Influence of Aspect Ratio & Plan Configurations on Seismic Performance of Multistoreyed Regular R.C.C. Buildings: An Evaluation by Response Spectrum Analysis

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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 Multistoreyed 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-2015 software and the results obtained on seismic response of buildings have been summarized.

Key Words: *Slenderness Ratio, Aspect Ratio, Building Configuration, Linear Elastic Dynamic Analysis, Response Spectrum Analysis, Seismic Performance, ETABS- 2015.*

1. 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 be insufficient to redistribute the horizontal load caused by an earthquake.

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. Therefore, proportions of buildings length-wise and height-wise need to be considered carefully.

1.1 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.

2. LITERATURE REVIEW

Arnold and Reitherman (1982) discussed a number of seismic design configuration problems, and explanations of architectural reasons for why they often arise in their research paper, Building configuration and seismic design.

C.V.R.Murty (2005) discussed in Importance of Architectural Features,that the behaviour of a building during earthquakes depends critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground.

Snigdha A. Sanyal (2008) focused in Multi Dimensional Building Planning For Safer Tomorrow, that the seismic performance of a building will benefit greatly from timely interaction between architects and structural engineers. A building that is poorly configured will never perform well in a damaging earthquake.

Pawan Pandey & Dilip Kumar (2014) studied in Seismic load Effect on Building Configuration, that the behavior of building during Earthquake depends critically on its overall shape, size and geometry. The Seismic performance of building is available and new design methods should account for the building ability to dissipate energy and the effect of the lateral deformation. These aspects involve both plan and structural configuration of building.

Dileshwar Rana, Prof. Juned Raheem (2015) shows the performance & behavior of regular & vertical geometric irregular RCC framed structure under seismic motion. Five types of building geometry are taken in this project: one regular frame & four irregular frames. A comparative study is made between all these building configurations height- wise and bay-wise. The change in the different seismic response is observed along different height.

3. METHODOLOGY

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.

4. STRUCTURAL MODELLING

4.1 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.

Table1: Formulation 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 **M_{11}**	12x12x48 **M_{14}**	12x12x72 **M_{16}**	12x12x96 **M_{18}**
H.A.R. 4 (8-Bay)	48x12x12 **M_{41}**	48x12x48 **M_{44}**	48x12x72 **M_{46}**	48x12x96 **M_{48}**
H.A.R. 6 (12-Bay)	72x12x12 **M_{61}**	72x12x48 **M_{64}**	72x12x72 **M_{66}**	72x12x96 **M_{68}**
H.A.R. 8 (16-Bay)	96x12x12 **M_{81}**	96x12x48 **M_{84}**	96x12x72 **M_{86}**	96x12x96 **M_{88}**

NOTE: 1)Model No. is denoted by M_{ij}, where,
i = Aspect Ratio, and
j = Slenderness Ratio
2) All dimensions of models are in meters.

Table2: Loading & Sectional properties of Models

Loading		
1	Live load	4.00 kN/ m²
2	Floor finish	1.00 kN/ m²
3	Water proofing	2.500 kN/ m²
4	Specific wt. of R.C.C.	25.00 kN/ m²
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

Table3: 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: 1893-2002)
Damping	5%
Fundamental natural period of building	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

5. 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 [M_{18} (12x12x12)], whereas highest in case of 16 bay-32nd storey [M_{88} (96x12x96)]. Storey-wise no significant variation is seen after 16th storey despite little increase or decrease.

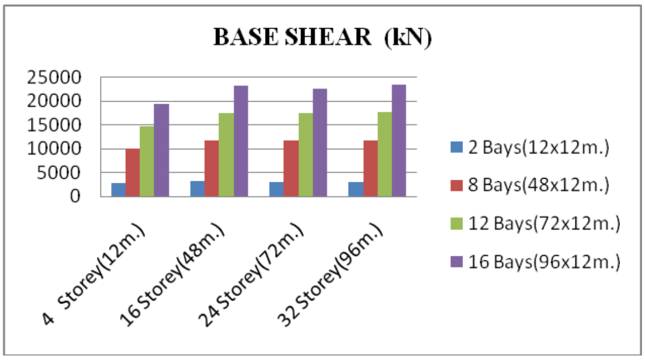
2. The Storey overturning moment increases gradually with increase in number of bay and storeys for all the cases of 2 bay,8 bay,12 bay & 16 bay buildings for each 4th, 16th, 24th & 32nd storey buildings. The Storey overturning moment is obtained lower for 2 bay buildings and higher for 16 bay buildings. 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)].

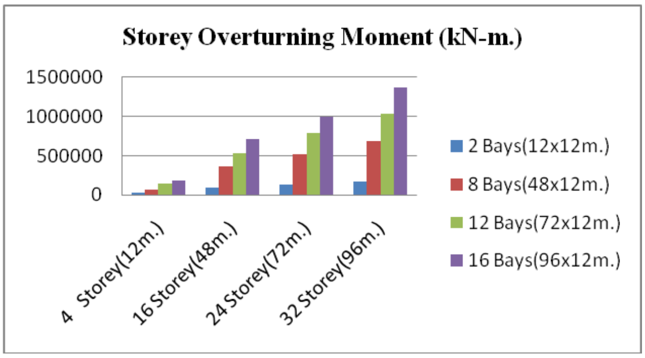
3. The Storey Drift (Y- Directional) increases gradually with increase in number of bays and storeys, for 4th, 16th, 24th & 32nd storey buildings for all the cases of 2 bay, 8 bay,12 bay & 16 bay buildings except the case of 2 bay-32nd storey, in which there is obtained some little decrease. The Storey Drift is obtained lower for 2 bay buildings and higher for 16 bay buildings. The figure clearly shows that the 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), which shows substantially excessive increase in comparison of the lowest one and is beyond the code specified permissible limit of 0.4% of storey height i.e. 12 mm, whereas the Storey Drift (X- Directional) exhibits conversely, in which opposite result are obtained. The Storey Drift decreases gradually with increase in number of bays, for 4th, 16th and 24th buildings for all the cases of 2 bay,8 bay, 12 bay & 16 bay buildings except the cases of 32nd storey for all the cases of 2 bay,8 bay,12 bay & 16 bay buildings, where Storey Drift increases gradually with increase in number of bays. Moreover, 8 bay-4th storey and 12 bay-24th storey also exhibited some little increase. The Storey Drift is obtained lower for 16 bay buildings and higher for 2 bay buildings. Lowest value is obtained in case of 16 bay-4th storey (Square) building **[M_{11} (96x12x12)]**, whereas highest in case of 16 bay-32nd storey **[M_{88} (96x12x96)].**

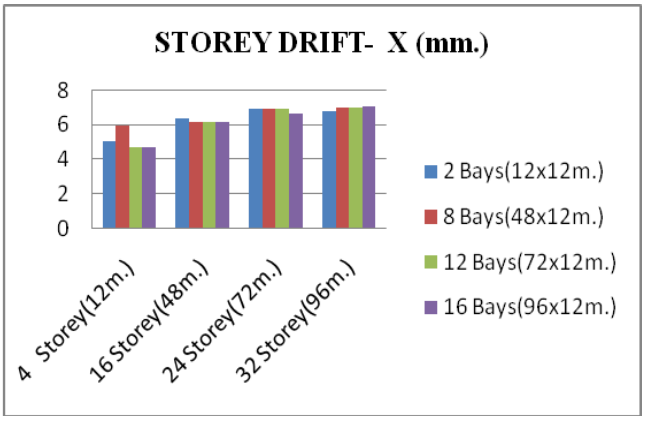
4. It has been observed that the Storey Displacement (Y- Directional) increases with the increase in bays and storey height for of 4th, 16th, 24th & 32nd storey for all the cases of 2 bay, 8 bay,12 bay & 16 bay buildings. By considering the maximum displacement of each storey, it is observed that, the 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 **[M_{18} (12x12x96)]**, and lowest in 16 bay - 4th storey case **[M_{81} (96x12x12)]**. The Figure shows that the 2 bay (square) building frames comprises more storey displacement than their corresponding rectangular 8 bay, 12 bay and 16 bay building frames.

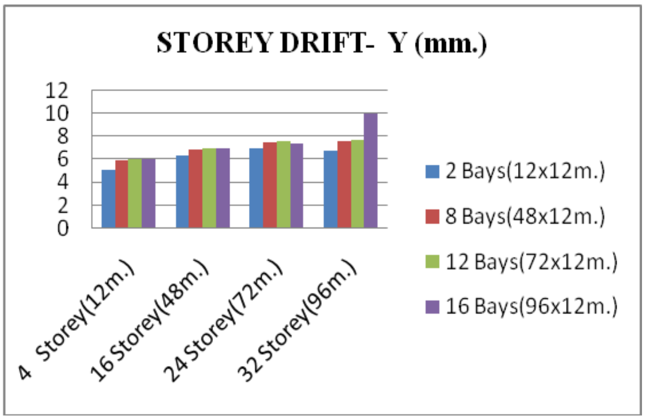
5. The Modal Period of Vibration increases with the increase in number of bay and storey height for 4th, 16th, 24th & 32nd storey buildings for all the cases of 2 bay,8 bay, 12 bay & 16 bay buildings as in a linear function. The above Figure shows that the 4th storey building frames comprise less Modal Period of Vibration as compare to other storey configurations. The above figure also shows that the least value of Modal Period of Vibration is obtained in case of 2 bay - 4th storey [M_{11} (12x12x12)], whereas the highest value of Modal Period of Vibration is obtained in case of 16 bay – 32nd storey [M_{88} (96x12x96)]. Earthquake records indicate that earthquakes concentrate their energy and greater accelerations in periods close to ½ second. from vibration point of view, up to 4th storey height, each bay buildings perform reasonably, while the buildings have upper storey heights, do not act satisfactorily.

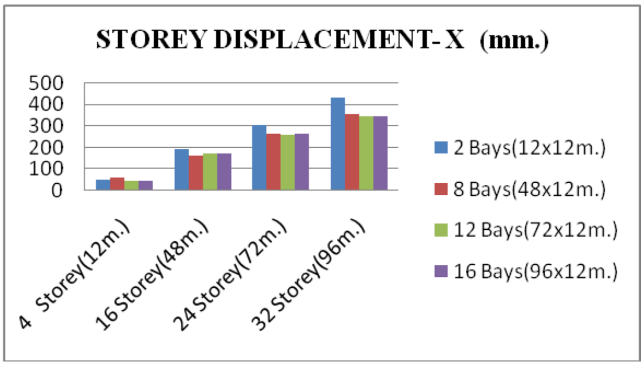
Figure1-7: Comparison of Critical Seismic Parameters

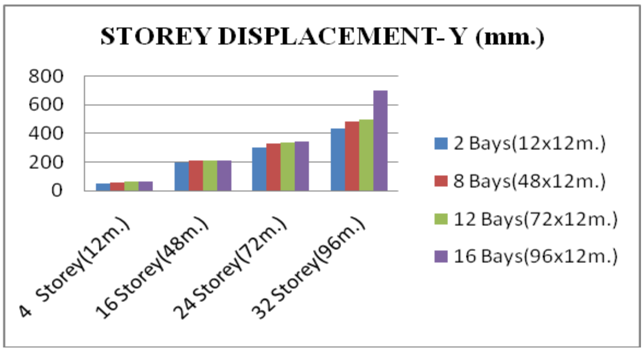


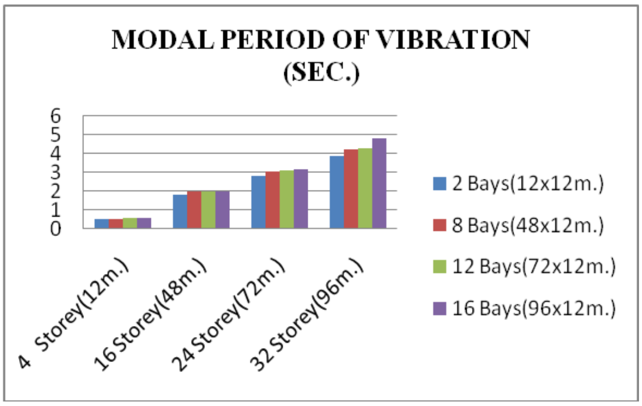












6. CONCLUSION

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.

5. In comparison as a whole, the present study demonstrates that the building frames whose Horizontal Aspect Ratios viz. 4, 6 and 8 do not perform seismically better in respect of the building frames whose Horizontal Aspect Ratios is 1.The study concludes that the buildings with Horizontal Aspect Ratios are less than 4, the seismic performance is reasonable. Above this, the worse effects of excessive forces, storey drift and displacement values may be obtained. Hence they should be discarded due to their unsatisfactory, weaker and unreasonable performances on the bases of above seismic parameters, which can cause detrimental and disastrous effects or otherwise be treated with the enough earthquake resistant elements.

6. Similarly, the building frames whose Vertical Aspect Ratios viz. 4, 6 and 8 do not perform seismically better, in respect of the building frames whose Vertical Aspect Ratios is 1. The present study concludes that the buildings with Vertical Aspect Ratios less than 4, the seismic performance is reasonable. Above this, the worse effects of excessive overturning, storey drift and displacement, period of vibration, etc. values may cause detrimental and disastrous effects to the buildings. Hence slender building configuration, as far as possible, should not be chosen, or otherwise be provided with the adequate earthquake resistant solutions.

REFERENCES

[1] Arnold,C., and Reitherman, R.,(1982), *Building Configuration and Seismic Design*, John Wiley & Sons, Inc., NY,USA

[2] J. S. Grossman, Slender concrete structures – the newedge, ACI Structural Journal 87 (1) (1990) 39-52.

[3] Charleason,A.W, ― Seismic design within architectural education‖, Victoria University of Wellington.

[4] Snigdha A. Sanyal, *Multi Dimensional Building Planning for Safer Tomorrow*, The 14th World Conference on Earthquake Engineering Oct. 12-17, 2008, Beijing, China.

[5] Christopher Arnold, Eric Elsesser, 2002,‖ Building configuration : problems and solutions‖, San Francisco, California, pp. 153-160.

[6] M.Mezzi, A. Parducci and P. Verducci.,"Architectural and Structural Configurations of Buildings with Innovative Aseismic Systems".13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada, (2004)Paper No. 1318.

[7] M. Ali and K. Moon, Structural developments in tall buildings: Current Trends and Future Prospects, Architectural Science Review Journal 50 (3) (2007) 205-223.

[8] Murty, C.V.R.,(2005), *IITK-BMTPC Earthquake Tips Learning Earthquake Design and Construction*, National Information Center of Earthquake Engineering, IIT Kanpur, India

[9] Tarek A.Awida, "The Structural Behavior of Low/Medium/High Rise Concrete Office Buildings in Kuwait" Journal of Civil Engineering and Architecture, ISSN 1934-7359, USA Oct. 2010, Volume 4, No.10 (Serial No.35)

[10] Murty, C.V.R., Goswami, R., Vijayanarayanan, A.R. and Mehta, V. (2012) Earthquake Behavior of Buildings. Gujarat State Disaster Management Authority, Gandhinagar, 53-79.

[11] Vinay Mohan Agrawal, (2013) A Thesis on "Effect of Setback on Fundamental Period of RC Framed Buildings".

[12] Md. Nazmul Haq, Wahid Hassan, Md. Arman Chowdhury, Evaluation of the Impact of Dynamic Analysis on Different Building Height, International Journal of Science and Research (IJSR), India Online ISSN: 2319-7064 Volume 2 Issue 8, August 2013

[13] Sangamnerkar Prakash, Dubey S.K. "Static and Dynamic behavior of Reinforced Concrete Framed Building: A Comparative Study". IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 10, Issue 4 , pp 01-07. (2013).

[14] S.S. Patil, S.A. Ghadge, C.G. Konapure, and C.A. Ghadge, Seismic Analysis of High-Rise Building by Response Spectrum Method, international Journal Of Computational Engineering Research, March 2013, Vol. 3 Issue. 3

[15] E. Pavan Kumar, A. Naresh, M. Nagajyothi, M. Rajasekhar –"Earthquake Analysis of Multi Storied Residential Building - A Case Study" Int. Journal of Engineering Research and Applications, Vol. 4, Issue 11 (Version 1), November 2014, pp.59-64

[16] Alashker, Y., Nazar, S. and Ismaeil, M.A. (2014) A Comparative Study of Seismic Strengthening of RC Buildings by Steel Bracings and Concrete Shear Walls. International Journal of Civil and Structural Engineering Research, 2, 24-34.

[17] Mohit Sharma, Dr. Savita Maru. "Dynamic Analysis of Multistoried Regular Building" I.O.S.R. Journal of Mechanical and Civil Engineering, Volume 11, Issue 1. Ver. II (Jan-2014), PP 37-42.

[18] Abhay Guleria , "Structural Analysis of a Multi-Storeyed Building using ETABS for different Plan Configurations", International Journal of Engineering Research&Technology (IJERT) Vol. 3Issue5,May- 2014

[19] Dileshwar Rana, Prof. Juned Raheem, "Seismic Analysis of Regular & Vertical Geometric Irregular RCC Framed Building," International Research Journal of Engineering and Technology (IRJET Volume: 02, Issue: 04 July-2015)

[20] Anupam Rajmani, Prof Priyabrata Guha "Analysis Of Wind & Earthquake Load For Different Shapes Of High Rise Building", International Journal of Civil Engineering and Technology (IJCIET) Volume 6, Issue 2, February (2015), pp. 38-45

[21] Mohammed Rizwan Sultan, D. Gouse Peera, "Dynamic Analysis Of Multi-Storey Building For Different Shapes", International Journal of Innovative Research in Advanced Engineering ,Issue 8,Volume 2 (August 2015)

[22] Sangamnerkar, P. and Dubey, S.K. (2015) " Effect of Base Width and Stiffness of the Structure on Period of Vibration of RC Framed Buildings in Seismic Analysis". Open Journal of Earthq. Research, 4,65-73.

[23] Jain Sudhir.K.-E Course on Indian seismic code IS-1893-2002-Part-I- IIT Kanpur.

[24] Agarwal Pankaj ; Shrikhande ,Manish, (2004), Earthquake Resistant Design of Structures‖, PHI publication, New Delhi , India

[25] Dr. S.K Duggal, Eq. Resistance Design of Structure.

[26] P.C.Varghese, Advanced Reinforced Concrete Design, Second Edition.

[27] IS-456-1978 and. IS-456-2000 "Indian standard of code and practice for plain and reinforced concrete" Bureau of Indian Standards, New Delhi -2000.

[28] SP-16-1980- Design Aids for Reinforced concrete to IS-456-1978-Bureau of Indian Standards, New Delhi.

[29] IS-875-1987. (Part-1) for *Indian standard code of practice for structural safety loadings standards* Bureau of Indian Standards, New Delhi.

[30] IS: 875-1987 (part-2) for *Live Loads or Imposed Loads, code of practice of Design loads* (other than earthquake) for buildings and structures.

[31] IS-13920."Ductile detailing of reinforced structures subjected to seismic force" Code of Practice Bureau of Indian Standards, New Delhi -1993.

[32] IS-1893:2002, Criteria for Earthquake Resistant Design of Structures: (Part 1) General provisions and Buildings, New Delhi, India.

[33] Kovvuri Naga Raju,**"**Effect of setback on RCframed buildings in fundamental period International Journal of Advanced Technology in Engineering. and Science, Vol. No. 03, Issue No. 05, May 2015.

[34] ETABS Software- 2015, Computer and Structures Incorporation (CSI), University Avenue, Berkeley, California, USA.