | | 10104 | 831.33 | C-400x750 | 0.96 |
| GF-1F | 9478 | 1330.12 | C1-450X1200 | 1.728 | | 11223 | 831.33 | C-400x750 | 0.96 |
| BASE-GF | 10669 | 1330.12 | C1-450X1200 | 1.728 | | 11889 | 831.33 | C-400x750 | 0.96 |
| **Sub Total Qty** | **94897** | **22944.62** | | **26.208** | | **112130** | **14132.63** | | **20.4432** |
| Column at grid J-12 | | | | | | | | | |
| 19F-20F | 3404 | 831.33 | C2-300X750 | 0.72 | | 3186 | 498.8 | L-230x450 | 0.83 |
| 18F-19F | 2359 | 831.33 | C2-300X750 | 0.72 | | 1980 | 498.8 | L-230x450 | 0.83 |
| 17F-18F | 2847 | 831.33 | C2-300X750 | 0.72 | | 2545 | 498.8 | L-230x450 | 0.83 |
| 16F-17F | 3198 | 831.33 | C2-300X750 | 0.72 | | 3010 | 498.8 | L-230x450 | 0.83 |
| 15F-16F | 3456 | 831.33 | C2-300X750 | 0.72 | | 3982 | 498.8 | L-230x450 | 0.83 |
| 14F-15F | 3653 | 831.33 | C2-300X750 | 0.72 | | 5031 | 498.8 | L-230x450 | 0.83 |
| 13F-14F | 3828 | 831.33 | C2-300X750 | 0.72 | | 5582 | 498.8 | L-230x450 | 0.83 |
| 12F-13F | 4005 | 831.33 | C2-300X750 | 0.72 | | 6427 | 498.8 | L-230x450 | 0.83 |
| 11F-12F | 4070 | 831.33 | C2-300X750 | 0.72 | | 7319 | 498.8 | L-230x450 | 0.83 |
| 10F-11F | 4641 | 831.33 | C2-300X750 | 0.72 | | 6614 | 498.8 | L-230x450 | 0.83 |
| 9F-10F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 2337 | 831.33 | L-230x750 | 0.935 |
| 8F-9F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 2337 | 831.33 | L-230x750 | 0.935 |
| 7F-8F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 2337 | 831.33 | L-230x750 | 0.935 |
| 6F-7F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 2337 | 831.33 | L-230x750 | 0.935 |
| 5F-6F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 2337 | 831.33 | L-230x750 | 0.935 |
| 4F-5F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 2337 | 831.33 | L-230x750 | 0.935 |
| 3F-4F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 2391 | 831.33 | L-230x750 | 0.935 |
| 2F-3F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 3944 | 831.33 | L-230x750 | 0.935 |
| 1F-2F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 5137 | 831.33 | L-230x750 | 0.935 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| GF-1F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 6802 | 831.33 | L-230x750 | 0.935 |
| BASE-GF | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 8114 | 831.33 | L-230x750 | 0.935 |
| **Sub Total Qty** | **82981** | **22944.62** | | **26.208** | | **86086** | **14132.63** | | **18.59872** |
| Column at grid B-1 | | | | | | | | | |
| 19F-20F | 5583 | 831.33 | C2-300X750 | 0.72 | | 3601 | 665.06 | T-230x600 | 0.714 |
| 18F-19F | 3315 | 831.33 | C2-300X750 | 0.72 | | 1785 | 665.06 | T-230x600 | 0.714 |
| 17F-18F | 3335 | 831.33 | C2-300X750 | 0.72 | | 1785 | 665.06 | T-230x600 | 0.714 |
| 16F-17F | 3345 | 831.33 | C2-300X750 | 0.72 | | 1785 | 665.06 | T-230x600 | 0.714 |
| 15F-16F | 3373 | 831.33 | C2-300X750 | 0.72 | | 1785 | 665.06 | T-230x600 | 0.714 |
| 14F-15F | 3593 | 831.33 | C2-300X750 | 0.72 | | 1785 | 665.06 | T-230x600 | 0.714 |
| 13F-14F | 4339 | 831.33 | C2-300X750 | 0.72 | | 1823 | 665.06 | T-230x600 | 0.714 |
| 12F-13F | 5468 | 831.33 | C2-300X750 | 0.72 | | 2420 | 665.06 | T-230x600 | 0.714 |
| 11F-12F | 6535 | 831.33 | C2-300X750 | 0.72 | | 4360 | 665.06 | T-230x600 | 0.714 |
| 10F-11F | 8275 | 831.33 | C2-300X750 | 0.72 | | 5287 | 665.06 | T-230x750 | 0.935 |
| 9F-10F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 2541 | 831.33 | T-230x750 | 0.935 |
| 8F-9F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4217 | 831.33 | T-230x750 | 0.935 |
| 7F-8F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 5342 | 831.33 | T-230x750 | 0.935 |
| 6F-7F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 6503 | 831.33 | T-230x750 | 0.935 |
| 5F-6F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 6746 | 831.33 | T-230x750 | 0.935 |
| 4F-5F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | T-300x850 | 1.344 |
| 3F-4F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | T-300x850 | 1.344 |
| 2F-3F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | T-300x850 | 1.344 |
| 1F-2F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | T-300x850 | 1.344 |
| GF-1F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 5091 | 1108.43 | T-300x850 | 1.344 |
| BASE-GF | 6600 | 1330.12 | C1-450X1200 | 1.728 | | 8228 | 1108.43 | T-300x850 | 1.344 |
| **Sub Total Qty** | **96961** | **22944.62** | | **26.208** | | **81404** | **17457.83** | | **20.098** |
| Column at grid J-11 | | | | | | | | | |
| 19F-20F | 3697 | 831.33 | C2-300X750 | 0.72 | | 3509 | 665.06 | T-230x600 | 0.714 |
| 18F-19F | 2812 | 831.33 | C2-300X750 | 0.72 | | 1785 | 665.06 | T-230x600 | 0.714 |
| 17F-18F | 3165 | 831.33 | C2-300X750 | 0.72 | | 1785 | 665.06 | T-230x600 | 0.714 |
| 16F-17F | 3402 | 831.33 | C2-300X750 | 0.72 | | 1785 | 665.06 | T-230x600 | 0.714 |
| 15F-16F | 3583 | 831.33 | C2-300X750 | 0.72 | | 1785 | 665.06 | T-230x600 | 0.714 |
| 14F-15F | 3774 | 831.33 | C2-300X750 | 0.72 | | 1785 | 665.06 | T-230x600 | 0.714 |
| 13F-14F | 4000 | 831.33 | C2-300X750 | 0.72 | | 1785 | 665.06 | T-230x600 | 0.714 |
| 12F-13F | 4955 | 831.33 | C2-300X750 | 0.72 | | 2873 | 665.06 | T-230x600 | 0.714 |
| 11F-12F | 5592 | 831.33 | C2-300X750 | 0.72 | | 3790 | 665.06 | T-230x600 | 0.714 |
| 10F-11F | 6110 | 831.33 | C2-300X750 | 0.72 | | 3343 | 665.06 | T-230x750 | 0.935 |
| 9F-10F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 2337 | 831.33 | T-230x750 | 0.935 |
| 8F-9F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 2337 | 831.33 | T-230x750 | 0.935 |
| 7F-8F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 2337 | 831.33 | T-230x750 | 0.935 |
| 6F-7F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 3381 | 831.33 | T-230x750 | 0.935 |
| 5F-6F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4732 | 831.33 | T-230x750 | 0.935 |
| 4F-5F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | T-300x850 | 1.344 |
| 3F-4F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | T-300x850 | 1.344 |
| 2F-3F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | T-300x850 | 1.344 |
| 1F-2F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | T-300x850 | 1.344 |
| GF-1F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | T-300x850 | 1.344 |
| BASE-GF | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 8993 | 1108.43 | T-300x850 | 1.344 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sub Total Qty** | **88610** | **22944.62** | | **26.208** | | **68742** | **17457.83** | | **20.098** |
| Column at grid B-2 | | | | | | | | | |
| 19F-20F | 5349 | 831.33 | C2-300X750 | 0.72 | | 2917 | 665.06 | PLUS230X600 | 0.714 |
| 18F-19F | 3527 | 831.33 | C2-300X750 | 0.72 | | 1932 | 665.06 | PLUS230X600 | 0.714 |
| 17F-18F | 3624 | 831.33 | C2-300X750 | 0.72 | | 1941 | 665.06 | PLUS230X600 | 0.714 |
| 16F-17F | 3734 | 831.33 | C2-300X750 | 0.72 | | 1851 | 665.06 | PLUS230X600 | 0.714 |
| 15F-16F | 3908 | 831.33 | C2-300X750 | 0.72 | | 1785 | 665.06 | PLUS230X600 | 0.714 |
| 14F-15F | 5071 | 831.33 | C2-300X750 | 0.72 | | 2457 | 665.06 | PLUS230X600 | 0.714 |
| 13F-14F | 6206 | 831.33 | C2-300X750 | 0.72 | | 3458 | 665.06 | PLUS230X600 | 0.714 |
| 12F-13F | 7491 | 831.33 | C2-300X750 | 0.72 | | 5048 | 665.06 | PLUS230X600 | 0.714 |
| 11F-12F | 8759 | 831.33 | C2-300X750 | 0.72 | | 5941 | 665.06 | PLUS230X600 | 0.714 |
| 10F-11F | 10655 | 831.33 | C2-300X750 | 0.72 | | 7744 | 665.06 | PLUS230X600 | 0.714 |
| 9F-10F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 3487 | 831.33 | PLUS230X750 | 0.935 |
| 8F-9F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4999 | 831.33 | PLUS230X750 | 0.935 |
| 7F-8F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 6240 | 831.33 | PLUS230X750 | 0.935 |
| 6F-7F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 7404 | 831.33 | PLUS230X750 | 0.935 |
| 5F-6F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 8297 | 831.33 | PLUS230X750 | 0.935 |
| 4F-5F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | PLUS300X1000 | 1.632 |
| 3F-4F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | PLUS300X1000 | 1.632 |
| 2F-3F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | PLUS300X1000 | 1.632 |
| 1F-2F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | PLUS300X1000 | 1.632 |
| GF-1F | 5039 | 1330.12 | C1-450X1200 | 1.728 | | 5368 | 1108.43 | PLUS300X1000 | 1.632 |
| BASE-GF | 8183 | 1330.12 | C1-450X1200 | 1.728 | | 8232 | 1108.43 | PLUS300X1000 | 1.632 |
| **Sub Total Qty** | **110426** | **22944.62** | | **26.208** | | **95421** | **17457.83** | | **21.605** |
| Column at grid right top corner I-11 | | | | | | | | | |
| 19F-20F | 5446 | 831.33 | C2-300X750 | 0.72 | | 2919 | 665.06 | PLUS230X600 | 0.714 |
| 18F-19F | 3781 | 831.33 | C2-300X750 | 0.72 | | 1974 | 665.06 | PLUS230X600 | 0.714 |
| 17F-18F | 3946 | 831.33 | C2-300X750 | 0.72 | | 1988 | 665.06 | PLUS230X600 | 0.714 |
| 16F-17F | 4134 | 831.33 | C2-300X750 | 0.72 | | 1941 | 665.06 | PLUS230X600 | 0.714 |
| 15F-16F | 4844 | 831.33 | C2-300X750 | 0.72 | | 2560 | 665.06 | PLUS230X600 | 0.714 |
| 14F-15F | 6136 | 831.33 | C2-300X750 | 0.72 | | 3729 | 665.06 | PLUS230X600 | 0.714 |
| 13F-14F | 7449 | 831.33 | C2-300X750 | 0.72 | | 5184 | 665.06 | PLUS230X600 | 0.714 |
| 12F-13F | 8830 | 831.33 | C2-300X750 | 0.72 | | 5970 | 665.06 | PLUS230X600 | 0.714 |
| 11F-12F | 9809 | 831.33 | C2-300X750 | 0.72 | | 7260 | 665.06 | PLUS230X600 | 0.714 |
| 10F-11F | 11718 | 831.33 | C2-300X750 | 0.72 | | 8406 | 665.06 | PLUS230X600 | 0.714 |
| 9F-10F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4076 | 831.33 | PLUS230X750 | 0.935 |
| 8F-9F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 5544 | 831.33 | PLUS230X750 | 0.935 |
| 7F-8F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 6767 | 831.33 | PLUS230X750 | 0.935 |
| 6F-7F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 7986 | 831.33 | PLUS230X750 | 0.935 |
| 5F-6F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 8864 | 831.33 | PLUS230X750 | 0.935 |
| 4F-5F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | PLUS300X1000 | 1.632 |
| 3F-4F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | PLUS300X1000 | 1.632 |
| 2F-3F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | PLUS300X1000 | 1.632 |
| 1F-2F | 4320 | 1330.12 | C1-450X1200 | 1.728 | | 4080 | 1108.43 | PLUS300X1000 | 1.632 |
| GF-1F | 5085 | 1330.12 | C1-450X1200 | 1.728 | | 5620 | 1108.43 | PLUS300X1000 | 1.632 |
| BASE-GF | 8204 | 1330.12 | C1-450X1200 | 1.728 | | 8379 | 1108.43 | PLUS300X1000 | 1.632 |
| **Sub Total Qty** | **118262** | **22944.62** | | **26.208** | | **105487** | **17457.83** | | **21.605** |
| **Sub Total** | **592137** | **137667.72** | | **157.248** | | **549270** | **98096.58** | | **122.4485** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Qty taken columns | | | | | | | | | |
| Total Qty | 729805 | | | 157.248 | | 647366.58 | | | 122.4485 |




**Checks for SSC as per IS1893 and IS 16700 requirements:**

1) As per clause 7.11. 1.1 of IS 1893 "storey drift due to seismic load in any storey shall not exceed 0.004 times the storey height and As per Clause 5.4.1 of IS 16700, inter storey drift shall be limited to $h_i/250 = 0.004\ h_i$ (where $h_i = 3.2m$ )

Storey drift ratio = 0.004 (Permissible)

Maximum storey drift due to wind load in any storey shall not exceed 0.002 times storey height

From above table-1, maximum storey drift ratio in Wx = 0.001698 and Wy = 0.001881, both < 0.002 hence safe.

From above table-1, maximum storey drift ratio in EQx = 0.002382 and EQy = 0.002523, both < 0.004 hence safe.

2) As per Clause 5.4.1 of IS 16700, allowable total drift at usable top floor (deflection) for wind loads = H/500 = 66500/500 = 133mm and for seismic loads = H/250 = 66500/250 = 266mm

From above Table-1, the deflections in Wx=69.91mm, Wy=87.63mm, both < 133mm and in EQx=115.36, EQy=121.8< 266mm Therefore deflections are under permissible limits.

3) Torsional Irregularity as per Table 5i of IS 1893, exists when

a) the maximum horizontal displacement of any floor in the direction of lateral force at one end is more than 1.5 times its minimum horizontal displacement at far end of same floor in that direction

In X- direction, displacement $\Delta max$ = 106.4mm, $\Delta min$ = 99.06mm

$\Delta max/\Delta min$ = 106.4/99.06 = 1.07 < 1.5 (Hence safe and No Torsional Irregularity Exist)

In Y- direction, displacement $\Delta min$ = 79.9mm, $\Delta max$ = 106.84 mm

$\Delta max/\Delta min$ = 106.84/79.9 = 1.34< 1.5 (Hence No Torsional Irregularity Exist)

b) The natural period corresponding to fundamental torsional mode of oscillation is more than first two translational modes.

T1, T2 are translational modes of oscillation, T3 is torsional mode of oscillation

T1=3.699, T2=3.319, T3=2.926 here T3 < T1 and T2 Hence safe and

b) Fundamental lateral natural periods of building in two principal plan directions are closer by 10% of larger value.

In Mode-1, Ux =0.7721, Uy = 0.0000, Rz = 0.0006

Mode-2, Ux = 0.0000, Uy = 0.7449, Rz = 0.0003

Mode-3, Ux = 0.0007. Uy = 0.0003, Rz = 0.7243

In Mode-1 and Mode-2, Ux and Uy are greater than Rz and In mode-3 Rz > Ux and Uy

So Mode-1 & Mode-2 are translational and Mode-3 is rotational and Mass participation mass ratio of three modes

Sum Ux = 0.7721, Sum Uy = 0.7449, Sum Rz = 0.7251

> 65%, hence safe. Hence No Torsional Irregularity Exist in the building.

4) Modal participation mass ratio as per Table 6 vii of IS 1893. A building is said to have lateral storey irregularity if

a) First three modes contribute less than 65% mass participation factor and

5) As per clause 5.5 of IS 16700, Natural period of fundamental torsional mode of vibration shall not exceed 0.9 times the smaller of fundamental translational modes.

Natural time period in Mode-1= T1=3.699 seconds, Mode-2 = T2 = 3.319 seconds, Mode-3 = T3 = 2.926 seconds.

Torsional period= T3=2.926, smaller translational period=T2=3.319

0.9x 3.319= 2.9871, therefore T3 < 0.9xT2 hence safe.

After study of analysis and design results tabulated in Tables-1 and 2, following points are observed:

1. Maximum storey displacements of all building models of 20 storeys irrespective of column shapes are under acceptable limits.
2. Deflection in buildings with rectangular columns is more than the buildings with SSC. Rectangular column building have 9% higher deflection in wind load conditions, 7% higher in static seismic load conditions and 6% higher in dynamic seismic load condition.
3. Base shear for seismic forces increases in model with SSC by 3% in static seismic load dynamic seismic load condition.
4. Overturning moment for seismic forces Decreases in model with SSC by 3% in static seismic load conditions and 2% in dynamic seismic load condition.
5. Storey drifts are under the permissible limits for both buildings under different load conditions. Rect,

Column Model has 14% higher inter storey drift compare to SSC Model.

6. SSC from 15 to 20 storeys have Less than 1% reinforcement requirement.
7. Main reinforcement in SSC is nearly 7% and shear reinforcement is 29% less as compared to rectangular columns.
8. Total concrete in special shaped column is nearly 22% less as compared to rectangular columns.
9. Building with rectangular columns has higher reinforcement requirement compared to building with special shaped columns.
10. Larger sections of rectangular columns are needed for the 20 storey building structure, while at the same time moderate size sections of special shaped columns are required.

## VII. CONCLUSION

After the detailed comparative study of different parameters above in compliance with IS standards requirements, it has been established that the building with non-rectangular special shaped columns performs better under seismic and wind load conditions compared to the building with conventional rectangular columns under the same loadings.

It has been found that the reinforcement requirement in SSC columns are minimum i.e. 1% in last 5 floors of the buildings, 3 storeys from foundation have little high steel consumption but overall reinforcement is lower compared to conventional rectangular columns.

It is also been concluded that buildings with non-rectangular columns will be more economical, columns flushed with brick wall gives good aesthetics. The outcome of this study is that the cost of construction of multi-storey buildings like apartments, hotels, offices etc., would be less with more free space and column free space is available the rooms.

Materials and cost savings has positive environmental impact as less concrete and steel reinforcement material consumption would lead to less carbon emission which is good for our environment and sustainability development.

In view of above, it is concluded that buildings with special shaped columns are advantageous over conventional shaped columns.

## VIII. SCOPE OF FURTHER STUDY

**Scope of Further Study**

There are many areas where work need to be done to use the Specially Shaped Columns in the buildings which are summarized as below:

1. Effect of infill walls has been ignored for the present study and need to be considered under further study.

2. Effect of shear wall and core wall need to be studied together with special shaped columns.

## IX. LIMITATIONS OF SPECIAL SHAPED COLUMNS

There are few limitations and disadvantages of special shaped columns in the buildings which are summarized as below:

1. Shuttering is non-standard and not readily available in the market and to be custom made, hence suitable for large construction only. High shuttering cost can be advantageous in case of large construction and multiple time usage of this custom made shuttering.

2. Skilled and trained manpower is needed to install the shuttering and reinforcement as it is not conventional rebar work.

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