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Analysis Of RC Frame Building Staircase Under Seismic Loadings

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Abstract: In RC frame structures, beams and columns are the primary structural systems that resist lateral loads. Besides, these primary systems, some elements also participate to resist lateral load, which fall in the category of secondary systems. Secondary system may be structural secondary like structural partition, staircase etc. and non-structural secondary like machinery, storage tanks etc. Concrete staircase, which are structural secondary members are normally designed for non-seismic forces. During earthquakes, performance of stairs has been given low attention in research field and in the field of professional practices. In the present study, the effects of staircase on the seismic performance of the RC frame Building of different heights and different plans are studied. Staircase must remain usable after moderate or severe ground shake so that they can continue to function for rapid evacuation of residents. The nature of the interaction between staircase and structures needs to be understood more deeply by engineers and clearly addressed by codes and standards. Shear force are always found to be less in values in all three analyzed columns of the building when the stairs are present either at corner of building or in front at center of the building under seismic loading for both 10 stories

***Index Terms* - Staircase, Shear Force ,RC Frame, Beams, Column.**

I. INTRODUCTION

In RC frame structures, beams and columns are the primary structural systems that resist lateral loads. Besides, these primary systems, some elements also participate to resist lateral load, which fall in the category of secondary systems. Secondary system may be structural secondary like structural partition, staircase etc. and non-structural secondary like machinery, storage tanks etc. Concrete staircase, which are structural secondary members are normally designed for non-seismic forces. During earthquakes, performance of stairs has been given low attention in research field and in the field of professional practices. In the present study, the effects of staircase on the seismic performance of the RC frame Building of different heights and different plans are studied. Staircase must remain usable after moderate or severe ground shake so that they can continue to function for rapid evacuation of residents. The nature of the interaction between staircase and structures needs to be understood more deeply by engineers and clearly addressed by codes and standards.

CONFIGURATIONS OF STAIRCASE

Architecturally, aesthetically and structurally staircases constitute a very important part of a structure. As the important vertical transport channels, the staircases assume to guarantee persons, goods and materials with emergency escape. They appear in different shapes and forms, each requiring its own method of analysis. Regarding their structural configurations based on pattern of steps in stairs, usually fall in one of the following categories: i) Stairs with cantilever steps that are supported on a shear wall along the stair, ii) Stairs whose steps are supported on a slab, iii) Stairs whose steps are supported on two girders, like simply supported beams, iv) Stairs with free standing landings, with branches perpendicular or parallel to each other, v) Helical stairs which are supported on the slabs of the upper and lower floors, without intermediate supports.

The structural configurations based on the support system for each landing are as: vi) landing is supported by two landing beams under the platform. One of the landing beams is supported by two landing columns erected on the frame beams and the other landing beam is supported by the frame columns in the story mid height. vii) There is no landing beam at the stair flight-landing junction, viii) The landing in separated from the primary structure and supported by four landing columns erected on the frame beams or on the floor, i) The stairway used widely in multi-storey masonry structures and the landing is directly supported by a load-bearing masonry wall at one end. The steps are supported by inclined slabs and monolithically cast together forming stair flights with planar under surfaces. j) The stairway is a one-way type, called a Z-shaped stairway, with a stair stringer supporting the steps.

All the following stair configurations are as shown below:

Fig. i) Stairs with cantilever steps that are supported on a shear wall

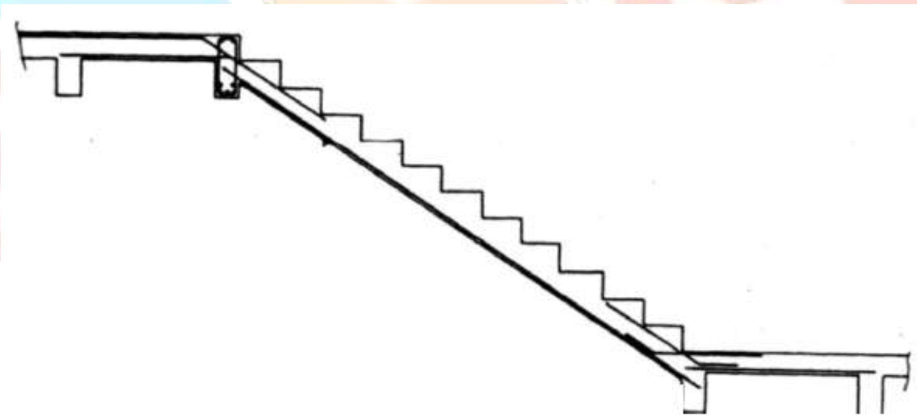


Fig. ii) Typical stair whose stairs are supported on slabs

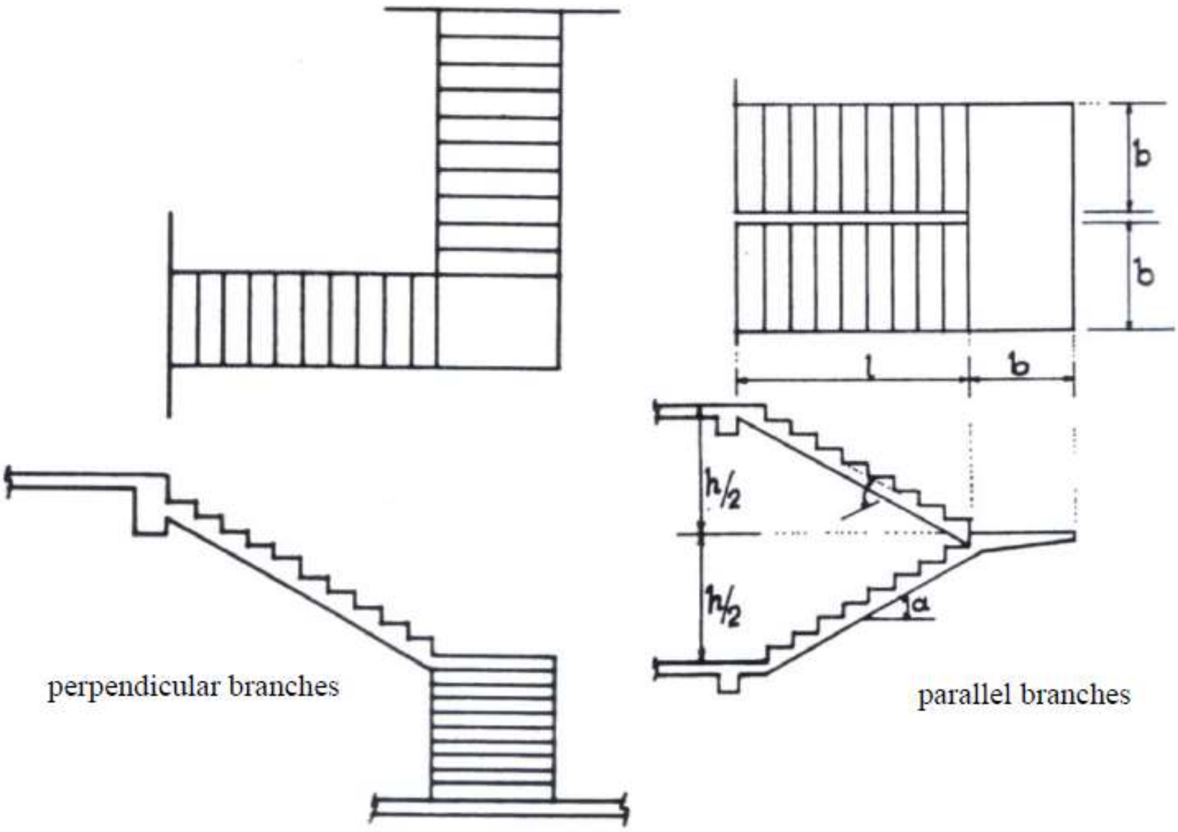


Fig. iii) Stairs whose steps are supported on two girders

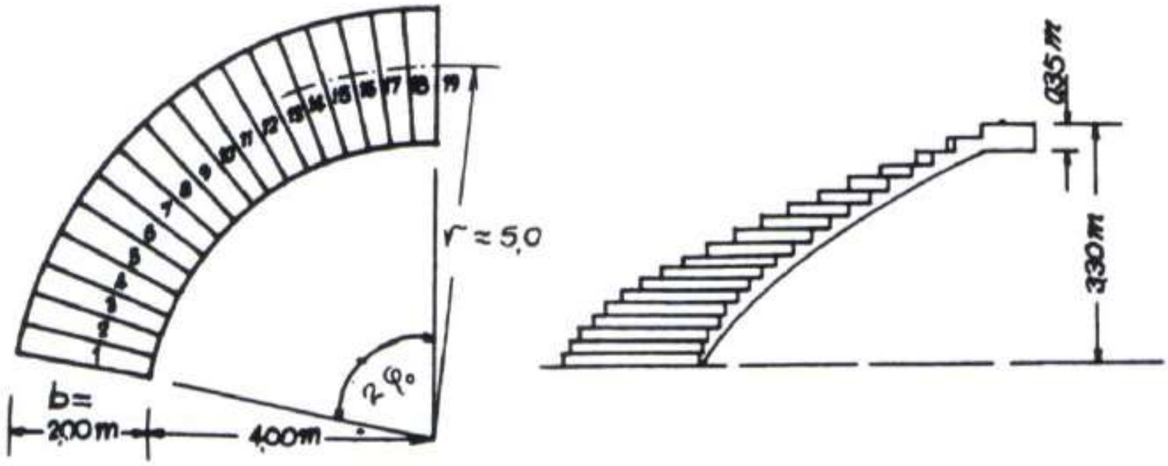


Fig. iv) Stairs with free-standing landings

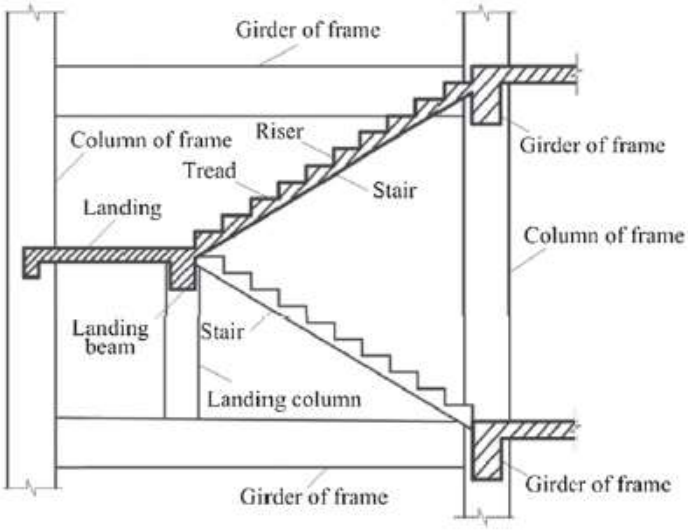


Fig. v) Typical helical stairs

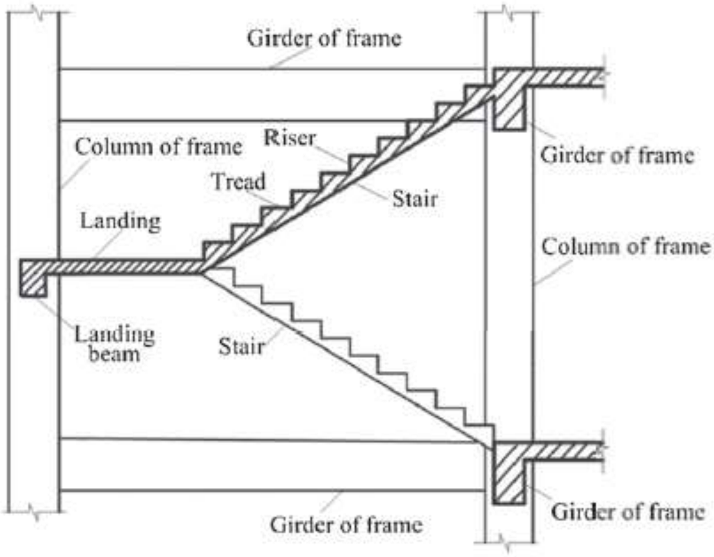


Fig. vi) Slab Stair with landing beam

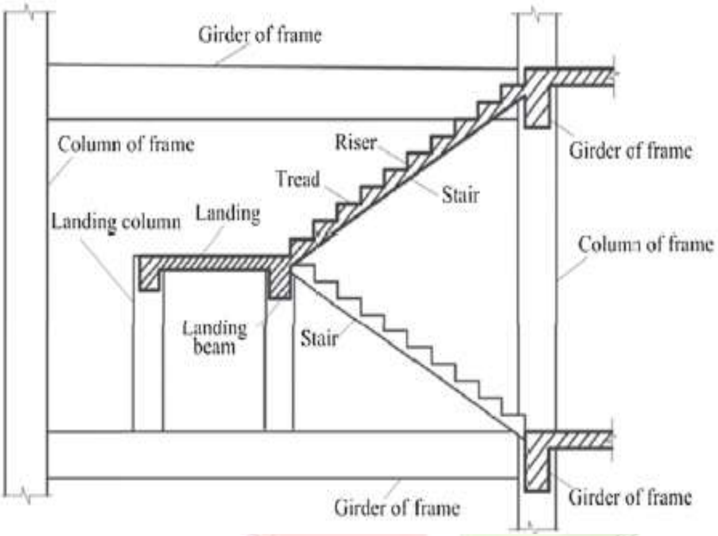


Fig. vii) Slab stair without landing beam under

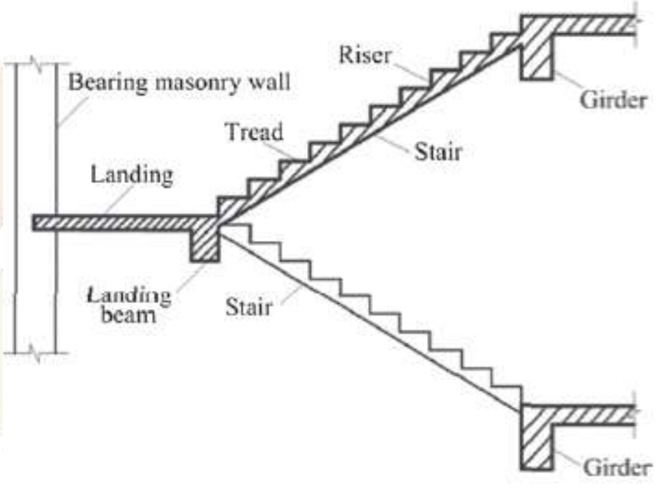


Fig. viii) Slab stair with freestanding landing

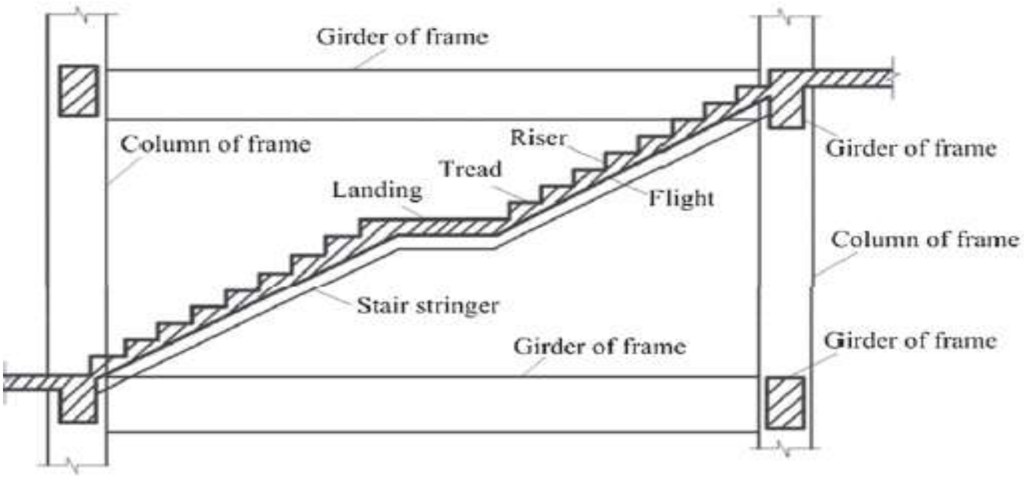


Fig. ix) Slab stair in masonry structure

I. RESEARCH METHODOLOGY

The purpose of the present work is to study the behavior of staircase at different locations in a building under seismic loads. For this purpose multi-storey BUILDING are considered. Structures are generally subjected to two types of load: static load and dynamic load. The analysis also depends on the behavior of the structure or structural material.

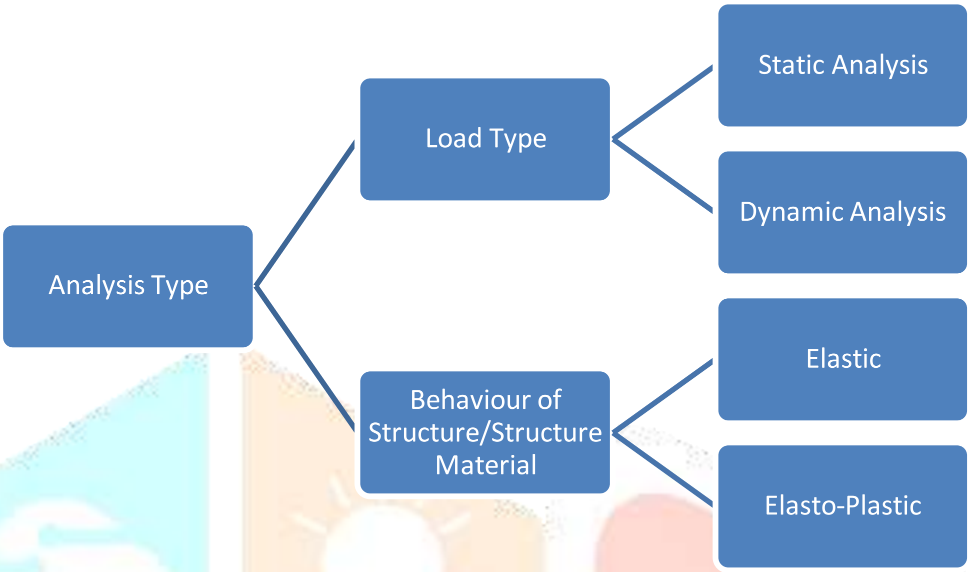


Fig. 3.2 Method of Analysis

The adopted methodology for the study of this dissertation is by considering linear Static & Dynamic loads on the RC frames in seismic zone V and analysis is done by using STAAD.Pro software. It is now common to estimate seismic demands in a simplified manner by dynamic analysis.

In this attempt, following major cases will be analyzed :-

1. An extensive survey of the literature on the response of stairs interaction with building at different locations to seismic loading is performed.
2. Provisions related to seismic analysis of stairs in building are presented.
3. Modelling of different height of structures which is ten and twenty is presented.
4. Problems of stairs in front, in interior and in corners of the building are taken and analyzed for static analysis.
5. Problems of stairs in front, in interior and in corners of the building are taken and analyzed by response spectrum for different storey.
6. Plot curve between bending moments and height of buildingfor different zones.
7. Plot curve between shear force and height of buildingfor different zones.
8. Plot curve between axial force and height of buildingfor different zones.

ANALYSIS PROCEDURES

Equivalent Lateral Force Procedure:

The equivalent lateral force procedure is the simplest method of analysis and requires less computational effort because the forces depend on the code based fundamental period of structures with some empirical modifier. The design base shear shall first be computed as a whole, and then be distributed along the height of the BUILDING based on simple formulas for BUILDING with regular distribution of mass and stiffness. The design lateral force obtained at each floor level shall then be distributed to individual lateral load resisting elements depending upon floor diaphragm action.

Response Spectra Method:

Response Spectra Method is an elastic dynamic analysis approach that relies on the assumption that the dynamic response of a structure may found by considering the independent response of each natural mode of vibration and then combining response in the same way. For analysis, the mass of the structure is assumed to be lumped at the floor levels. Thus, for planer system, only one degree of freedom per floor-Two lateral translation and angle of twist around the vertical axis must be considered.

The first step in the analysis of Response Spectra method is determining the lumped masses at the floor level due to dead load and appropriate amount of live load. Then the free vibration analysis of entire building shall be performed as per establishment methods of mechanics using the appropriate masses and elastic stiffness of the structural system, to obtain natural periods (T) and mode shapes {φ}. The clause 7.8.4.2 of IS 1893:2002 gives guideline for the number of modes to be considered. As per this clause the number of modes to be considered in the analysis should be such that the sum of modal masses of all modes considered is at least 90 percent of the total seismic mass. If modes with natural frequency beyond 33 Hz are to be considered, modal combination shall be carried out only for modes upto 33 Hz. The effect of modes with natural frequency beyond 33 Hz shall be included by considering missing mass correction. As per clause 7.8.4.5 BUILDING with regular and nominal irregular plan configuration may be modeled as a system of masses lumped at the floor level with each mass having one degree of freedom, that of lateral displacement in the direction under consideration. After satisfying the above condition the modal mass is calculated using the expression given in the code,

$$M_K = \frac{[\sum W_i \phi_{ik}]^2}{g \sum W_i (\phi_{ik})^2}$$

Where, M_K is the modal mass of mode k, g is acceleration due to gravity, $\phi_{ik}$is mode shape coefficients of floor i in mode k and W_i is the seismic weight of floor i. The percent mass contributing in each mode is calculated and if total percent of mass is less than 90% of total seismic mass, either the number of modes should be increased up to 33Hz or missing mass correction should be applied.

Now the design lateral force at each mode is calculated by formula, given in clause 7.8.4.5(c) of IS 1893 (Part I):2002

$$Q_{ik} = A_k \phi_{ik} P_k W_i$$

Where A_K is design horizontal acceleration spectrum value using natural period of vibration (T_k) of mode k, P_k is the modal participation factor of mode k and is given by

$P_k = \frac{\sum W_i \emptyset_{ik}}{\sum W_i (\emptyset_{ik})^2}$

The peak storey shear (V_{ik}) acting in storey i in mode k is given by,

$V_{ik} = \sum Q_{ik}$

The peak storey shear force (V_i) in storey i due to all modes considered is obtained by combining those due to each mode. Code has given various methods for combining the response quantities (for eg. Member forces, displacements, storey force, storey shear and base reactions). The complete quadratic combination (CQC) method should be used when the modes are well separated or when the modes are closely spaced.

$$\lambda = \sqrt{\sum \sum \lambda_i Þ_{ij} \lambda_i}$$

Where r is the number of modes being considered, λ_i is the response quantity in mode I (including sign), $\lambda_i$is the response quantity in mode j (including sign), $Þ_{ij}$ is cross modal coefficient

$$Þ_{ij} = \frac{8\zeta^2(1+\beta)\beta^{1.5}}{(1+\beta^2)^2+4\zeta^2\beta(1+\beta)^2}$$

ζ = Modal damping ration (in fraction) as specified in 7.8.2.1

β = Frequency ratio = ω_j/ω_i

ω_i = circular frequency in i^{th} mode

ω_j = circular frequency in j^{th} mode

But when the building does not have closely spaced modes, the square root of squares (SRSS) method should be used, then the peak response quantity (λ) due to all modes considered shall be obtained as,

$$\lambda = \sqrt{\sum {\lambda_k}^2}$$

Where

λ_{ik}= Absolute value of quantity in mode k, and

r = Number of modes being considered

when the building has few closely spaced modes then peak response quantity (λ^*) due to these modes shall be obtained as

$\lambda^* = \sum \lambda_{c'}$

When the summation is for the closely spaced modes only. This peak response quantity due to closely spaced modes (λ^*) is then combine with those of remaining well separated modes by CQC method as described above.

After combining the peak storey shear (V_{ik}) the design lateral forcec at roof and floor level is obtained as per clause 7.8.4.5(f) of IS1893(Part I):2002 as

$F_{roof}=V_{roof}$

$F_i = V_i – V_{i+1}$

Code has also introduced a lower bound seismic force (clause 7.8.2) , this clause requires that in case of dynamic analysis gives lower seismic forces, these to be scaled up to level of forces obtained based on empirical fundamental period T_a.

IV. RESULTS AND DISCUSSION

The performance of stairs forces and moments (in three columns A,B & C) in front, interior and corners are assessed for building areas and different building heights through various cases each having different models for earthquake zone V.

Column A is at center at front, column B is in interior present behind column A and column C is the corner column of the building.

Forces and moments behaviour in columns are studied when stairs are at different location, and results are reported. By this study observations are made that which location of stair produced minimum axial force, shear force and bending moments in all columns.

The results obtained from analysis are given in various figures are as follows:

- Graphical representation showing variation of bending momentsalong with the height of storeyin each columnsis presented from fig 5.1.1.1 to 5.1.1.12.
- Graphical representation showing variation of shear force along with the height of storey in each columns is presented from fig 5.1.1.1 to 5.1.2.12.
- Graphical representation showing variation of axial force along with height of storey in each columns is presented from fig 5.1.3.1 to 5.1.3.12.

Bending Moments in Column A, Column B & Column C

- Static Analysis

(10 stories)

- Dynamic Analysis

(10 tories and 20 stories)

-ZONE V RESULTS

Values of maximum parameter

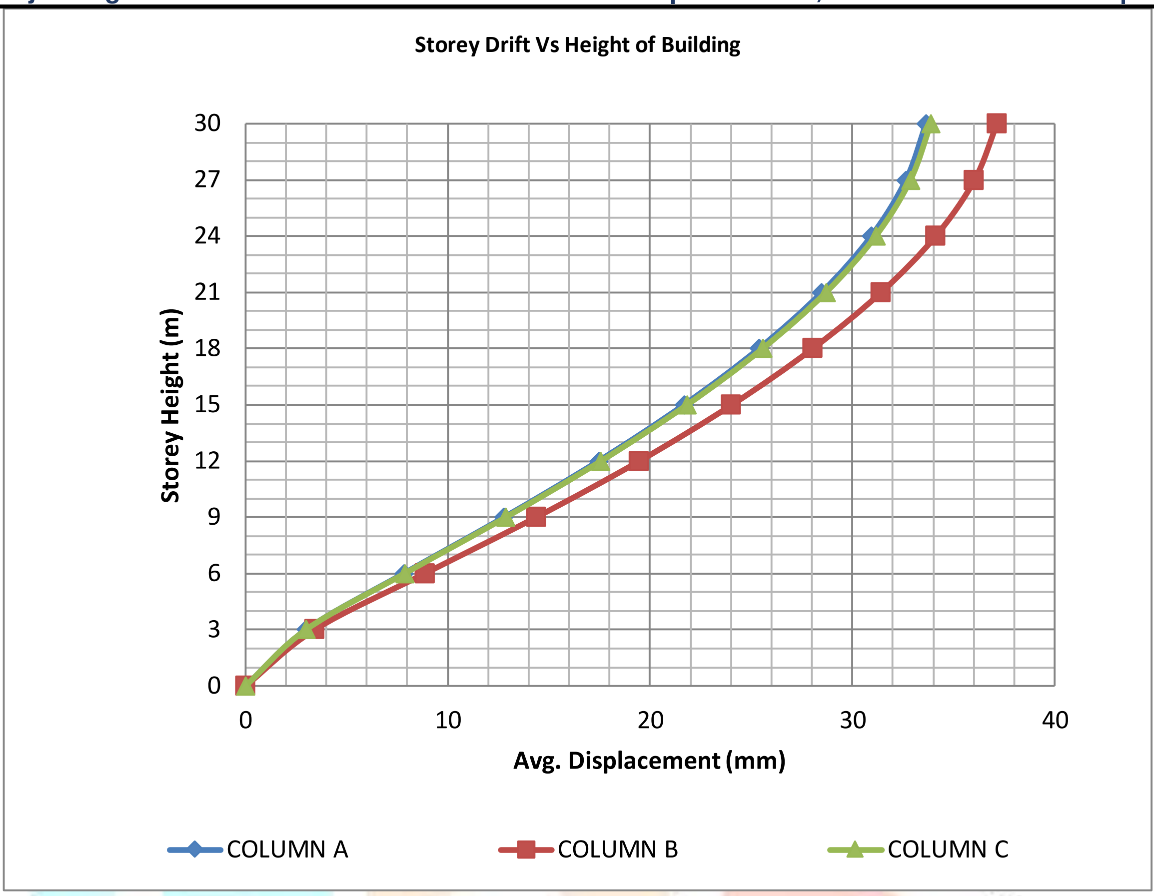
For 10 Storey Building

Location	Max. B.M.	Max. S.F.	Max. Axial Load
At Corner	157.488	78.791	367.645
At Center	181.399	90.509	314.677
At Interior	168.709	91.575	248.736

Storey Drift Diagram

for 10 Storey Building

staircase at center of front of building



CONCLUSIONS

- Moments are always found to be high in all three analyzed columns of the building when the stairs are present in interior of the building under seismic loading for both 10 and 20 stories.
- Moments are always found to be less in values of all three analyzed columns of the building when the stairs are present either at corner of building or in front at center of the building under seismic loading for both 10 and 20 stories.
- Shear force are always found to be maximum in all three analyzed columns of the building when the stairs are present in interior of the building under seismic loading for both 10 and 20 stories.
- Shear force are always found to be less in values in all three analyzed columns of the building when the stairs are present either at corner of building or in front at center of the building under seismic loading for both 10 and 20 stories.

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