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Seismic Analysis and Design of Vertically Irregular RC Building Frames

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ABSTRACT- This paper is concerned with the effects of various vertical irregularities on the seismic response of a structure. The objective of the project is to carry out Response spectrum analysis (RSA) and Time history Analysis (THA) of vertically irregular RC building frames and to carry out the ductility based design using IS 13920 corresponding to Equivalent static analysis and Time history analysis. Comparison of the results of analysis and design of irregular structures with regular structure was done. The scope of the project also includes the evaluation of response of structures subjected to high, low and intermediate frequency content earthquakes using Time history analysis. Three types of irregularities namely mass irregularity, stiffness irregularity and vertical geometry irregularity were considered. According to our observation, the storey shear force was found to be maximum for the first storey and it decreases to minimum in the top storey in all cases. The mass irregular structures were observed to experience larger base shear than similar regular structures. The stiffness irregular structure experienced lesser base shear and has larger inter-storey drifts. The absolute displacements obtained from time history analysis of geometry irregular structure at respective nodes were found to be greater than that in case of regular structure for upper stories but gradually as we moved to lower stories displacements in both structures tended to converge. Lower stiffness results in higher displacements of upper stories. In case of a mass irregular structure, time history analysis gives slightly higher displacement for upper stories than that in regular structures whereas as we move down lower stories show higher displacements as compared to that in regular structures. When time history analysis was done for regular as well as stiffness irregular structure, it was found that displacements of upper stories did not vary much from each other but as we moved down to lower stories the absolute displacement in case of soft storey were higher compared to respective stories in regular structure. Tall structures were found to have low natural frequency hence their response was found to be maximum in a low frequency earthquake. It is because low natural frequency of tall structures subjected to low frequency earthquake leads to resonance resulting in larger displacements. If a high rise structure (low natural frequency) is subjected to high frequency ground motion then it results in small displacements. Similarly, if a low rise structure (high natural frequency) is subjected to high frequency ground motion it results in larger displacements whereas small displacements occur when the high rise structure is subjected to low frequency ground motion.

KEYWORDS- STAAD PRO, Earthquake, Irregular building, Seismic response parameters, Response Method, Equivalent Static Analysis, Time History Analysis

I. INTRODUCTION

During an earthquake, failure of structure starts at points of weakness. This weakness arises due to discontinuity in mass, stiffness and geometry of structure. The structures having this discontinuity are termed as Irregular structures. Irregular structures contribute a large portion of urban infrastructure. Vertical irregularities are one of the major reasons of failures of structures during earthquakes. For example structures with soft storey were the most notable structures which collapsed. So, the effect of vertically irregularities in the seismic performance of structures becomes really important. Height-wise changes in stiffness and mass render the dynamic characteristics of these buildings different from the 'regular' building.

IS 1893 definition of Vertically Irregular structures: The irregularity in the building structures may be due to irregular distributions in their mass, strength and stiffness along the height of building. When such buildings are constructed in high seismic zones, the analysis and design becomes more complicated.

As per IS 1893, Part 1 Linear static analysis of structures can be used for regular structures of limited height as in this process lateral forces are calculated as per code based fundamental time period of the structure. Linear dynamic analysis are an improvement over linear static analysis, as this analysis produces the effect of the higher modes of vibration and the actual distribution of forces in the elastic range in a better way. Buildings are designed as per Design based earthquake, but the actual forces acting on the structure is far more than that of DBE. So, in higher seismic zones Ductility based design approach is preferred as ductility of the structure narrows the gap. The primary objective in designing an earthquake resistant structures is to ensure that the building has enough ductility to withstand the earthquake forces, which it will be subjected to during an earthquake.

RESPONSE SPECTRUM ANALYSIS:

This approach permits the multiple modes of response of a building to be taken into account. This is required in many building codes for all except for very simple or very complex structures. The structural response can be defined as a combination of many modes. Computer analysis can be used to determine these modes for a structure. For each mode, a response is obtained from the design spectrum, corresponding to the modal frequency and the modal mass, and then they are combined to estimate the total response of the structure. In this the magnitude of forces in all directions is calculated and then effects on the building is observed. Following are the types of combination methods:

- absolute - peak values are added together
- square root of the sum of the squares (SRSS)
- complete quadratic combination (CQC) - a method that is an improvement on SRSS for closely spaced modes

The result of a RSM analysis from the response spectrum of a ground motion is typically different from that which would be calculated directly from a linear dynamic analysis using that ground motion directly, because information of the phase is lost in the process of generating the response spectrum. In cases of structures with large irregularity, too tall or of significance to a community in disaster response, the response spectrum approach is no longer appropriate, and more complex analysis is often required, such as non-linear static or dynamic analysis.

OBJECTIVES:

- To calculate the design lateral forces on regular and irregular buildings using response spectrum analysis and to compare the results of different structures.
- To study three irregularities in structures namely mass, stiffness and vertical geometry irregularities.
- To calculate the response of buildings subjected to various types of ground motions namely low, intermediate and high frequency ground motion using Time history analysis and to compare the results.
- To carry out ductility-based earthquake-resistant design as per IS 13920 corresponding to equivalent static analysis and time history analysis and to compare the difference in design.

II. LITERATURE REVIEW

Rajeeva and Tesfamariam (2012) Fragility based seismic vulnerability of structures with consideration of soft -storey (SS) and quality of construction (CQ) was demonstrated on three, five, and nine storey RC building frames designed prior to 1970s. Probabilistic seismic demand model (PSDM) for those gravity load designed structures was developed, using non-linear finite element analysis, considering the interactions between SS and CQ. The response surface method is used to develop a predictive equation for PSDM parameters as a function of SS and CQ. Result of the analysis shows the sensitivity of the model parameter to the interaction of SS and CQ.

Sarkar et al. (2010) proposed a new method of quantifying irregularity in vertically irregular building frames, accounting for dynamic characteristics (mass and stiffness). The salient conclusions were as follows:

(1) A measure of vertical irregularity, suitable for stepped buildings, called 'regularity index', is proposed, accounting for the changes in mass and stiffness along the height of the building.

(2) An empirical formula is proposed to calculate the fundamental time period of stepped building, as a function of regularity index.

Karavasilis et al. (2008) studied the inelastic seismic response of plane steel moment-resisting frames with vertical mass irregularity. The analysis of the created response databank showed that the number of storeys, ratio of strength of beam and column and the location of the heavier mass influence the height-wise distribution and amplitude of inelastic deformation demands, while the response does not seem to be affected by the mass ratio.

Athanassiadou (2008) concluded that the effect of the ductility class on the cost of buildings is negligible, while performance of all irregular frames subjected to earthquake appears to be equally satisfactory, not inferior to that of the regular ones, even for twice the design earthquake forces. DCM frames were found to be stronger and less ductile than the corresponding DCH ones. The over strength of the irregular frames was found to be similar to that of the regular ones, while DCH frames were found to dispose higher over strength than DCM ones. Pushover analysis seemed to underestimate the response quantities in the upper floors of the irregular frames.

Lee and Ko (2007) subjected three 1:12 scale 17-story RC wall building models having different types of irregularity at the bottom two stories to the same series of simulated earthquake excitations to observe their seismic response characteristics. The first model had a symmetrical moment-resisting frame (Model 1), the second had an infilled shear wall in the central frame (Model 2), and the third had an infilled shear wall in only one of the exterior frames (Model 3) at the bottom two stories. The total amounts of energy absorption by damage are similar regardless of the existence and location of the infilled shear wall. The largest energy absorption was due to overturning, followed by the shear deformation

Devesh et al. (2006) agreed on the increase in drift demand in the tower portion of set-back structures and on the increase in seismic demand for buildings with discontinuous distributions in mass, strength and stiffness. The largest seismic demand was found for the combined stiffness and strength irregularity. It was found out that seismic behavior is influenced by the type of model.

Sadjadi et al. (2007) presented an analytical approach for seismic assessment of RC frames using nonlinear time history analysis and push-over analysis. The analytical models were validated against available experimental results and used in a study to evaluate the seismic behavior of these 5-story frames. It was concluded that both the ductile and the less ductile frames behaved very well under the earthquake considered, while the seismic performance of the GLD structure was not satisfactory. The retrofitted GLD frame had improved seismic performance.

Poonam et al. (2012)- Results of the numerical analysis showed that any storey, especially the first storey, must not be softer/weaker than the storeys above or below. Irregularity in mass distribution also contributes to the increased response of the buildings. The irregularities, if required to be provided, need to be provided by appropriate and extensive analysis and design processes.

III. PROPOSED METHODOLOGY

RESPONSE SPECTRUM ANALYSIS:

Response Structure analysis was performed on regular and various irregular buildings using Staad-Pro. The storey shear forces were calculated for each floor and graph was plotted for each structure.



STRUCTURAL MODELLING:

SPECIFICATIONS:

Live Load	3kN/m ²
Density of RCC considered:	25kN/m ³
Thickness of slab	150mm
Depth of beam	400mm
Width of beam	350mm
Dimension of column	400x400mm
Density of infill	20kN/m ³
Thickness of outside wall	20mm
Thickness of inner partition wall	15mm
Height of each floor	3.5m
Earthquake Zone	IV
Damping Ratio	5%
Importance factor	1
Type of Soil	Rocky
Type of structure	Special Moment Resisting Frame
Response reduction Factor	5

Four types of Irregular buildings were considered, Regular structure, Mass irregular structure, structure with ground storey as the soft storey and vertically geometric irregular building. The first three structures were 10 storeyed.

1 Regular structure (10 storeys):



(Fig 3.1: plan of regular structure (10 storeys))

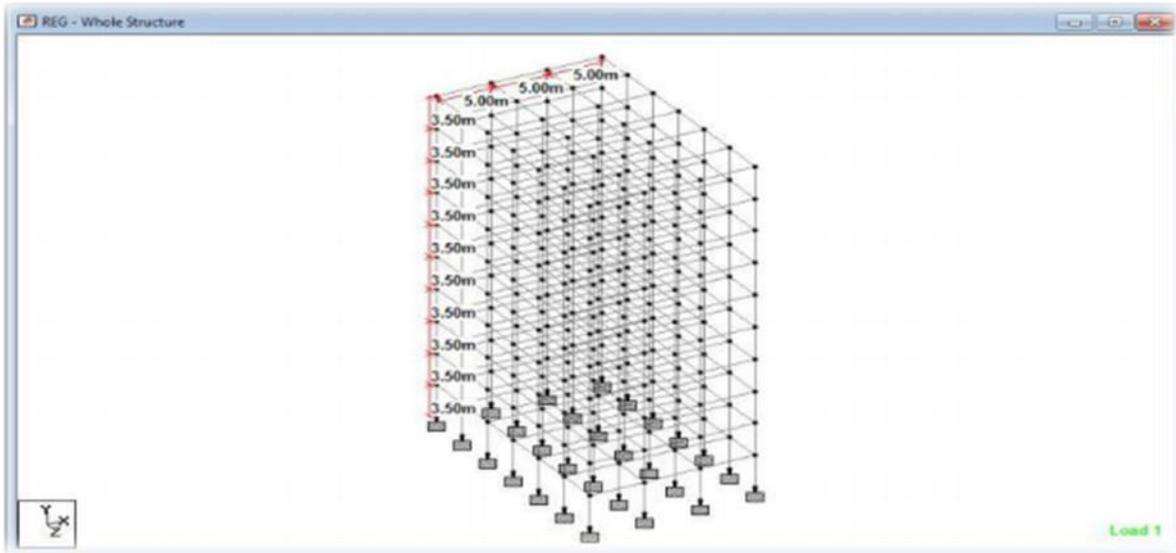


Fig 3.2: 3D view of regular structure (10 storeys)

2 Mass Irregular Structure(10 storeys):

The structure is modeled as same as that of regular structure except the loading due to swimming pool is provide in the fourth and eighth floor. Height of swimming pool considered- 1.8m Loading due to swimming pool -18kN/m²

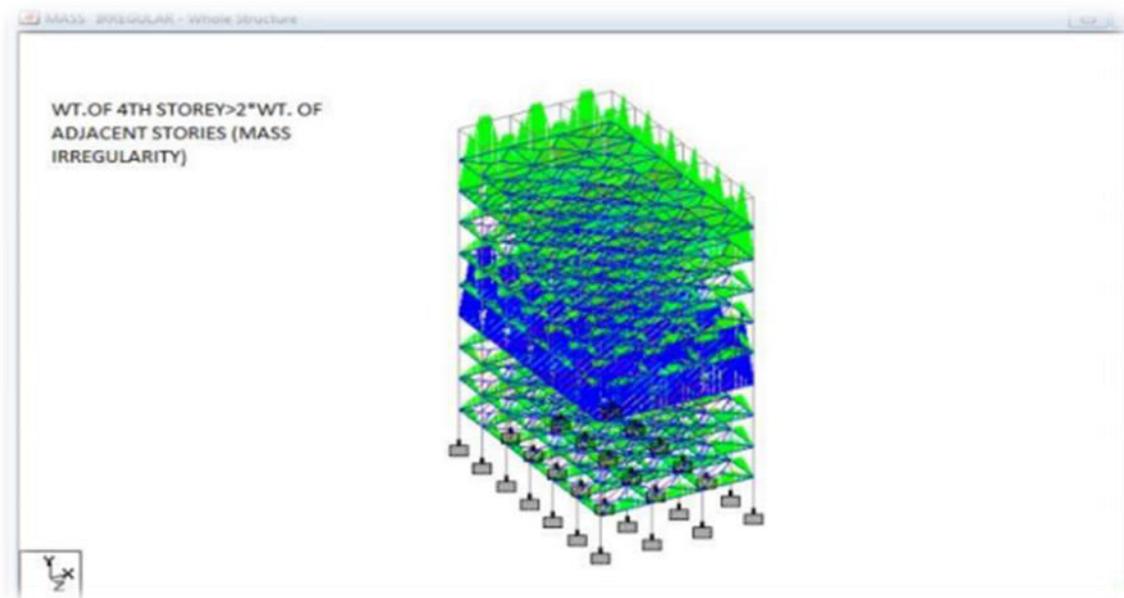


Fig 3.3: 3D view of mass regular structure (10 storeys) with swimming pools on 4th and 8th storeys

3 Stiffness Irregular Structure (Soft Storey):

The structure is same as that of regular structure but the ground storey has a height of 4.5 m and doesn't have brick infill. Stiffness of each column= $12EI/L^3$ Therefore, Stiffness of ground floor/stiffness of other floors= $(3.5/4.5)^3 = 0.47$

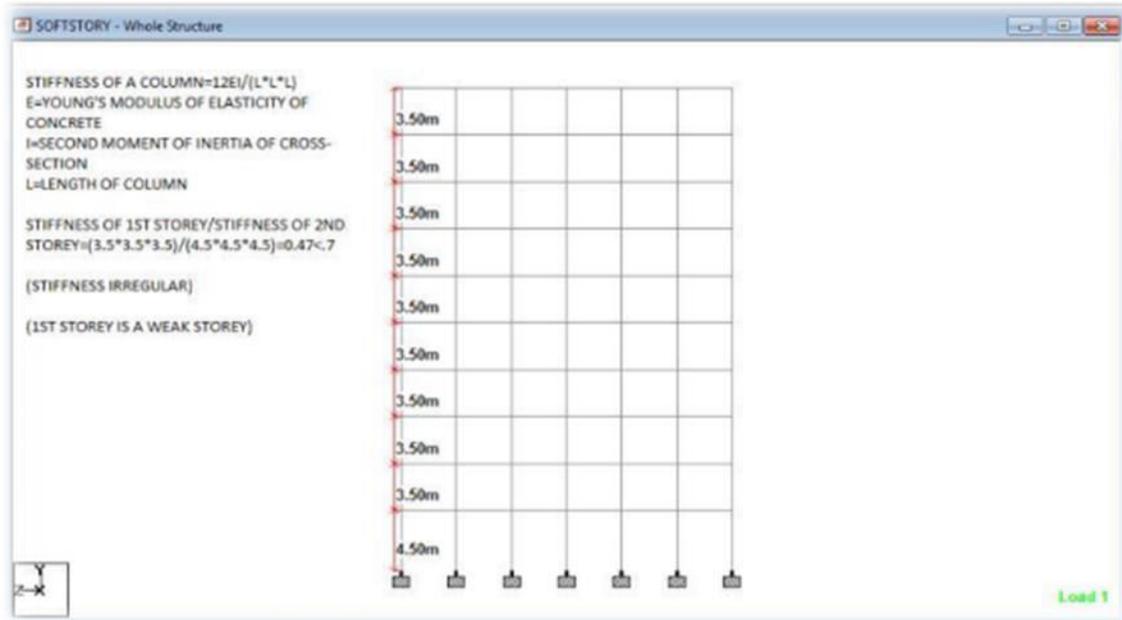


Fig 3.4: stiffness irregular structure (10 storeys)

4 Vertically Geometric Irregular-

The structure is 14 storeyed with steps in 5th and 10th floor. The setback is along X direction. Width of top storey = 20m Width of ground storey = 40 $40/20 = 2 > 1.5$ Hence, as per IS 1893, Part 1 the structure is vertically geometric irregular structure.

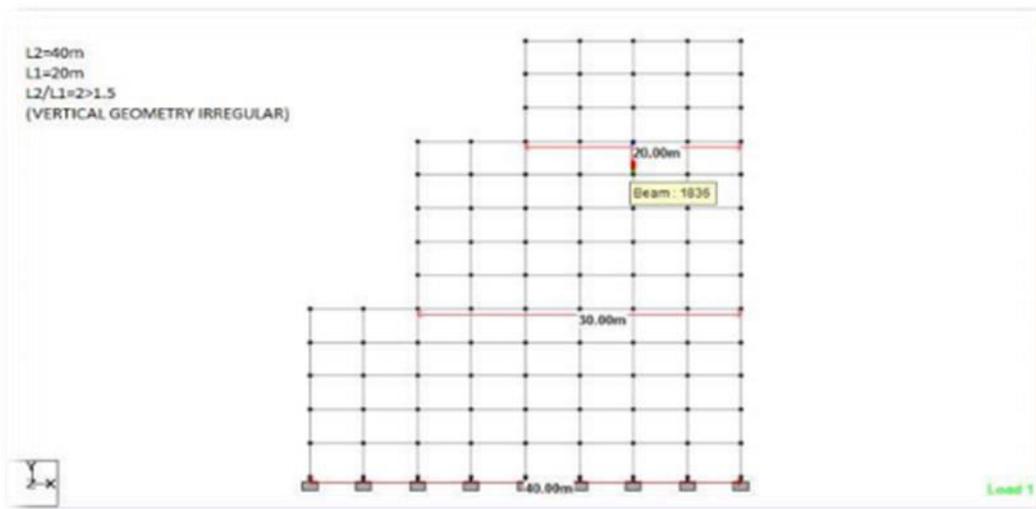


Fig 3.5: Vertical Geometric irregular structure (14 storeys)

Comparison of Peak storey shear forces of Regular structure and Mass Irregular structure

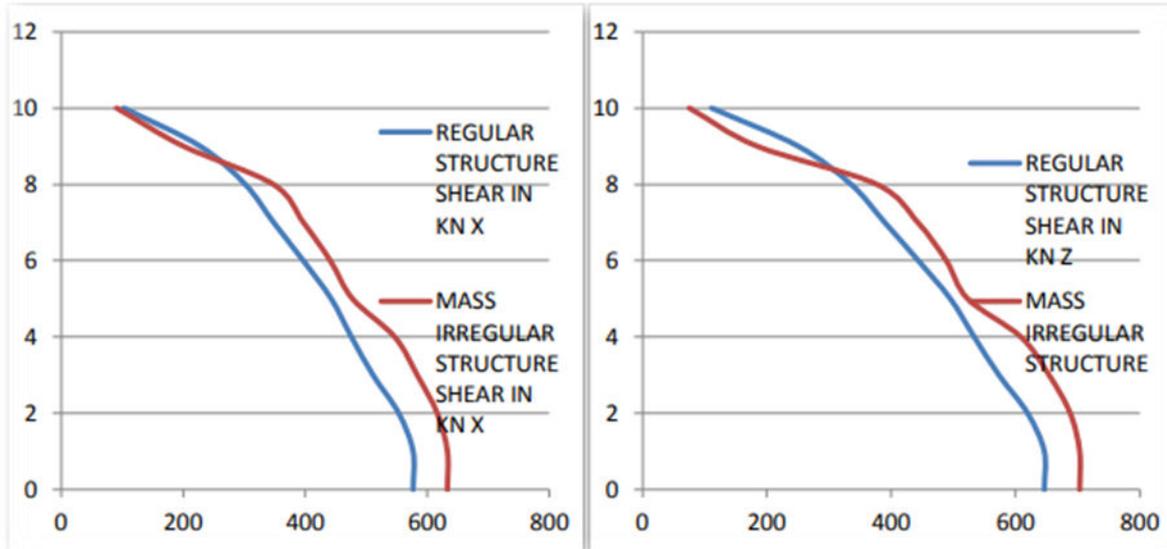


Fig 3.6: Comparison of Peak storey shear forces of regular and mass irregular structure.

The storey shear force is maximum in ground storey and it decreases as we move up in the structure. Mass irregular storey shear force is more in lower storeys as compared to regular structure. The graph closes in as we move up the structure and the mass irregular storey shear force becomes less than that in regular structure above 8th storey.

Comparison of Peak storey shear forces of Regular structure and Stiffness Irregular structure

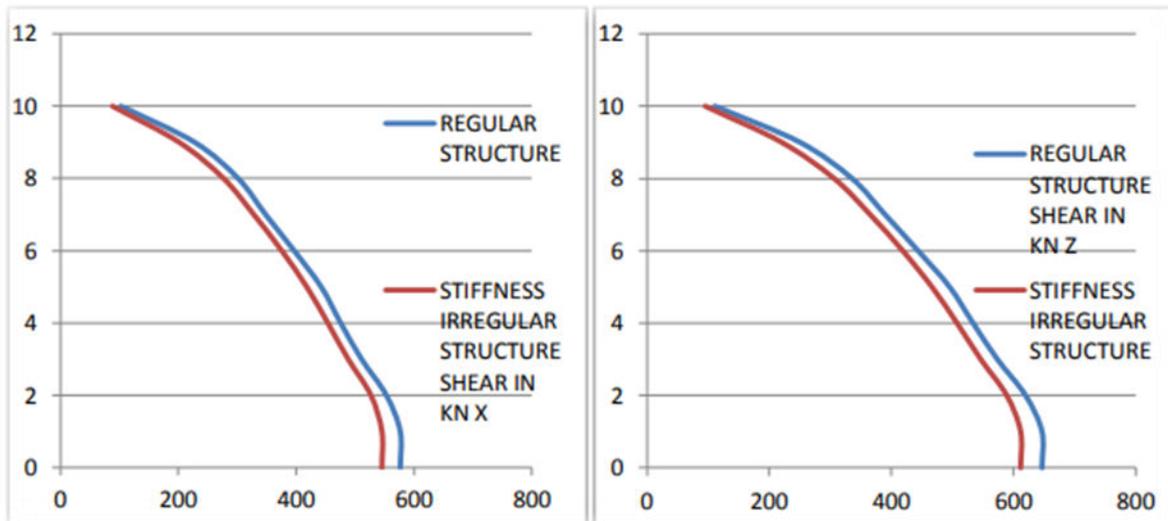


Fig 3.7: Comparison of Peak storey shear forces of regular and stiffness irregular structure.

The Stiffness Irregular structure has a ground storey height of 4.5m (more than height of the above storeys). This makes the building less stiff than regular structure. Hence the interstorey drift is observed to be more in stiffness irregular structure. And hence, the storey shear force is more in regular structure as compared to stiffness irregular structure.

IV. CONCLUSION

Three types of irregularities namely mass irregularity, stiffness irregularity and vertical geometry irregularity were considered. All three kinds of irregular RC building frames had plan symmetry. Response spectrum analysis (RSA) was conducted for each type of irregularity and the storey shear forces obtained were compared with that of a regular structure. Three types of ground motion with varying frequency content, i.e., low (imperial), intermediate (IS code), high (San Francisco) frequency were considered.

- According to results of RSA, the storey shear force was found to be maximum for the first storey and it decreased to a minimum in the top storey in all cases.
- According to results of RSA, it was found that mass irregular building frames experience larger base shear than similar regular building frames.

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REFERENCES

1. Dileshwar Rana, Prof. Juned Raheem (2015) Seismic Analysis of Regular & Vertical Geometric Irregular RCC Framed Building
2. Achyut S Naphade, Prof. Grpatil (2015), "Push over analysis of RCC building with soft storey at different levels" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
3. Suchita Hirde Ganga Tepugade (2014), "Seismic performance of multistorey building with soft storey at different level with RC shear wall" International Journal of Current Engineering and Technology
4. Devendra Dohare 1, Dr. Savita Maru 2 (2014) "Seismic Behaviour of soft Storey Building : A Critical Review" International Journal of Engineering Research and General Science Volume 2, Issue 6, October-November, 2014
5. Akshay V. Raut 1, Prof. RVRK Prasad 2 (2014) "Pushover Analysis of G+3 Reinforced Concrete Building with soft storey" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
6. Bhattacharjee, B. and ASV, N., 2007. Computer aided analysis and design of multi-storeyed buildings (Doctoral dissertation).
7. Saatcioglu, M. and Humar, J., 2003. Dynamic analysis of buildings for earthquake resistant design. Canadian Journal of Civil Engineering, 30(2), pp.338-359.
8. Duan, X.N. and Chandler, A.M., 1993. Inelastic seismic response of code-designed multistorey frame buildings with regular asymmetry. Earthquake engineering & structural dynamics, 22(5), pp.431-445.
9. Fu, F., 2010. 3-D nonlinear dynamic progressive collapse analysis of multi-storey steel composite frame buildings—Parametric study. Engineering Structures, 32(12), pp.3974-3980.
10. Mwafy, A.M. and Elnashai, A.S., 2001. Static pushover versus dynamic collapse analysis of RC buildings. Engineering structures, 23(5), pp.407-424.
11. BIS, IS 456:2000, — Plain and reinforced concrete code of practice | Bureau of Indian Standards, Fourth revision.
12. BIS, IS-875 (Part-1): (1987) Dead Loads- Unit weights of building materials and stored materials
13. BIS, IS-875 (Part-2): (1987) Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures
14. Agarwal P. and Shrikhande M, Earthquake Resistant Design of Structures, PHI Publication, 2004.
15. Duggal S.K, Earthquake Resistant Design of Structures Second edition Oxford Publications, 2007
16. A.K Chopra "Dynamic of structures theory and Earthquake Engineering" fourth edition, Prentice Hall, 2012
17. Anirudh Gottala, Kintali Sai Nanda Kishore and Dr. Shaik Yajdhani "Comparative Study of Static and Dynamic Seismic Analysis of a Multistoried Building" International Journal of Science Technology & Engineering, Volume 2, Issue 01, July 2015
18. B. Srikanth and V.Ramesh "Comparative Study of Seismic Response for Seismic Coefficient and Response Spectrum Methods", International Journal of Engineering Research and Applications, ISSN : 2248-9622, Vol. 3, Issue 5, Sep-Oct 2013, pp.1919-1924
19. Pankaj Agarwal, Manish Shrikhande "Earthquake Resistant Design Of Structures" Prentice Hall of India private limited, 2006

20. Sayed Mahmoud and Waleed Abdallah Saudi Arabia "Response Analysis of Multi-Story RC Buildings under Equivalent Static and Dynamic Loads according to Egyptian Code ", International Journal of Civil and Structural Engineering Research, ISSN 2348-7607 (Online), Vol. 2, Issue 1, pp: (79-88), Month: April 2014 - September 2014
21. S.K. Duggal "Earthquake Resistant Design of structures" Oxford university Press, 2007
22. D.R. Deshmukh, A.K. Yadav, S. N Supekar, A. B. Thakur, H. P Sonawane, I. M. Jain, "Analysis and Design of G+19 Storied Building Using Staad-Pro", Pg. 17-19, ISSN: 2248-9622, Vol. 6, Issue 7, (Part-1) July 2016.
23. Ankit Purohit, LovishPamecha "Seismic Analysis of G+12 Multistory Building Varying Zone and Soil Type SSRG" , International Journal of Civil Engineering (SSRG – IJCE) – Volume 4 Issue 6 – June 2017.
24. Patil S.S. (2013), " Seismic Analysis of High-Rise Building by Response Spectrum Method", International Journal Of Computational Engineering Research (Ijceronline.Com) Vol. 3 Issue. 3.
25. 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 www.ijera.com ISSN : 2248-9622, Vol. 4, Issue 11(Version 1), November 2014.
26. Prof.Komal S. Meshraml, SamikshaKumbhare,SagarThaku ,Diksha Mate, Amit Moundekar, RakshaWaghmare, "Seismic Analysis of Building Using Staad-Pro", International Journal of Innovations in Engineering and Science, Vol. 4, No. 5, 2019.
27. Sangeeta Uikay, Er. Rahul Satbhay, "Seismic Response Analysis of Tall Building Using STAAD Pro Software", Journal of Earthquake Science and Soil Dynamics Engineering Volume 3 Issue 1, (2020) DOI: <http://doi.org/10.5281/zenodo.3685732>
28. Siddhartha S. Ray, Alkesh S. Bhalerao, Rahul Chandrasekhar, "Earthquake Analysis of Multistory Building", International Journal of Advanced Science and Technology Vol. 29, No. 4, (2020), pp.7650-7658, ISSN: 2005 - 4238 IJAST Copyright @2020 SERSC
29. Valmundsson and Nau, 1997, Seismic Response of Building Frames with Vertical Structural Irregularities, Journal of structural engineering, 123:30-41.
30. Anibal G Costa, Carlos S. Oliviera, Ricardo T Duarte,1998, Influence of Vertical Irregularities on Response of Buildings
31. Lee Han Seon ,Dong Woo Kee, 2007, Seismic response characteristics of high-rise RC wall buildings having different irregularities in lower stories, Engineering Structures 29 (2007):3149–3167
32. Sadjadi R, Kianoush M.R. , Talebi S , 2007, Seismic performance of reinforced concrete moment resisting frames, Engineering Structures 29 (2007):2365–2380
33. Athanassiadou C.J, 2008, Seismic performance of R/C plane frames irregular in elevation, Engineering Structures 30 (2008):1250–1261
34. Karavallis, Bazeos and Beskos, 2008, Estimation of seismic inelastic deformation demands in plane steel MRF with vertical mass irregularities, Engineering Structures 30 (2008) 3265–3275 [7] Sarkar P, Prasad A Meher, Menon Devdas, 2010, Vertical geometric irregularity in stepped building frames, Engineering Structures 32 (2010) 2175–2182
35. Poonam, Kumar Anil and Gupta Ashok K, 2012, Study of Response of Structural Irregular Building Frames to Seismic Excitations, International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD), ISSN 2249-6866 Vol.2, Issue 2 (2012) 25-31
36. Ravikumar C M, Babu Narayan K S, Sujith B V, Venkat Reddy D, 2012, Effect of Irregular Configurations on Seismic Vulnerability of RC Buildings, Architecture Research 2012, 2(3): 20-26 DOI: 10.5923/j.arch.20120203.01
37. HaijuanDuana, Mary Beth D. Hueste, 2012, Seismic performance of a reinforced concrete frame building in China, Engineering Structures 41 (2012):77–89



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