Comparative analysis of multi storey mono column structures for different plan configuration with same plan area

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Abstract. Wind load and Earthquake load play an indispensable role in structural analysis. Many research works carried out on analysis & design of single column structures. Being inspired from the previous works on effect of earthquake and wind load on single column structure, this paper presents effects of six different plan configurations i.e., Square, Rectangular, Circular, Triangular, Pentagon and Hexagon with same plan area (144 m²). Mono column structure with different plan geometry react adversely in contrast to earthquake and wind loads. Modelling, analysis and design of Multi storey mono column structure is done by using CSI ETABS software. Seismic and wind analysis has been done and maximum values of Storey displacement, Storey drift, Storey shear, overturning moment, Storey stiffness and Time period results are manifest in form of figures. The purpose of this analysis is to determine the most effective and vulnerable shape of structure in prone areas. Storey displacement, storey drift values are minimum in circular shape structure in all seismic zones. Storey shear, overturning moment, storey stiffness is minimum in square shape structure, maximum in triangular shape structure. Time period is maximum for mono column structure with rectangular plan configuration.

Keywords: Mono column structure; Seismic analysis; wind analysis; ETABS

1. Introduction
Structure supported on just a single column is known as mono column structural system. Due to boom of population in to urban cities there is need to house the influx within the cities. However, due to rapid increase of land cost, and limited availability of land the trend is to build multi storey building. The RCC mono column structure provides good architectural view as compared to conventional RCC structure. They save ground space as requires less area for providing foundation and provides more space for parking or other purposes. They are very unique. Mono column structure can be made either RCC or Steel or Composite. Greatest space use is viewed as will serve its most extreme usefulness. In this research describes planning of structure, seismic and wind load analysis of mono column structure. The primary motivation of this overwhelming paper point is the structure of a TREE. The weight of the leaves and branches are conveying into bark and distributed into soil by the root. In this paper we like to study a unique dimension of the existing construction techniques. This paper illustrates planning and structural analysis of mono column structure of different shapes. The structure has a central mono column it will convey load of the super structure to the ground. Since a mono column is supporting the entire structure, all other members act as cantilever. This structure is modelled, analysed in E-TABS software which is based on finite element method and it is analysed
and designed for the crucial condition. In the present situation computer hardware’s and software’s for modelling and analysis of structures are widely available. We come to know how the knowledge gained in the academic syllabus is applied in these practical works.

2. Objectives

2.1 To develop, planning and analysis model of the Mono column structure for different plan configuration with same plan area (Square, Rectangle, Circular, Triangle, Pentagon, Hexagon) in E-Tabs software.
2.2 To assess Seismic performances of mono column structure with different plan configuration located in different earthquake zones in India by linear static method of analysis, response spectrum analysis and Modal analysis method.
2.3 To assess Wind performances of mono column structure for different plan configuration located in different wind zones in India.
2.4 To compare the maximum storey displacement, storey shear, storey drift, overturning moment, storey stiffness and Time period of mono column structure for different plan configuration subject to seismic and wind load.
2.5 To find the most suitable and vulnerable plan configuration for mono column structure subjected to seismic and wind loads.

3. Methodology

3.1. Equivalent static load method of analysis
This method characterizes a progression of the forces, following up on a structure to speak with the impact of the earthquake ground motion, generally identified by response spectrum. This method expect that structure react at its basic mode. To achieve the structure should not twist altogether during structure subjected to ground motion. The natural frequency of the building is obtained by design a response spectrum to get response of the structure to the earthquake. The application of this method was stretched out in so many construction regulations by applying variables to represent the tall structure with same highest modes. The equivalent static load method for a quake is an extraordinary idea utilized in seismic designing.

3.2. Response spectrum method of analysis
To accomplish the earthquake analysis and design of building constructing at a specific place the genuine time history record is compulsory. At every location we can’t find time history records. And also, Earthquake analysis of structure not done for every location. Maximum value of the earth acceleration of the structures alone cannot beneficial to conduct seismic analysis of structure based on the frequency content of ground motion and its dynamic properties. Response spectrum method is only prominent means in the earthquake analysis of structures. Displacement and member forces in structure can be find easily as computational advantage. Damping and Time period during earthquake ground motions, of single degree freedom system can described in most extreme reaction condition. The RSA should confirm to IS1893-2016 (part1). Zone factor, type of soil, Response reduction factor, Importance factor should take from IS1893-2016 (part1). The response spectra for all type of soil can be analysed in ETABS software.

3.3. Modal analysis method
Investigation of dynamic assets of the structure during vibration excitation is called modal analysis. The response of the structure estimated and analysed by the help of modal analysis. General mass and stiffness of a structure can be used by modal analysis to locate and find the natural period of the structure at which it will normally resonate. In earthquake engineering these periods of vibrations are noted, the structural natural frequency is not coordinate with the frequency of expected quakes at the
place where the structure built. When a structural natural frequency coordinates with a seismic frequency then structure can proceed to vibrate and encounter basic structural damage.

3.4. Wind Load Analysis
Wind is the air, moving with the outside of the earth surface. The radiations of winds are may move upwards or downwards. The wind hit the ground surface at high speed. The wind speed is measured by using anemometers or anemographs which are available in meteorological department. The impact of wind on the structure is on internal and external pressures. The structure failure due to wind loads is not only depends on geological area, and vicinity of different obstacles to wind stream but also depends upon the qualities of structure itself. In present days all tall structures are constructed to wind delicate since the structure shapes, slenderness ratio, stiffness, size & lightness of structure. The structural design for wind load confirm to IS 875-2015 (part 3).

3.5. Material properties
Table 1 shows materials and their properties used in structural component of all mono column structure models.

| Table 1. Material properties. |
|-----------------------------|
| Grade of Concrete M-50      |
| Grade of Rebar FE-500       |
| Poison’s Ratio of Concrete 0.2 |
| Poison’s Ratio of Steel 0.15 |
| Modulus of Elasticity (E) of M50 35355.34 N/mm² |
| Grade Concrete              |
| Modulus of Elasticity (E) of Fe-500 200000 N/mm² |
| Grade Steel                 |
| Density of RCC 25 KN/m³     |
| Density of Brick Masonry 20 KN/m³ |

3.6. Member dimensions of all models
Table 2 shows member dimensions of structural components used in modelling and analysis of all mono column structure models.

| Table 2. Member dimensions of all models. |
|-----------------------------------------|
| Central column size | Floating Column size | Inclined beam size | Beams size | Thickness of slab |
| 2.0mx2.0m          | 0.45mX0.6m           | 0.6mX0.6m          | B1-0.45mX0.45m | 0.15m           |
|                     |                       |                    | B2-0.45mX0.6m |
|                     |                       |                    | B3-0.6mX0.75m |
3.7. Building geometry of models
Table 3 shows Mono column building geometry of Square, Rectangular, Circular, Triangular, Pentagon and Hexagon shape plan configuration.

Table 3. Building geometry of models.

| Model     | Plan dimensions For 144 m² area | Number of storeys | Typical storey height | Bottom storey height | Height from GL to First storey | Total height of building |
|-----------|---------------------------------|-------------------|-----------------------|---------------------|-------------------------------|--------------------------|
| Square    | 12mX12m                          | 10                | 3.2m                  | 1.5m                | 5m                            | 35.8m                    |
| Rectangular | 16mx9m                           | 10                | 3.2m                  | 1.5m                | 5m                            | 35.8m                    |
| Circular  | 13.4 m Dia.                      | 10                | 3.2m                  | 1.5m                | 5m                            | 35.8m                    |
| Triangular | Sides=18.073m, Height=15.6m      | 10                | 3.2m                  | 1.5m                | 5m                            | 35.8m                    |
| Pentagon  | Sides=9.14m                      | 10                | 3.2m                  | 1.5m                | 5m                            | 35.8m                    |
| Hexagon   | Sides=7.44m                      | 10                | 3.2m                  | 1.5m                | 5m                            | 35.8m                    |

3.8. Plans of models from ETABS
Figure 1 shows Plans of mono column structure of Square, Rectangular, Circular, Triangular, Pentagon and Hexagon shape plan configuration.
3.9. Static load details
Dead load of structure is programme calculated. Live load for floors is 3.5 KN/m², live load for roof is 1.5 KN/m². Floor finish for floors and roof is 1.5 KN/m², Cladding load is 0.6 KN/m.

3.10. Seismic load details
Seismic zones considered, II, III, IV and V and zone factors are 0.1, 0.16, 0.24, 0.36 respectively. Response reduction factor is SMRF 5.0 for all structures, Importance factor is 1.5, Type of soil is Medium type 2.

3.11. Wind load details
Wind zones considered I, II, III, IV, V and VI and basic wind speeds are 33, 39, 44, 47, 50, 55 m/sec respectively. Terrain category is 3, Importance factor is 1.0, Risk coefficient (k1) is 1.0, Topography factor (k3) is 1.0.

4. RESULTS AND DISCUSSION

4.1. Earthquake load analysis
4.1.1 Equivalent static load method of analysis results

Figure 2. Storey displacement in mm.

Figure 2 Shows Storey displacement of mono column structures of square, rectangular, circular, triangular, pentagon and hexagon shapes mono column structure at all 4 seismic zones. Storey displacement increases with increase in storey height in X and Y direction for EQX & EQY respectively. The storey displacement is within the permissible limit H/250=143.2m in all structures. Storey displacement is less in Circular shape and more in rectangular shape mono column structures at all seismic zones.
Figure 3. Storey drift.

Figure 3 shows Storey drift of mono column structures of square, rectangular, circular, triangular, pentagon and hexagon shapes mono column structure at all 4 seismic zones. Storey drift is more at storey 6. The storey drift is within permissible limit $3200 \times 0.004 = 12.8$ (Drift value) Drift ratio = 0.004 in all structures. Storey drift is less in Circular shape and more in rectangular shape in all seismic zones.

Figure 4. Storey shear in KN.

Figure 4 shows Storey shear of mono column structures of square, rectangular, circular, triangular, pentagon and hexagon shapes mono column structure at all 4 seismic zones. Storey shear decreases with increase in storey height in X and Y direction for EQX & EQY respectively. Storey shear is less in Square shape and more in triangular shape in all seismic zones.

Figure 5. Overturning moment in KN-m.

Figure 5 shows Overturning moment of mono column structures of square, rectangular, circular, triangular, pentagon and hexagon shapes. Storey overturning moment decreases with increase in storey
height in X and Y direction for EQX & EQY respectively. Overturning moment is less in Square shape and more in triangular shape in all seismic zones.

Figure 6. Storey stiffness in KN/m.

Figure 6 shows Storey stiffness of mono column structures of square, rectangular, circular, triangular, pentagon and hexagon shapes. Storey stiffness is more at storey 1. Storey stiffness is less in Square shape and more in triangular shape in all seismic zones.

4.1.2. Response spectrum method of analysis results.

Figure 7. Storey displacement in mm.

Figure 7 Shows Storey displacement of mono column structures of square, rectangular, circular, triangular, pentagon and hexagon shapes mono column structure at all 4 seismic zones. Storey displacement increases with increase in storey height in X and Y direction for RSA-X & RSA-Y respectively. The storey displacement is within the permissible limit H/250=143.2m in all structures. Storey displacement is less in Circular shape and more in rectangular shape in all seismic zones.
Figure 8. Storey drift.

Figure 8 shows storey drift of mono column structures of square, rectangular, circular, triangular, pentagon, and hexagon shapes mono column structure at all 4 seismic zones. Storey drift is more at storey 6. The storey drift is not exceeding the permissible limits 3200*0.004=12.8 (Drift value) Drift ratio= 0.004 in all structures. Storey drift is less in circular shape and more in rectangular shape in all seismic zones.

Figure 9. Storey shear in KN.

Figure 9 shows storey shear of mono column structures of square, rectangular, circular, triangular, pentagon, and hexagon shape. Storey shear decreases with increase in storey height in X and Y direction for RSA-X & RSA-Y respectively. Storey shear is less in square shape and more in triangular shape in all seismic zones.

Figure 10. Overturning moment in KN-m.
Figure 10 Shows Overturning moment of mono column structures of square, rectangular, circular, triangular, pentagon and hexagon shapes mono column structure at all 4 seismic zones. Storey overturning moment decreases with increase in storey height in X and Y direction for RSA-X & RSA-Y respectively. Overturning moment is less in Square shape and more in triangular shape in all seismic zones.

Figure 11 shows Storey stiffness of mono column structures of square, rectangular, circular, triangular, pentagon and hexagon shape. Storey stiffness is more at storey 1. Storey stiffness is less in Square shape and more in triangular shape in all seismic zones.

4.1.3. Modal analysis results

Figure 12 shows Time period of mono column structures of square, rectangular, circular, triangular, pentagon and hexagon shape. Time period is less in Circular shape and more in rectangular shape in all seismic zones.
4.2 *Wind load analysis results*

**Figure 13.** Storey displacement in mm.

Figure 13 shows Storey displacement of mono column structures of square, rectangular, circular, triangular, pentagon and hexagon shape mono column structures at all wind zones. Storey displacement increases with increase in storey height in X and Y direction for WLX & WLY respectively. The storey displacement is within the permissible limit H/500=71.6 mm in all structures. Storey displacement is less in Circular shape and more in rectangular shape in all seismic zones.

**Figure 14.** Storey drift.

Figure 14 shows Storey drift of mono column structures of square, rectangular, circular, triangular, pentagon and hexagon shapes mono column structures at all wind zones. Storey drift is more at storey 6. The storey drift is not exceeding the permissible limits 3200*0.004=12.8 (Drift value) Drift ratio=0.004 in all structures. Storey drift is less in Circular shape and more in rectangular shape in all seismic zones.

**Figure 15.** Storey shear in KN.
Figure 15 shows Storey shear of mono column structures of square, rectangular, circular, triangular, pentagon and hexagon shapes mono column structures at all wind zones. Storey shear decreases with increase in storey height in X and Y direction for WLX & WLY respectively. Storey shear is less in Square shape and more in triangular shape in all seismic zones.

![Overturning moment in KN-m](image)

**Figure 16.** Overturning moment in KN-m.

Figure 16 shows Overturning moment of mono column structures of square, rectangular, circular, triangular, pentagon and hexagon shapes mono column structures at all wind zones. Storey overturning moment decreases with increase in storey height in X and Y direction for WLX & WLY respectively. Overturning moment is less in Square shape and more in triangular shape in all seismic zones.

![Storey stiffness in KN/m](image)

**Figure 17.** Storey stiffness in KN/m.

Figure 17 shows Storey stiffness of mono column structures of square, rectangular, circular, triangular, pentagon and hexagon shapes mono column structures at all wind zones. Storey stiffness is more at storey 1. Storey stiffness is less in Square shape and more in triangular shape in all seismic zones.

5. Conclusion

5.1 From static and dynamic analysis, the Storey displacement, Storey drift, Storey shear, overturning moment of all shapes increases as we go to higher seismic zone.

5.2 Storey displacement & Storey drift are less in circular shape structure, more in rectangular shape mono column structure in all seismic zones of India.

5.3 The storey shear, overturning moment and storey stiffness is minimum in Square shape structure and maximum in triangular shape mono column structure in all seismic zones of India.

5.4 Time period is more for Rectangular shape and less for circular shape mono column structure.
5.5 Storey displacement of Square, Circular, Triangular, Pentagon, and Hexagon shape mono column structures are within permissible limit in I, II, III, IV, V wind zones, and exceeding permissible limit in VI wind zone of India.

5.6 Storey displacement of rectangular shape mono column structure is within permissible limit in I, II, III, wind zones, and exceeding permissible limit in IV, V, VI wind zone of India.

5.7 The storey shear, overturning moment and storey stiffness is minimum in Square and circular shape mono column structure and maximum in triangular shape structure in all wind zones.

5.8 Mono column structure of Rectangular shape is not preferable in high seismic and high wind prone areas due to large displacement. Irregular shapes are not suitable for mono column structures. Mono column structure with Circular, Triangular and Hexagon shape plan configuration gives good performance against seismic and wind loads.

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