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Influence of Aspect Ratio & Plan Configurations on Seismic Performance of Multi-storeyed R.C.C. Buildings using Response Spectrum Analysis

Swapnil Nagargoje[1], Ganesh Deshmukh[2]

[1]*Post Graduate Student, Department of Civil Engineering, Pankaj Laddhad institute of Technology and Management Studies Buldhana, Maharashtra, India.*

[2] *Assistant Professor, Department of Civil Engineering, Pankaj Laddhad institute of Technology and Management Studies Buldhana, Maharashtra, India*

***Abstract* - The behavior of a building during earthquakes depends critically on its overall shape, size and geometry. Earthquake resistant design of buildings depends upon providing the building with strength, stiffness and inelastic deformation capacity which are great enough to withstand a given level of earthquake generated force. This is generally accomplished through the selection of an appropriate building configuration and the careful detailing of structural members. Configuration is critical to good seismic performance of buildings. The important aspects affecting seismic configuration of buildings are overall geometry, structural systems, and load paths. The building slenderness ratio and the building core size are the key drivers for the efficient structural design.**

This paper focuses on the effect of both Vertical Aspect Ratio (H/B ratio i.e. Slenderness Ratio) and Horizontal or Plan Aspect Ratio (L/B ratio), where H is the total Height of the building frame, B is the Base width and L is the Length of the building frame with different Plan Configurations on the Seismic Analysis of Multistoried Regular R.C.C. Buildings.

The test structures are kept regular in elevation and in plan. Here, height and the base dimension of the buildings are varied according to the Aspect Ratios. The values of Aspect Ratios are so assigned that it provides different configurations for Low, Medium and High-rise building models.

In the present study, four building models having different Horizontal Aspect ratios viz. 1, 4, 6 & 8 ranging from 12m.to 96m.length of different Vertical Aspect ratios (slenderness ratios) viz. 1, 4, 6 & 8 of varying 4, 16, 24 & 32 storeys have been considered and their influence on the behavior of the RCC Multistoried buildings is demonstrated, using the parameters for the design as per the IS-1893- 2002-Part-1 for the seismic zone- 3. In this way total 16 building models are analyzed for different load combinations by Linear Elastic Dynamic Analysis (Response Spectrum analysis) with the help of ETABS software and the results obtained on seismic response of buildings have been summarized.

***Index Terms* - Slenderness Ratio, Aspect Ratio, Building Configuration, Linear Elastic Dynamic Analysis, Response Spectrum Analysis, Seismic Performance, ETABS- 2015.**

I.INTRODUCTION

Buildings oscillate during earthquake shaking and inertia forces are mobilized in them. Then, these forces travel along different paths, called load paths, through different structural elements, until they are finally transferred to the soil through the foundation. The generation of forces based on basic oscillatory motion and final transfer of force through the foundation are significantly influenced by overall geometry of the building, which includes: (a) plan shape, (b) horizontal aspect ratio or plan aspect ratio and (c) slenderness ratio of the building.

The length divided by width (both in plan) of a building is termed as its Aspect Ratio and the ratio of height to least lateral dimension of a building is termed as its Slenderness Ratio. Increase in length of a building increases the stresses in a floor working as a horizontal distribution diaphragm in a transverse direction. An increased length of the building increases efforts at a level that acts as a diaphragm horizontal distribution. The rigidity of the floor may Therefore, proportions of buildings length-wise and height-wise need to be considered carefully.

In seismic design, the proportions of a building may be more important than its absolute size. For tall buildings the slenderness ratio of a building is one of the important considerations than just the height alone.

The more slender the building is worse are the overturning effects of an earthquake and greater are the earthquake stresses in the outer columns, particularly the overturning compressive forces, which can be very difficult to deal with. Increasing the height of a building may be similar to increasing the span of a cantilever beam. As the building grows taller there is a change in the level of response to the seismic forces.

II. OBJECTIVES

The salient objectives of this study are:

1. To perform a comparative study of the various seismic parameters of reinforced concrete moment resisting frames with varying number of bays in horizontal configurations and number of stories in vertical configurations to investigate the effect of aspect ratios.
2. To study the change in different seismic response parameters along the increasing height and increasing bays.
3. To evaluate base shear, storey overturning moment, storey drift, storey displacements and modal period of vibration.
4. To propose the best suitable building plan configuration in the existing condition.

III. METHEDOLOGY

In the present study, I.S. Code (1893:2002) based Dynamic Analysis (Response Spectrum Analysis) is performed. This study includes comparative study of behaviour of Low, Medium, High-Rise R.C.C. building frames considering different geometrical plan configurations based on different aspect ratios under earthquake forces. Following steps of methods of analysis are adopted in this study:

Step-1: Selection of different models having different building geometry, No. of bays for Horizontal Aspect Ratio and No. of storeys for Slenderness Ratio (4 geometry)

Step-2: Selection of seismic zone. (III)

Step-3: Formation of load combination.

Step-4: Modelling of building frames using ETABS-2015 software.

Step-5: Analyses each models considering each load combinations for (16 Model Cases) by Response Spectrum Analysis.

Step-6: Comparative study of results in terms of Base shear, Storey overturning moments, Storey drift, Storey displacement and Modal period of vibration.

IV. STRUCTURAL MODELLING

Formulation of Models:

According to Table 1, four types of building geometry are taken in this project.

To study the effect of Horizontal Aspect Ratio, the horizontal aspect ratios are formulated in terms of number of bays- 2 Bay, 8 Bay, 12 Bay and 16 Bay. The base model (2 Bay-12x12m.) having Aspect Ratio 1, is increased by 4, 6 and 8 respectively by increasing the number of bays.

To study the effect of Vertical Aspect Ratio, the vertical aspect ratios are formulated in terms of number of storeys- 4 Storeys, 16 Storeys, 24 Storeys, and 32 Storeys. The base model (2 Bay-12x12m.) having Aspect Ratio 1, is increased by 4, 6 and 8 respectively by increasing the number of storeys.

In this way, total 16 building models are formulated by assigning different aspect ratios, height wise and bay wise, as listed. All structures are symmetrical, non-twisting and without infill walls.

Two types of Configurations are used in this study, viz. Square Building Frames and Rectangular Building Frames. Square Building Frames have Aspect Ratio 1, whereas Rectangular Building Frames have Aspect Ratio 4, 6 and 8.

Each bay is of 6.00 m. length and each storey is of 3.00 m. height. The depth of foundation is 2.00 m. for 4 storey and 16 storey buildings, whereas 2.40 m. for 24 storey and 32 storey buildings.

Table 1: Formulations of Models Geometry

Aspect Ratios	V.A.R. 1	V.A.R. 4	V.A.R. 6	V.A.R. 8
	4 Storeys	16 Storeys	24 Storeys	32 Storeys
H.A.R.1 (2-Bay)	12x12x12 M11	12x12x48 M14	12x12x72 M16	12x12x96 M18
H.A.R. 4 (8-Bay)	48x12x12 M41	48x12x48 M44	48x12x72 M46	48x12x96 M48
H.A.R. 6 (12-Bay)	72x12x12 M61	72x12x48 M64	72x12x72 M66	72x12x96 M68
H.A.R. 8 (16-Bay)	96x12x12 M81	96x12x48 M84	96x12x72 M86	96x12x96 M88

Table 2: Loading and Sectional Properties of Models

	Loading	
1	Live load	4.00 kN/ m^2

2	Floor finish	1.00 kN/ m^2
3	Water proofing	2.500 kN/ m^2
4	Specific wt. of R.C.C.	25.00 kN/ m^2
	Sectional properties	
5	Beam dimensions	300 x 600 mm
6	Column dimensions	800 x 800 mm
7	Slab thickness	125 mm
8	Support conditions	Fixed

Table 3: Details of Seismic Parameters

Seismic Parameters	
Seismic Zones	III
Earthquake load	As per IS-1893-2002
Type of soil	Type -II, Medium soil as per IS-1893
Dynamic Analysis	Response Spectrum Analysis.
Software used	ETABS-2015
Zone Factor (Z)	0.16 (Zone III) [moderate seismic intensity] As per IS-1893-2002 Part -1 clause 6.4.2.
Response Reduction Factor (RF)	5.0 (SMRF Structure) (Table 7 of IS: 1893-2002)
Importance Factor (I)	1.00 (Table 6 Clause 6.4.2 of IS: 18932002)
Damping	5%
Fundamental natural period of building Table 2: Loading and Sectional Properties of Models	Ta = 0.075 $h^{0.75}$ for moment resisting RC frame building without brick infill panels Ta = 0 .09 h /√d for all other building i/c moment resisting RC frame building with brick infill walls, Where h = height of building d = base dimension of building at plinth level in m along the considered direction of lateral forces.
S_a/g	2.5

V. RESULTS AND DISCUSSION

The comparison of results obtained from Response Spectrum Analysis, done on the bases of seismic parameters, has been carried out storey wise first for each bay and then bay wise for each storey height.

1.The Base shear increases gradually with increase in number of bay and up to 16th storey for each 4th, 16th, 24th & 32nd storey Buildings for all the cases of 2 bay,8 bay,12 bay & 16 bay buildings and then randomly decreases for 24th & 32nd storey Buildings for 2 bay buildings, while base shear in 8 bay and 16 bay buildings decreases for 24th storey and again increases for 32nd storey. The 12 bay buildings show increase in storey height for 16th, 24th & 32nd storey buildings. The Base Shear is obtained lower for 2 bay buildings and higher for 16 bay buildings. Lowest value is obtained in case of 2 bay-4th storey (Square) building [M18 (12x12x12)], whereas highest in case of 16 bay-32nd storey [M88 (96x12x96)]. Storey-wise no significant variation is seen after 16th storey despite little increase or decrease.

2.The Storey overturning moment increases gradually with increase in number of bay and storeys for all the cases of 2 bay,8 bay,12 bay & 16 bay buildings for each 4th, 16th, 24th & 32nd storey buildings. The Storey overturning moment is obtained lower for 2 bay buildings and higher for 16 bay buildings. Lowest value is obtained in case of 2 bay-4th storey (Square) building [M11 (12x12x12)], whereas highest in case of 16 bay-32nd storey [M88 (96x12x96)].

3. It has been observed that the Storey Displacement (Y- Directional) increases with the increase in bays and storey height for of 4th, 16th, 24th & 32nd storey for all the cases of 2 bay, 8 bay,12 bay & 16 bay buildings. By considering the maximum displacement of each storey, it is observed that, the maximum displacement is increasing from first storey case to last one. The Storey Displacement is obtained lower values for 4th storey for all the cases of 2 bay,8 bay,12 bay & 16 bay buildings. The increase from 4th storey to 16th storey is observed remarkably higher. The figure shows that the Storey Displacement is obtained lowest in case of 2 bay-4th storey case [M11 (12x12x12)], and highest in 16 bay - 32nd storey case [M88 (96x12x96)], which shows substantial increase of 70.13 cm. in comparison of the lowest one. Hence, it is beyond the acceptable limit. The Storey Displacement (X Directional) exhibits conversely in which opposite results are obtained. The Storey

Displacement decreases with increase in number of bay for 4th ,16th, 24th & 32nd storey Buildings for all the cases of 2 bay,8 bay, 12 bay & 16 bay buildings except the cases of 8 bay - 4th storey, 12 bay - 16th storey, 16 bay - 24th storey and 16 bay - 32nd storey which show some little increase. The figure shows that the Storey Displacement is obtained highest in case of 2 bay -32nd storey case [M18 (12x12x96)], and lowest in 16 bay - 4th story case [M81 (96x12x12)].

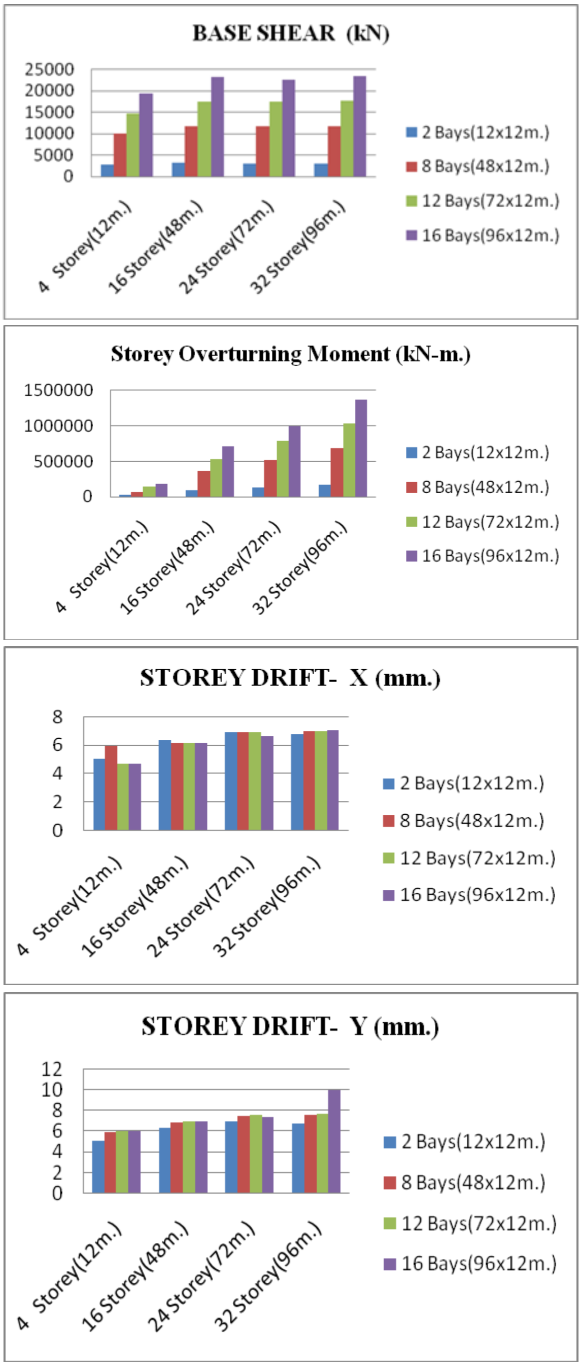

Figure1-4: Comparison of Critical Seismic Parameters

VI. CONCLUSION

Based on the present study, following conclusions can be drawn: -

1. It is concluded that all the seismic parameters, viz. Base Shear, Storey Overturning Moment, Storey Drift, Storey Displacement and Modal Period of Vibration increase with the number of bays (Horizontal Aspect ratio/ Plan Aspect Ratio) and number of storeys (Vertical Aspect ratio/Slenderness Ratio). The higher the number of bays, higher the values of all these parameters. When we go for higher number of bays or storeys, the values of all these parameters increase excessively and tremendously.
2. In comparison of Square and Rectangular Configurations (Aspect ratio 4, 6, and 8), the Square Configurations (Aspect ratio 1) perform better, as they possess lesser values of all these seismic parameters. Therefore, configurations which have elongated shape/ long narrow diaphragms should not be preferred. The configuration must have some adequate base width.
3. It is seen that the critical seismic parameteric values of 2-bay (12x12m.) building frames up to 4 storey building (12m. height) are lesser than corresponding 8 bay (48x12m.),12 bay (72x12m.) and 16 bay (96x12m.) building frames. Therefore, 2 bay buildings (12x12m.) are appropriate for lower building heights.
4. The present study reveals that the square configuration, which has the Aspect Ratio 1 (both Horizontal and Vertical) performs seismically amongst the best, on the bases of the above seismic parameters, would be the most suitable plan configuration option to be chosen.

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