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Analytical Study of Irregular RC Structure in Severe Seismic Zone as per is 1893:2016- A Literature Review

[1]Sarthak Jain, [2]Dr J N Vyas

[1]PG Student, [2]Professor
[1,2] Department of Civil Engineering
[1,2] Mahakal Institute of Technology & Management, Ujjain

ABSTRACT—

RC Buildings are very ordinary type of construction in India. Analytically while modelling the structure, we design only structural members which transmit the load like beams, columns, slabs and footings, where walls are not considered while designing and their impact on the structural response is neglected. Their impact is shown in the global behaviour of RC frames subjected to seismic loads. So it is very important to study the behaviour of infill on the RC bare frames. The presence of infill results in increase in the structural stiffness; it also increases natural frequency of vibration which depends on seismic spectrum. In addition to that, it also decreases the storey drift demands and increases the storey lateral forces. Now a day's irregularities are the typical features in multi storied buildings constructions. Irregular Structures are those which have discontinuity in geometry, distribution of mass, stiffness. These buildings are highly susceptible to earthquake and due to that loss of properties and casualty is there. Tall building is considered having stiffness irregularity, i.e., making different floors as a soft storey and masonry wall is used for stiffening the other floors, and having mass irregularity i.e. distribution of mass is different on consecutive floors. So in this paper a literature study is performed on the previous examples building with the effect of infill walls with and without openings, stiffness irregularity and mass irregularity to bring out the importance of explicitly recognizing their presence in the analysis. This study presents a brief review on static and dynamic analysis for reinforced concrete (RC) frames and steel frames as per different standards with different types of irregularties.

Keywords: Reinforced concrete frames, Infill, Time period, Stiffness, Base shear, Mass Distribution, Response Spectrum.

1.1 Introduction -

Due An Earthquake is the most natural disaster in which shaking of the earth's surface takes place. Ground rupture and ground shaking are the most vulnerable effects creates by earthquakes, resulting in less or more severe destruction to building and other rigid infrastructure. Though many studies and experiments are done about earthquake, it is difficult to avoid the structure undergoing damage or failure during this distinctive shaking. Earthquake damages is caused due to deficiency in few aspects such as, the building with irregularities, soft storey, insufficient lateral strength, structural behaviour between the building and the ground (type of foundation used).

Many building structure having parking or commercial areas in their ground stories, suffered major structural damages and collapsed in the recent earthquakes. Large open areas with less infill and exterior walls and higher floor levels at the ground level result in soft stories and hence damage. In such buildings, the stiffness of the lateral load resisting systems at those stories is quite less than the stories above or below.

During an earthquake, if abnormal inter-story drifts between adjacent stories occur, the lateral forces cannot be well distributed along the height of the structure. This situation causes the lateral forces to concentrate on the storey (or stories) having large displacement(s).

1.2 IRREGULAR STRUCTURES -

In Modern Urban Infrastructure, irregular structure constitutes a larger portion. Also, it is the major characteristics which affect the structure during earthquake. Irregular Structures are those which have discontinuity in geometry, distribution of mass, stiffness. As per IS Code 1893 (Part 1):2016, irregularities are classified as Plan Irregularities and Vertical Irregularities.

Soft storey is one of the reasons for the failure of the structure during earth shaking. It is also the Stiffness defect which comes under vertical Irregularities. The recent trend is to construct the high rise building with an open ground floor which is used as a parking area or for any other utilities. These structures are usually designed as framed structure, having a masonry wall at the upper floors. This wall makes the upper floors to be stiffer against the lateral loads in compared to ground floor and the building is performed as a soft storey. According to IS 1893:2016 (part 1), Soft storey is in which the lateral stiffness will be less than 70% of the stiffness in the above storey or it will be less than 80% of the average lateral stiffness of other above 3 story's. The code suggests following considerations for a building with soft storey. (Page 27)

- Special arrangements are done to make the lateral strength and stiffness of the soft storey more.
- Members are designed according to the analysis carried out, i.e., dynamic analysis.
- After the analysis is over, the beams and columns should be designed to satisfy more than 2.5 times of the obtained moments and shear.
- Apart from the above column design, shear wall should be placed symmetrically on both sides of the building.
- These walls to be designed for 1.5 times the lateral storey shear force.

Plan Irregularity -

The coverage area of the building is concerned with this type of irregularity. The most common irregular structures are L-shape, Plus-shape, U-Shape, O-shape, plan wise. When the two adjacent sides are not orthogonal to each other, the building is said to be irregular.

1) Irregularity of Torsion

2) Re-entrant Corners

3) Discontinuity of Diaphragm

4) Out of plane offsets

5) Non-parallel the Systems

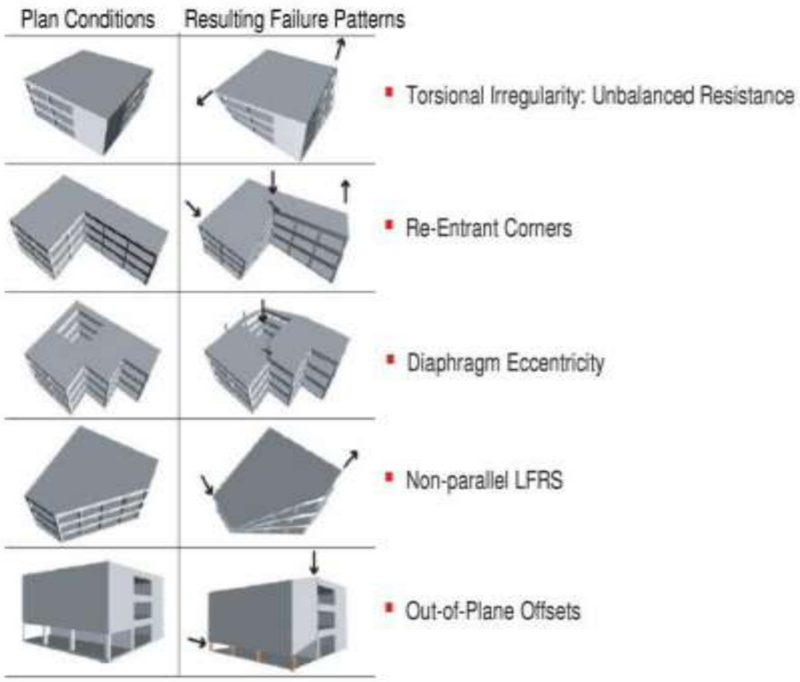

FIG. 1 – PLAN IRREGULARITIES

B. Vertical Irregularity

The building: irregularity of rigidity irregularity of mass, vertical geometric irregularity, etc. The vertical irregularity of the building is involved. This is more prevalent than it-plan irregularity

1) Irregularity of Stiffness

2) Irregularity of Mass

3) Irregularity of Vertical Geometric

4) Capacity Discontinuity- Weak Storey.

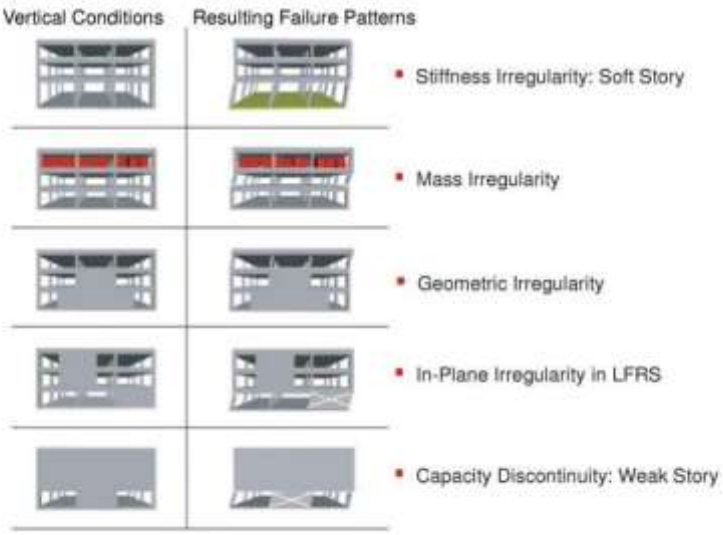

FIG. 2 – VERTICAL IRREGULARITIES

1.3 Need of the Study

Review of their structural behaviour is done by changing different parameters like different kind of irregularities, with the effect of infill walls and actual model of stair case in models in order to observe the response of structure under the seismic effect with such irregularities and to review the measures which should be considered during the design of such structures.

2. LITERATURE REVIEW

The important research studies pertaining to the investigations and performance evaluation of the irregular buildings were identified. This section provides a review summary of important research studies carried out by different authors giving an idea about the earthquake-resisting performance of regular and irregular buildings.

Sahil Tomer1, Mohit Bhandari2- Evaluation of Seismic Response of Irregular Buildings: A Review, ICASF-2022, IOP Conf. Series: Earth and Environmental Science 1110 (2023) 012012 IOP Publishing doi:10.1088 / 1755 – 1315 / 1110 / 1 / 012012 (2023) - This study presents a review summary of seismic performance of irregular buildings considering vertical irregularity subjected to earthquake loadings. The seismic performance can be found by using linear and nonlinear time history analysis. Different types of irregular buildings are analyzed to review the seismic performance of the structure. It was found that the buildings with the soft story having variation in the storey stiffness yield large inter-storey drift values showing more damage as compared to types of building irregularities.

Sharma, S., Tiwary, A.K. Influence of Distinctive Parameters on Fundamental Time Period of the Building (2022) Lecture Notes in Civil Engineering, 196, pp. 699-710 - studied the response of multi-storied buildings with plan irregularities subjected to wind and earthquake load. 20 storey four different building geometry frames having one regular and other L, inverted U and T shapes frames are analyzed by a seismic coefficient method using STAAD Pro. It was concluded there is no effect of torsional cause in regular the frame for the reason of symmetry. Due to the wind lateral act on the windward face, it shows more response than the leeward face. There was torsional revolving in the structure with plan irregularities. Column parallel located in the 2-D frame the action of force does not affect much the magnitude of displacement.

Tiwary, A.K. - Different types of outrigger system in high-rise buildings: a preliminary comparative seismic analysis in a 40-story RC building (2022) Innovative Infrastructure Solutions, 7 (6), art. no. 347 - analyzed multi-storey buildings with different shapes. 12 storey with different plans rectangular, C-shape, T-shape, and O-shape analyzed on ETABS by non-linear dynamic analysis for medium soil at zone Z. Structural displacement, overturning moments, storey shear and storey drift comparison of the result. It was concluded that among all shape building C-shape building was more vulnerable.

S. VIJAYALAKSHMI, J. SAIBABA (2022) - EXPERIMENTAL STUDY ON ANALYSIS OF RCC STRUCTURE WITH OR WITH OUT INFILL DIFFERENT SEISMIC ZONES – Journal of Engineering Sciences, Vol. 13, Issue 06, June / 2022 ISSN NO: 0377-9254 - In this study, 3D analytical model of G+10 multi-storey building has been generated for different buildings models and analyzed using structural analysis tool 'E-TABS'. In the analytical building model, all of the significant components are included that affect the mass, strength, and stiffness of the structure. As part of the research, seismic analysis using linear dynamic (response spectrum technique) and nonlinear static (pushover) procedures will be used to assess the capacity, demand, and performance level of the model under consideration. The ductility coefficients of structures are assessed using numerical findings for the following seismic demands, which take the inelastic behaviour of the building into consideration.

Sharma, S., Tiwary, A.K. Analysis of multi-story buildings with hybrid shear wall: steel bracing structural system (2021) Innovative Infrastructure Solutions, 6 (3), art. no. 160, analyzed seismic response and evaluation of building with vertical irregularity. 10 storeys regular and irregular buildings are analyzed by a static and dynamic non-linear method using ETABS. The main parameters are storey drift, performance point, base shear, lateral displacement, column shear, and moment. It was concluded that as the irregularity of structure increases, storey displacement increase and maximum displacement will be places where storey stiffness was L-shape model displaced more as compared to other. Column shear and moment on the re-entrant corner of the structure is almost 40 to 50% more than others.

Hakan Dilmac, Hakan Ulutas, Hamide Tekeli and Fuat Demir, "The investigation of seismic performance of existing RC buildings with and without infill walls" International Journal of Advanced Research in Science, Engineering and Technology, Vol. 22, No. 5 (2018) - This paper investigates the effects of infill walls on seismic performance of the existing structure of residential building by considering requirements of the Turkish Earthquake Code (TEC). Seismic performance levels of residential RC buildings with and without masonry walls in high-hazard zones were find according to the nonlinear procedure given in the code. Pushover curves were obtained by considering the effect of masonry infill walls on seismic performance of RC buildings. The analysis results are going shows that the infill masonry walls beneficially affected to the rigidity, roof displacements and seismic performance of the building.

Reddy, K. U., & Arunakanthi, E. (2017), Dynamic analysis of multi storey structure for different shapes. International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES), 3(12), 8-17 - observed the response of building among horizontal and vertical irregularities. Different shapes are taken as 15-storey regular, T-shape, E-shape, F-shape, and S- shape. Ten different models one regular, second to fifth models with plan irregularities, and the remaining sixth to tenth have horizontal and vertical irregularities. The entire model was analyzed by linear static method and linear dynamic analysis using ETABS. It was concluded that with a higher number of setbacks increases the critical storey shear force. Large displacements and drift in T- shape model.

Ahmed Abrar, 2017, Seismic Analysis on Building with Horizontal and Vertical Irregularities, International Journal of Advance Engineering and Research Development and Research Development,4(1).545-556 - studied the response of vertical irregular RC building models. 15 storeys E-shape building with the soft storey, mass irregularity, and vertical geometric irregular models were analyzed by response spectrum method using ETABS. It was concluded that a building with mass irregularities experiences small base shear and has a high storey drift ratio. Lower stiffness results in the higher displacement of upper stories.

Sekhar, H. V., & Das, T. V. (2017) Analysing the Seismic Behaviour of Set Back Building By Using E-Tabs. International Journal of Civil Engineering and Technology, 8(1), 444-451 - analyzed the response of mass irregularity on RC structure. Building of 10 storeys with mass irregularity provided in 3rd and 6th storey and structure with no mass irregularity were analyzed on ETABS and wind load was applied as per IS 875 part III, it was conducted that 67% moment increases in the mass irregular building than with no mass irregularity but the drift was more in without mass irregular building. The size of load resisting structural part also increased for structure with mass irregularity.

Habib, M. Z., Alam, M. A., Barua, S., & İslam, M. (2016) Effect of plan irregularity on RC buildings due to BNBC-2006 Earthquake load, İJSER, 7(1), 761-765 - observed the response of vertical irregularity and plan irregularity on RC buildings. 6- Storeys buildings with different inverted L-shape, rectangular, square, T-shape, U-shape & L-shape. Buildings are analyzed by Bangladesh National Code 2006using ETABS. Values such as period, tensional irregularity, base shear, overt turning moment, base shear, and irregularity ratio are taken. It was concluded that the maximum drift, as well as lateral displacement, base shear, and overturning moment in a rectangular-shaped building, were maximum for a T-shaped building.

Rana, D., & Raheem, J. (2015), Seismic Analysis of Regular & Vertical Geometric Irregular RCC Framed Building. International Research Journal of Engineering and Technology, 2(04), 2395-0056 - analyzed the seismic response of regular and vertical geometric irregular RC frame building. Four storeys having one regular and four irregular setback buildings were analyzed by a seismic coefficient method using STAAD Pro. Parameter storey drift, bending moment, storey displacement and shear force are too higher, the maximum bending moment having irregular frame was higher than regular frame building for all height and with an increase of the number of bays of the building seismic response of all regular and setback irregular building to be better.

Pathi, N. L., Guruprasad, T. N., Dharmesh, N., & Madhusudhana, Y. B. (2015) Static Linear and Non-Linear (Pushover) Analysis of Multi Storey RC Frame with and without Vertical Irregularities. International Journal for Scientific Research & Development, 245- 250 - presented an invariable study of the vertical irregular buildings having stiffness and mass irregularities on different floors. All models were analyzed by equivalent static analysis and linear dynamic method using ETABS at zone III. It was concluded that lateral displacement increases with increased irregularities. The maximum moment found at mass irregular was placed.

Sultan, M. R., & Peera, D. G. (2015), Dynamic Analysis of Multi-storey building for different shapes, International Journal of Innovative Research in Advanced Engineering (IJIRAE), 2, 2349-2163 -focused on the dynamic response of multi-storey structures for different shapes. C-shape, L-shape, H-shape, and regular shape 15 storey high rises building are used for dynamic analysis by linear dynamic method RSM and equivalent static force method using ETABS. The result shows that in a high seismic zone severe irregularity produces more deformation as compared to less irregularity. Regular shape buildings were higher storey base shear of regular as compared to the irregular building – shape building was more vulnerable than others.

Rahman, S. A. A. A., & Deshmukh, G. (2013) Seismic response of vertically irregular RC Frame with stiffness irregularity at fourth floor. International Journal of Emerging Technology and Advanced Engineering, 3(8), 2250-2459 -observed the seismic performance having vertically irregular reinforced concrete frame provided stiffness irregular at 4th floor. 10 storey vertically irregular frames with one frame having equal floor height and another having fourth-floor height increases. Frames were analyzed by a linear static method using ETABS. It was conducted that the frame has stiffness irregular with vertical highly damage in an earthquake-prone zone

Poonam, A. K., & Gupta, A. K. (2012) Study of response of structurally irregular building frames to seismic excitations. International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development, 2(2), 25-31 evaluated the response of vertically irregular building frames to seismic excitation. 10-storey building seven frame models with mass irregularities, floating column, and soft storey are analysed by an equivalent static method using ETABS software. The result was found that a frame having a floating column was a maximum storey drift value and storey displacement value was maximum for a soft storey frame and storey shear is maximum for the mass irregular frame. Also, it was indicated irregularities are harmful to the structure.

3. CONCLUSION

This paper primarily discussed the various studies performed on vertical irregularities in structures having the effect of different varying stiffness parameters also. Following conclusion have been made -

- In the irregular buildings, top displacement is higher than in regular frames.
- The displacement in the building increases due to increase in overall mass of the building.
- The storey drift ratio curve was gradually changed in the regular building as compared to irregular buildings.
- The storey shear is also reduced due to the high number of setbacks in the model.
- The building with vertical irregularities included in the bottom storey shows the maximum value of the storey drift ratio.
- Base shear values of mass irregular building, floating column building and stiffness irregular building are higher as compared to regular building.

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