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Structural and Seismic Analysis of G+10 RC Building using ETABS

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***Abstract* -** The Demand for multi-storey reinforced concrete (RC) buildings has increased significantly due to rapid urbanisation and limited land availability. The structural safety of these buildings under earthquake loading is an important aspect of modern civil engineering. This study presents the seismic analysis of a regular G+10 square RC building model developed in ETABS Version 19. The Equivalent Static Method (ESM), in accordance with the relevant Indian Standard provisions, was adopted to evaluate the structural response. The building was analysed for gravity and seismic loads, and the response parameters considered include storey drift, storey forces, storey lateral force distribution, and maximum displacement. The study provides a systematic modelling approach and discusses the significance of these parameters in assessing the seismic performance of regular reinforced concrete buildings.

Keywords: ETABS Version 19, Equivalent Static Method, RC Building, Storey Drift, Storey Forces, Maximum Displacement, Seismic Analysis.

I. INTRODUCTION

Seismic performance of multi-storey buildings is an important aspect in structural engineering due to the fact that earthquake forces are known to generate significant lateral displacements, internal stresses and possible damage to structural elements. Building response is dependent on its mass distribution, stiffness, geometry, and lateral load resistance system; hence the need to account for both seismic and non-seismic conditions in analysis (Nagasai et al., 2019; Rajesh Reddy et al., 2017). It has been observed through research that there is a considerable influence of the earthquake load on structural response in terms of storey displacement, storey drift and base shear. Studies related to base isolation, shear walls, and reinforced masonry have shown that there are measures of reinforcement that can make the building resistant to earthquakes and reduce the lateral load (Lingeshwaran & Poluraju, 2020; Rajesh Reddy et al

The above results suggest that the effects of the earthquake should be taken into account in the design and evaluation of reinforced concrete buildings (Nagasai et al., 2019; Kolli & Lingeshwaran, 2019).In India, seismic design of buildings is carried out following the provisions of IS 1893 (Part 1):2016 while the reinforced concrete structures and loads are usually designed based on IS 456 and IS 875, respectively (Bureau of Indian Standards, 1987, 2000, 2016). The above codes provide necessary provisions for safe and reliable structural design under the action of gravity and earthquakes. Additionally, the books on structural dynamics explain the theoretical principles behind the reaction of the structure to dynamic excitations and the importance of stiffness and ductility in earthquake-resistant design (Agarwal & Shrikhande, 2006; Chopra, 2017; Clough & Penzien, 1993; Paulay & Priestley, 1992).

Software for structural analysis like ETABS is extensively used for building modelling and evaluation under different loading conditions. Using this software, one can easily analyse displacement, drift and base shear, which makes it well suited for seismic and non-seismic comparative studies (CSI, 2020). Thus, the study involves comparative analysis of the multi-storey building under seismic and non-seismic conditions using ETABS (Nagasai et al., 2019; Bureau of Indian Standards, 2016; CSI, 2020).

STRUCTURE DESIGN OF CODES AND STANDARDS

The design of the structure and Investigation of the proposed G+10 RCC commercial building in seismic zones (III, IV, &V) were performed by following the applicable (IS) codes. These standards ensure that the structure meets the required safety, strength, durability, and serviceability criteria under different loading conditions. The design was based on the following codes: IS 456:2000 – the design of plain and RC structures.

- IS 875 (Part 1):1987 – Specifies dead loads to be considered in structural design.
- IS 875 (Part 2):1987 – Provides recommendations for imposed (live) loads on structures.
- IS 1893 (Part 1):2016 – specifies for design of seismic-resistant buildings.
- IS 1786:2008 – Specifies the requirements for high-strength deformed steel bars and wires used for concrete reinforcement.

II. METHODOLOGY AND DESCRIPTIONS OF THE BUILDING MODEL

A. Structural layout

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The structural model was developed using ETABS Version 19. A regular square reinforced concrete building consisting of a ground plus ten storeys building, as shown in Figs. 1-3. for a commercial building. Material properties and sectional dimensions were assigned according to the adopted design codes. The storey force varied over the building height, with larger forces acting at the lower levels due to cumulative seismic effects. Building accessories are listed in Table 1.

TABLE 1: DESCRIPTION OF THE STRUCTURE MODEL

PARAMETERS	***VALUES***
Type of the building	RC Moment Resisting Frame
Number of storeys	G+10
Height of storey	3.0 m
Size of Plan	18m X18m
Bay Dimension	4.5 m
thickness of the slab	150 mm
Beam dimension	350 X 450 mm
Column dimension	450 mm

B. Loads and combinations

- Dead Load – The force of gravity acting on all the existing structural components, such as columns, beams, floor slabs, brick walls, and the surface finish.
- Live Load – It is the temporary loads caused by the use of the structure and includes the movable loads of the structure, including humans, their belongings, tools, and other movable components in the building.

C. Earthquakes load

The Lateral forces generated due to seismic forces depend upon the EQ response of the structure to the design Equivalent Static Methods (ESM) specified in IS 1893 (Part 1): 2016. Seismic hazard & zone factor The Projects under consideration in Zone III, IV, V for earthquakes, and the factors related to that zone (Z = 0.16, 0.24, 0.36) are taken into consideration. The mass of the building taken from the IS code 1893 (part-1):2016 which produces the earthquake-induced lateral (forces) loads, includes Dead Weight of all the structural and non-structural elements are taken 100%. Live (Imposed) Load on the structure, which arranged per floor height on the basics of engineers may attentive imposed load 25%. that mentioned in table 3 and 4.

The calculation of Design base shear is done automatically in ETABS according to IS code1893 (Part 1): 2016 these are the standard following formula to find out the parameters.

$$V_b = A_h * W$$

Where,

$$A_h = (Z*I*Sa)/(2*R*g)$$

V_b = The Design Base Shear

A_h = The Design Horizontal acceleration of Seismic Coeff.

W = Total Seismic Weight of the Building

Z = The Zone factor (Z- 11, 111, 1V, V)

I = Importance factor

Sa/g = Average Response Acceleration Coefficient

R = Response Reduction Factor

g = Acceleration due to gravity

TABLE 3: DEAD LOAD (IS 875 PART-1)

LOADS	***VALUES***
Floor Finishing	1 KN/m^2
Water Proofing	2 KN/m^2
Terrace Finishing	1 KN/m^2
Thickness of Wall	230 mm

TABLE 4: LIVE LOAD (IS 875 PART-2)

LOADS	**VALUES**
Live load of Terrace	1.5 N/mm^2
Floor live load	3 KN/mm^2
Uniformity distributed Live load on floor	25%

TABLE 5: EARTHQUAKE LOADS (IS 1893:2016 (PART-1)

D. Loads Combinations

INPUT PARAMENTS	***VALUE***
Seismic Zone	III, IV, V
Zone Factor (Z)	0.16, 0.24,0.36
Importance Factor (I)	1.2
Type of Soil	Soft soil
Type of the Frame	SMRF
Response Reduction Factor (R)	5
Damping Ratio	0.05

The structure must be designed to meet the needs of strength and the limit state of serviceability. In strength design, the load combinations suggested in IS 456:2000 using the required partial safety factors must be used. For the analysis of the RC structure based on service loads, the loads of the combinations given in the code without any partial safety factors must be taken into account. They are primarily required to check the serviceability needs, such as deflections of individual members and also that of the entire structure. Combinations of loads in

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different ways along with partial safety factors as per IS 456:2000 are given in Table 6.

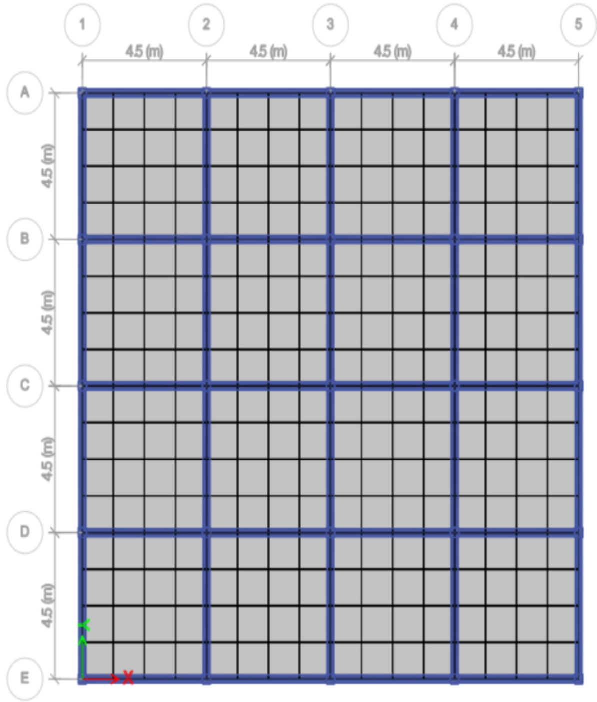
TABLE 6: LOAD COMBINATIONS (IS CODE 456:2000)

COLLAPSE DESIGN	*SERVICEABILITY DESIGN*
1.5DL+1.5LL	1.0DL+1.0LL
1.2DL+1.2LL+1.2WL/EL	1.0DL+0.8LL+0.8WL/EL
1.5DL+1.5WL/EL	1.0DL+1.0WL/EL
0.9DL+1.5WL/EL	--------------------------

Abbreviations: LL- Live Load, DL- Dead Load, WL- Wind Load, EQ- Earthquake Load.

III. SEISMIC ANALYSIS OF BUILDING STRUCTURE

In terms of IS code 1893 (Part 1): 2016, there exist two approaches to the Design of Structure, against earthquakes using the Linear Elastic Analysis techniques: the Equivalent Lateral Force Method (ELFM), which is also known as the EQ Coefficient Method, and the RSA. The Equivalent Lateral Force Method involves the calculation of earthquake actions through the transformation of the dynamic ground motion into a static system of equivalent lateral forces that are applied to the structure. The design base shear, which is defined as the Lateral EQ force, is computed through the multiplication of the total weight of the structure with the Lateral EQ Coefficient. This coefficient calculated according to the specific parameters of the project: the seismic zone factor (Z), importance factor (I), Response Reduction Factor (R), and the Natural Fundamental Period (T) of vibration of the structure. After the design of base shear is found, it should be Assigned along the Elevation of the building according to the floor weights and elevations. In other words, the Investigation of the Essential vibration mode is approximated. The Equivalent Lateral Force Method might be inaccurate when used in the cases of the irregular distribution of mass/stiffness, complicated geometry of the structure, and nonorthogonal lateral load-resisting systems. When such cases arise, the dynamic analysis is more appropriate due to the consideration of different modes of the vibration. In this case, the dynamic analysis can be moved out using one of the following methods: the Response Spectrum Method and the Time History Method. The RSM makes use of the Analysis spectrum, which is the Representation of the Maximum Displacement of the storey, acceleration of a series of SDOF models when excited by a given earthquake input. The RS Produced by studying the highest analyzed of SDOF oscillators with various Natural Time Periods and damping of ratios. On the other hand, in modal RSM analysis, the Structural analysis of each significant mode of vibration is computed separately and is later combined together through normal modal combination techniques. In this study, the EQ behavior of the building has been analyzed using Modal RSM. The seismic input has been taken into account in the Lateral direction only, but not the vertical direction, as the effect of the latter is usually negligible for RC buildings.



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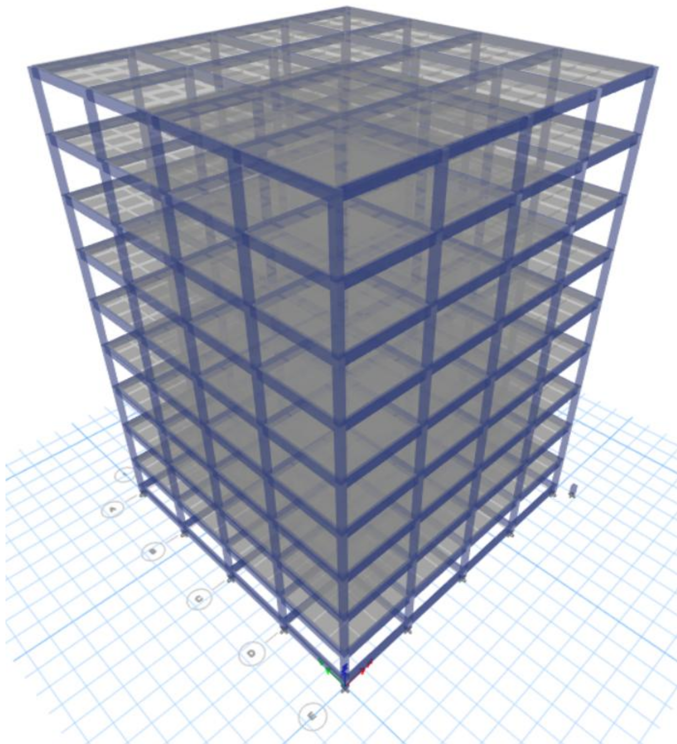

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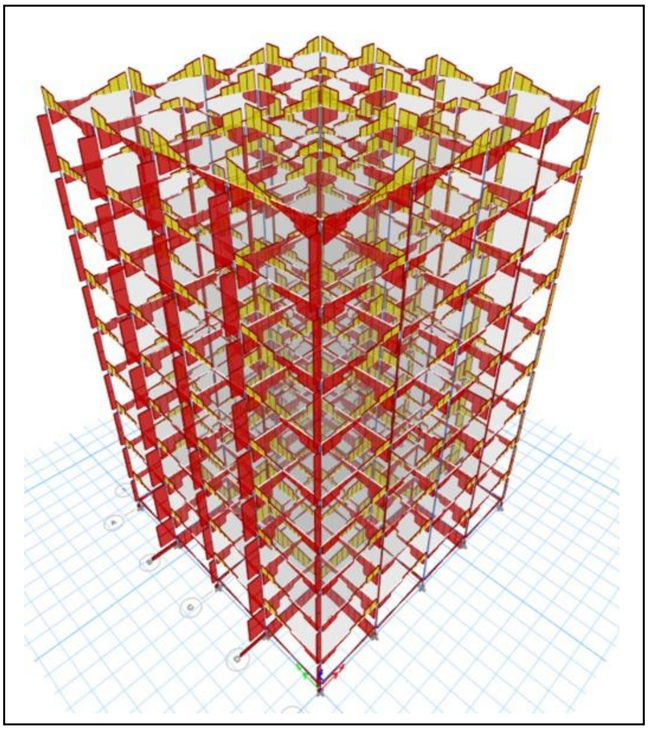

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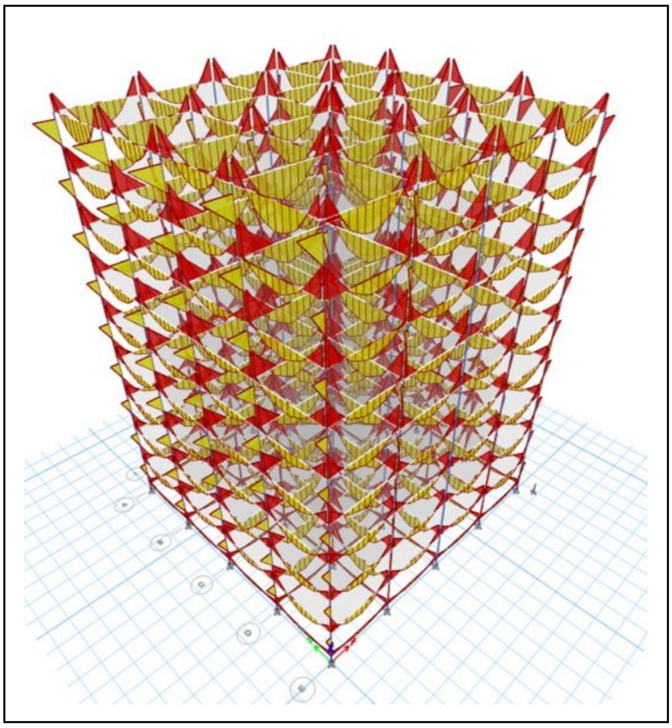

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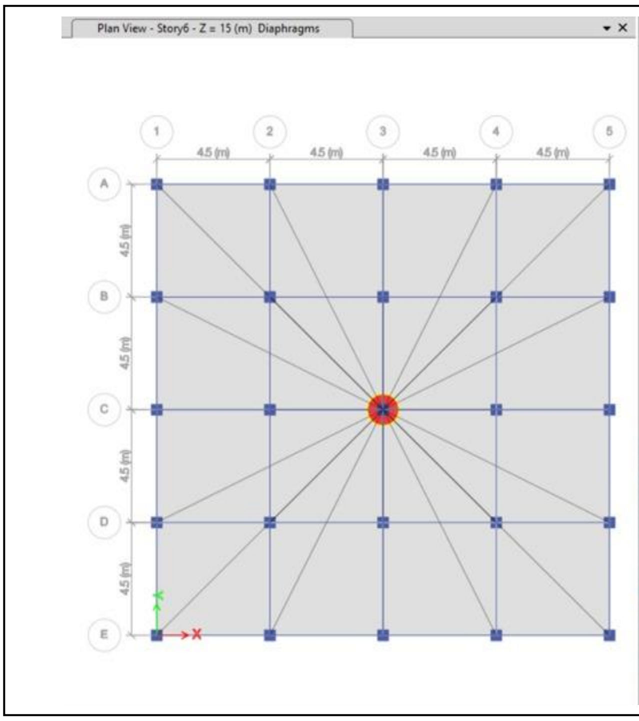

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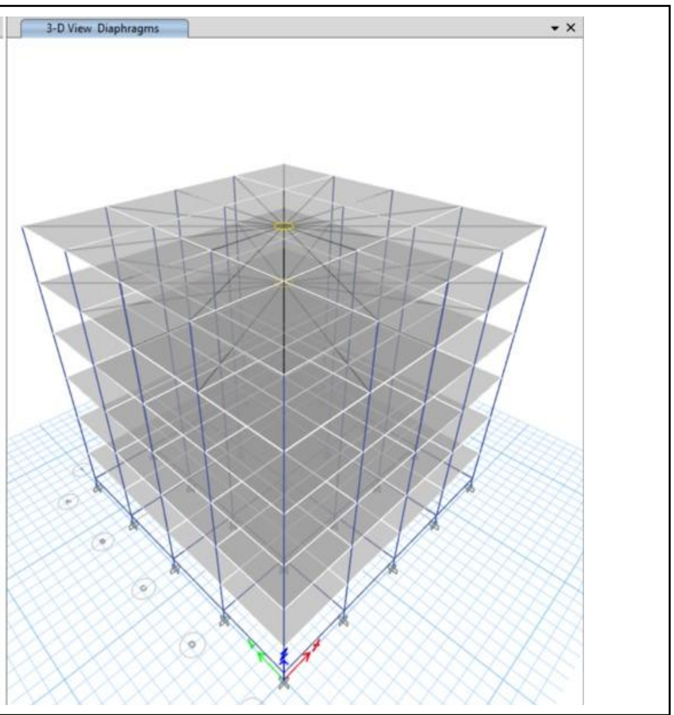

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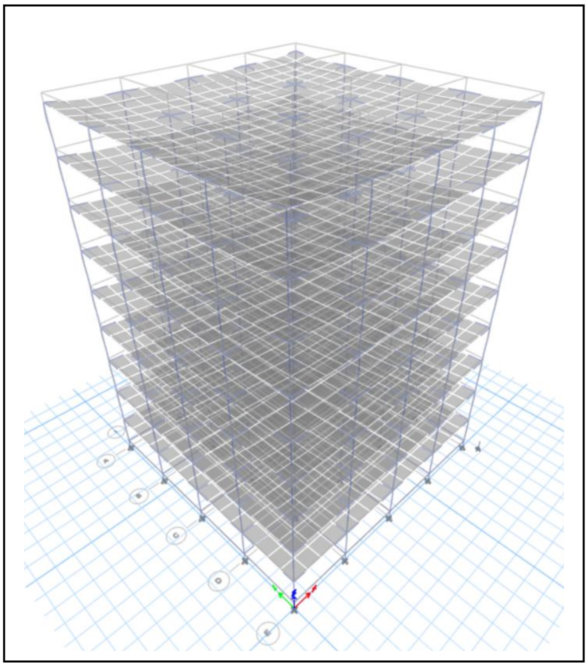

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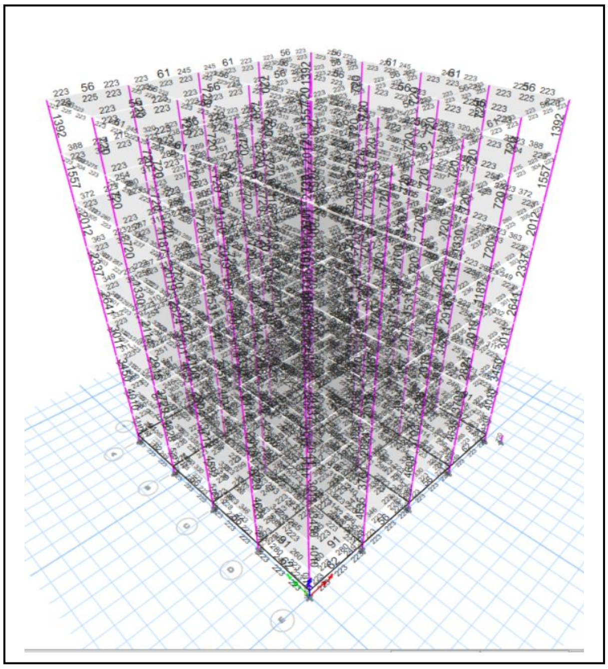
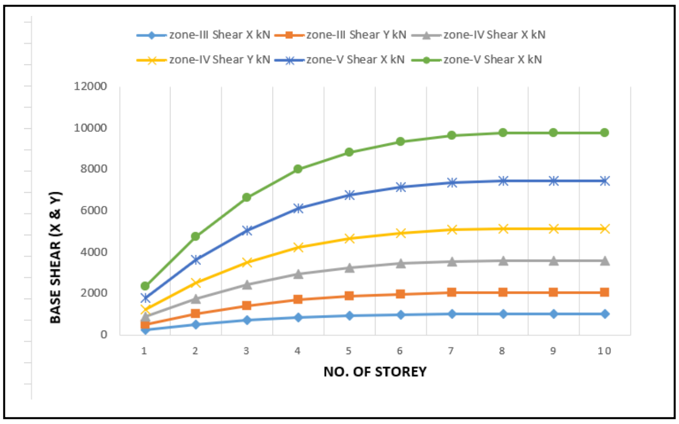


(h)

Fig. 1. ETABS Model under study (a) Reference regular Model 2D view (RRM) (b) 3D view (c) Shear Force (SF) (d) Bending Moment (BM) (e) Apply Rigid Diaphragm (2D) (f) Apply Rigid Diaphragm (3D) (g) Displacement Analysis (DA) (h) Design of structure

An RC building of type G+10 has been modeled and analyzed using ETABS Version 19 software utilizing the Finite Element Method (FEM). The mathematical model has been formulated based on the definition of geometry, section, materials, supports, and loading of the structure as per the design assumptions made. The detailed information about the material properties, loading condition, and load composites of the structure used in the analysis is mentioned in the table above. The developed analytical model whereas Figure (b) gives the 3D view of the model. The analysis and investigation of the results are summarized in Figures (c)–(h). The SF Apportionment obtained from the structural analysis is presented in Figure (c), while the analogous BM Apportionment shown in Fig. (d). To ensure rigid in-plane action of each floor, a rigid diaphragm was assigned to the entire slab system. The diaphragm assignment is illustrated in Fig. (e), and its three-dimensional view is provided in Fig. (f).

IV. ANALYSIS AND INTERPRETATION OF RESULTS



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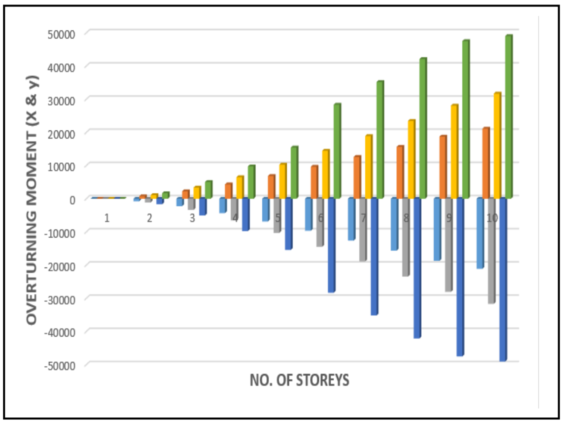

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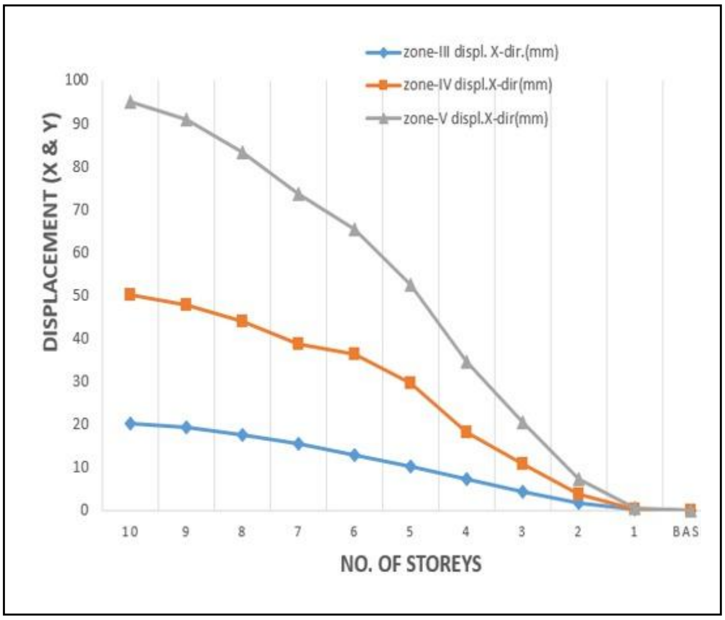

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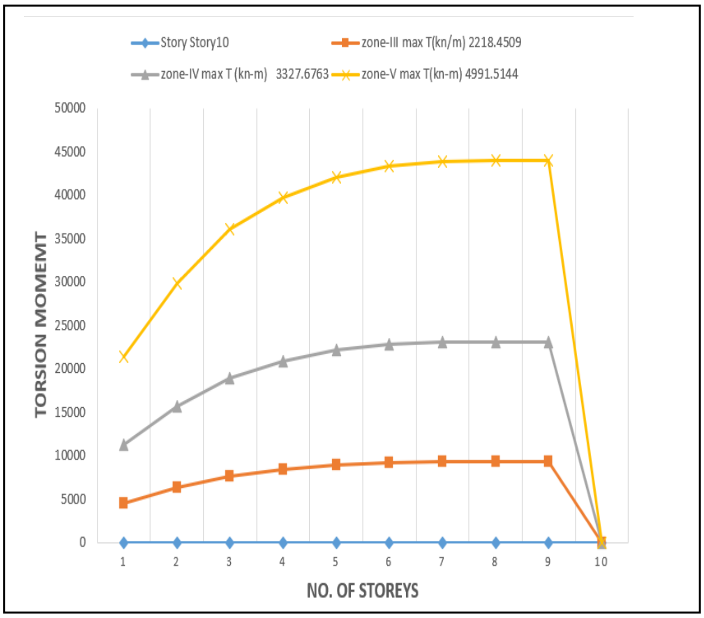

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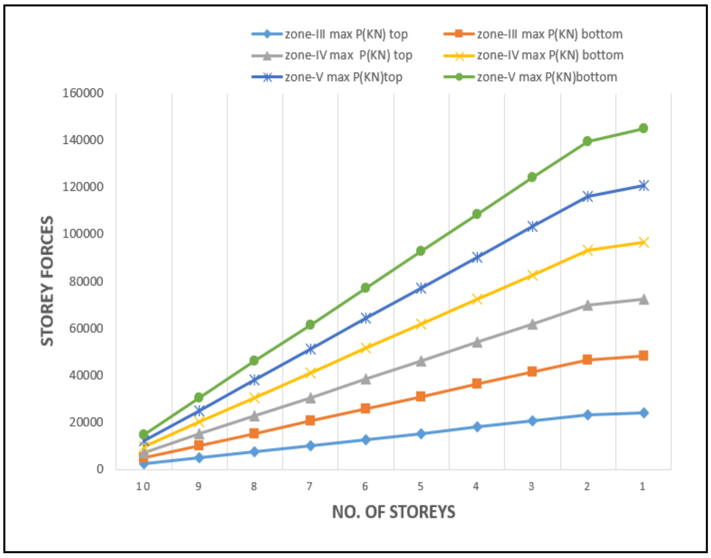

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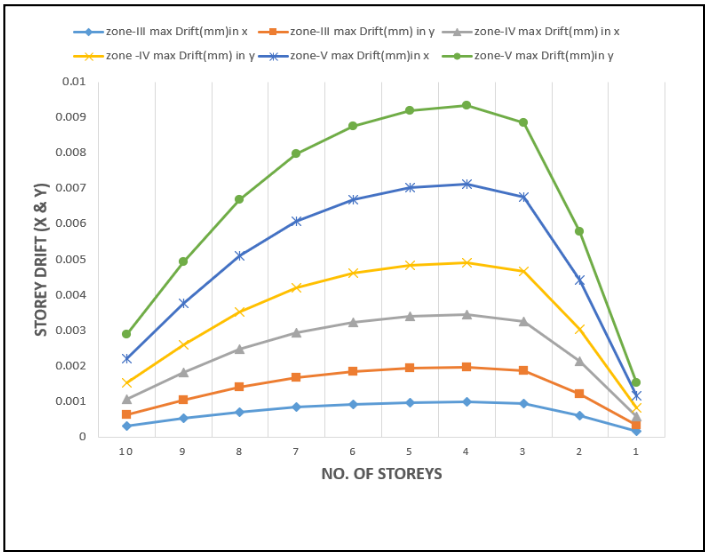

(f)

Fig. 2.(a) Base Shear in X & Y Direction along with the No. of storetys (b) Overturning Moment in X & Y Direction along with the No. of storeys (c) Displacement in X & Y Direction along with the No. of storeys (d) Torsion Moment in X & Y Direction along with No. of storeys (e) storey force in X & Y Direction along with the no. of storeys (f) storeys drift in X & Y Direction along with the no. of storeys.

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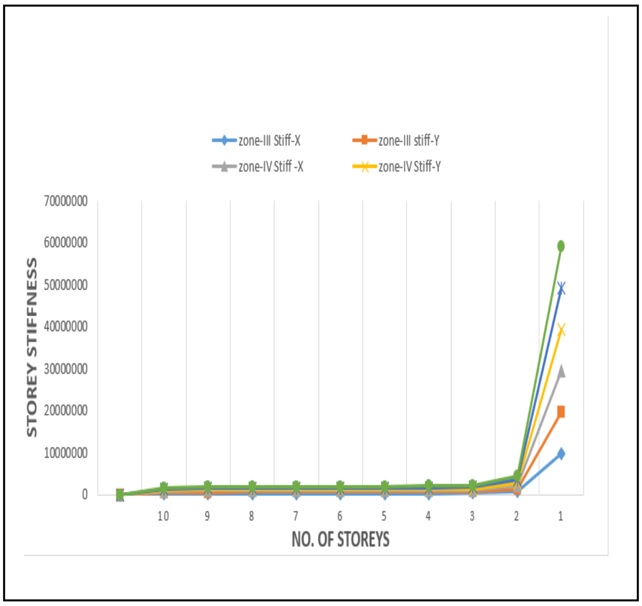

Fig. 3. (h) storey stiffness X & Y Direction along with no. of storeys.

EQ behavior of the RC structure was analyzed for Seismic Zone III, IV, and V with the help of graphical plots of Base Shear, Overturning Moment, Displacement, and Torsional moment depending on the height of building (number of storeys). From the analysis of results, it is evident that there is an increasing trend in all structural Limits as the seismic zone moves from Zone III to Zone V. This is because of increased earthquake intensity of the structure and seismic design forces in higher seismic zones. It can be seen from the plot of Base Shear for X and Y directions that the Base Shear value gradually increases from Zone III to Zone V. With the increase in seismic intensity, there is an increase in horizontal load acting on the structure and consequently there is an increase in base shear value. Out of the three seismic zones considered, Zone III has the lowest base shear value, while Zone V has the highest base shear value. A Similar trend is also observed in the overturning moments along both the zX and Y directions.

From the graph results, it is evident that there is an increase of both positive and negative overturning moments due to the increase in the seismic zone due to high rotation effects created by the high earthquake forces. Thus, the structure must resist high Rotational instability of the structure. Displacement also shows an upward trend as we move from Zone III to Zone V. It is clear from the graphs that maximum lateral displacement takes place in Zone V, whereas minimum displacement takes place in Zone III. This clearly means that buildings in higher seismic zones(Z) experience higher lateral displacements due to the higher earthquake loads of the structure.As far as the Torsional Moment(TM) is concerned, the graph results also indicate a steady increase Due to the increase in seismic zone. This implies that Earthquake-induced torsion becomes high in higher seismic zones. Although the structure is regular, higher seismic loadings result in increased torsion that must be considered while designing of the structure. For Seismic Zones III to V, the evaluation of storey forces, drift of the storey, and Lateral stiffness of the storey was carried out graphically based on the number of storeys in both the X & Y axises. Comparative analysis shows that structural demands escalate from Seismic Zone III to V, corresponding to the increase in Earthquake Force of the structure and EQ loading. The graph of the storey forces in both the X & Y axises shows that storey forces are relatively larger at lower levels but decrease with rise in storey level. In addition, the value of storey forces Rises continuously from Zone III to Zone V, thus showing that the Higher seismic zones cause the higher lateral Earthquake Forces on the structure. On the other hand, the storey drift in both the X & Y directions increases with increasing seismic zone. The max. storey drift found in Zone V, while the minimum drift is found in Zone III. This shows that higher earthquake forces lead to greater relative Parallel Displacement of the storey between adjacent storey levels.

The diagram of the Rigidity of the storey in both the X & Y orientation also shows the impact of increasing the level of seismic intensity. It is Evidence from the findings that the nature of the structural due to Rigidity of the storey becomes significant from Zone III to Zone V, thus stressing the impact of higher seismic forces on the structure. This shows the problems of stiffness and Optimized detailing in such structures so that they do not fail under seismic loads.

V. CONCLUSION

Overall, the FEA examination & design show that the suggested G+10 RC structure performs satisfactorily under the considered loadings and meets all the necessary structural Safety Criteria and Requirements. Overall, the graphical analysis shows an increasing trend in the Displacement of the storey, torsion force, Overturning Moment, Base Shear, Storey Force, Storey Drift (SF), and Storey Stiffness-related Response from Zone III to V. It is evident that structures situated in higher seismic zones experience greater loads and deformations; therefore, among the three, Zone V is the critical one, whereas Zone III is comparatively noncritical.

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