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Seismic Analysis of Regular & Vertical Geometric Irregular RCC Framed Building

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Abstract - *The performance of a multi-storey framed building during sturdy earthquake motions depends on the distribution of mass, stiffness, and strength in both the horizontal and vertical planes of the building. In multi-storeyed framed buildings, smash up from earthquake ground motion generally initiates at locations of structural weaknesses present in the lateral load resisting frames. In some cases, these weaknesses may be produced by discontinuities in stiffness, strength or mass between adjoining storeys. Such discontinuities between storeys are often allied with sudden variations in the frame geometry along the height. A common type of discontinuity is vertical geometrical irregularity arising from the rapid drop of the height.*

This work 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. All building frames are modeled & analyzed in software Staad.Pro V8i. Various seismic responses like shear force, bending moment, storey drift, storey displacement, etc. are obtained. The seismic analysis is done according to IS 1893:2002 part (1). Seismic zone IV & medium soil strata are taken for all the cases. The change in the different seismic response is observed along different height.

Key Words: Regular building, Vertical Geometric Irregular building, Seismic response parameters etc.

1. INTRODUCTION

The word earthquake is used to express any seismic occurrence whether natural or caused by humans that can produce seismic influence around any particular area. Earthquakes are caused generally by rupture of geological faults inside the earth, but also by other events such as volcanic movement, landslides, mine blasts, and atomic tests. Vertical irregularities are characterized by vertical discontinuities in the geometry, distribution of mass, rigidity and strength. Setback buildings are a subset of vertically irregular buildings where there are discontinuities with respect to geometry. However, geometric irregularity also introduces discontinuity in the distribution of mass, stiffness and strength along the vertical direction. Majority of the studies on setback buildings have focused on the elastic response. The behavior of these types of building is something different. There is a need of more work to be done in this regard. So this research work is an attempt to reach on more accurate conclusion to reduce their effect on the structure.

We observe that real structures are frequently irregular as perfect regularity is an idealization that rarely occurs in the practice. Regarding buildings, for practical purposes, major seismic codes across the globe differentiate between irregularity in plan and in elevation, but it must be realized that irregularity in the structure is the consequence of a combination of both types. It is seen that irregular structural configurations either in plan or in elevation were often recognized as one of the major causes of collapse during precedent earthquakes

1.1 Objectives

As such, the goal of this research is to investigate various seismic responses of RC framed regular and vertical geometric irregular structure. The comparison between various seismic parameters would allow us to propose the best suitable building configuration on the existing condition. More specifically, the salient objectives of this research are:

1) To perform a comparative study of the various seismic parameters of different types of reinforced concrete moment resisting frames (MRF) with varying number of stories, configuration, and types of irregularity.
2) Comparison between *regular and vertical irregular frame* on the basis of shear force, bending moment, storey drift, & node displacement etc.

3) To study the change in different seismic response parameters along the increasing height and increasing bays.

4) To propose the best suitable building configuration on the existing condition.

1.2 Methodology

The steps undertaken in the present study to accomplish the above-mentioned objectives are as follows:

a) Select an exhaustive set of regular *and setback building* frame models with different heights (4 to 16 storeys), assuming equal bay width of 3 m in both horizontal direction and different irregularities.
b) Perform static analysis for each of the 40 building models taken in this study.
c) Analyzing and comparison of the result of seismic analysis.
d) Presentation of results in the form of graphs and tables.
e) Detailed discussion on the results with the help of graphs and tables considering all the included parameters.

2. LITERATURE REVIEW

A number of studies have been performed on the seismic behavior of reinforced concrete framed structures. Civil engineering structures are mainly designed to resist static loads. Generally the effects of dynamic loads performing on the structure are not considered. This feature of ignoring the dynamic forces at times becomes the reason of calamity, predominantly in case of earthquake

Prakash Sangamnerkar *et. al.* has done the comparative study on the *static and dynamic behavior of reinforced concrete framed regular building*. Comparison of static and vibrant behavior of a six storey's structure is considered in this paper and it is analyzed by using computerized solution available in all four seismic zones i.e. II, III, IV and V. It is observed that parameters like base shear, nodal displacements and beam ends forces varies in the same ratio as described above, hence it is very important conclusion derived in the analysis. [7]

Mohit Sharma *et. al.* considered a *G+30 storied regular reinforced concrete framed building.* Dynamic analysis of multistoried Building was carried out. These buildings have the plan area of 25m x 45m with a storey height 3.6m each and depth of foundation is 2.4 m. & total height of chosen building including depth of foundation is 114 m. The static and dynamic analysis has done on computer with the help of STAAD-Pro software using the parameters for the design as per the IS-1893- 2002-Part-1 for the zones- 2 and 3. It was concluded that not much difference in the values of Axial Forces as obtained by Static and Dynamic Analysis. [8]

M. S. Aainawala *et. al.* done the comparative study of multistoried R.C.C. Buildings with and without Shear Walls. They applied the earthquake load to a building for G+12, G+25, G+38 located in zone II, zone III, zone IV and zone V for different cases of shear wall position. They calculated the lateral displacement and story drift in all the cases. It was observed that Multistoried R.C.C. Buildings with shear wall is economical as compared to without shear wall. As per analysis, it was concluded that displacement at different level in multistoried building with shear wall is comparatively lesser as compared to R.C.C. building without shear wall.[1]

Anwaruddin M. *et. al.* carried out the study on non linear Static Pushover Analysis of G plus 3 medium rise reinforced cement concrete structure with and without vertical irregularity. It was seen that irregularity in height of the building reduces the performance point of structure. There was reduction in displacement or deformation of the RCC building also. They concluded seeing that the no of bays reduces upright, the lateral load carrying capacity increases with decline in lateral displacement. [3]

Rui Pinho *et.al.* revised eurocode 8 formulae for periods of vibration and their employment in linear seismic analysis. This paper takes a critical look at the way in which seismic design codes around the world have allowed the designer to estimate the period of vibration for use in both linear static and dynamic analysis. Based on this review, some preliminary suggestions are made for updating the clauses related to the estimation of the periods of vibration in Eurocode 8. [6]

Rakesh K. Goel and Anil K. (1997) studied the period formulas for moment-resisting frame buildings. Based on analysis of the available data for the fundamental vibration period of 27 RC MRF buildings and 42 steel MRF buildings, measured from their motions recorded during earthquakes different formulas were used for estimating, conservatively, the period of RC and steel buildings; respectively .Regression analysis was done to obtain the coefficient of empirical formula for fundamental period. [9]

Sarkar *et. al.* proposed a new method of quantifying irregularity in vertical geometric irregular building frames, which deals with the dynamic characteristics i.e. stiffness and mass. This paper discusses some of the important issues regarding analysis and design of stepped buildings. They proposed a fresh method for quantifying the irregularity in stepped building. This approach is found to execute better than the existing procedures to quantify the irregularity. The total 78 stepped frames with varying irregularity and height were taken in this study. They proposed a correction factor to the empirical code formula for fundamental period, to provide it applicable for vertical geometric stepped buildings. [10]

Sujit Kumar *et. al* (2014) studied the effect of sloping ground on structural performance of rcc building under seismic load. The seismic analysis of a G+4 storey RCC building on varying slope angles i.e., 7.5^0 and 15^0 is carried and compared with the same existing on the flat ground. The seismic loadings are as per IS: 1893-2002. STAAD Pro v8i is used in this study to see the effect of sloping ground on building performance during earthquake. Seismic analysis has been done using equivalent Linear Static method. The analysis is carried out to estimate the effect of sloping ground on structural forces. The bending moment, horizontal reaction in footings and axial force in columns are critically analyzed to enumerate the effects of various sloping ground[5]

3. STRUCTURAL MODELLING

The method used in this study is *Seismic Coefficient Method* which is an equivalent static analysis considering a design seismic coefficient. In equivalent lateral procedure dynamic effects are approximated by horizontal static forces applied to the structure. This work is based on three dimensional reinforced concrete building with varying heights and widths. Various building geometries are taken for the study. These building configurations represent different degree of vertical irregularity or amount of setback. The same bay width of 3m is taken in both the horizontal direction .Two cases are considered for the bays. In first case, the numbers of bays are four and in second case, these are eight. The uniform storey height of 3.5m is considered in all the cases. The regular frame is designated as R. The classification of the buildings considered are expressed in the form of V-X-Y, where V represents the type of irregularity (*i.e.*, V1 to V4 or R). X represents the number of storeys and Y represents the number of bay in both the horizontal direction.

Total five different building geometries, one regular and four irregular, for each height category are considered in the present study. Figure given below presents the elevation of all five different geometries of a typical four storey building. The buildings are three dimensional, with the vertical irregularity in the direction of setback i.e. X, in the other horizontal direction the building is just repeating its geometric configuration. The same building configurations are repeated in all the cases considered in this study. Vertical irregular frames are named as V1, V2, V3 and V4 depending on the percentage reduction of floor area and height as shown in the figure below

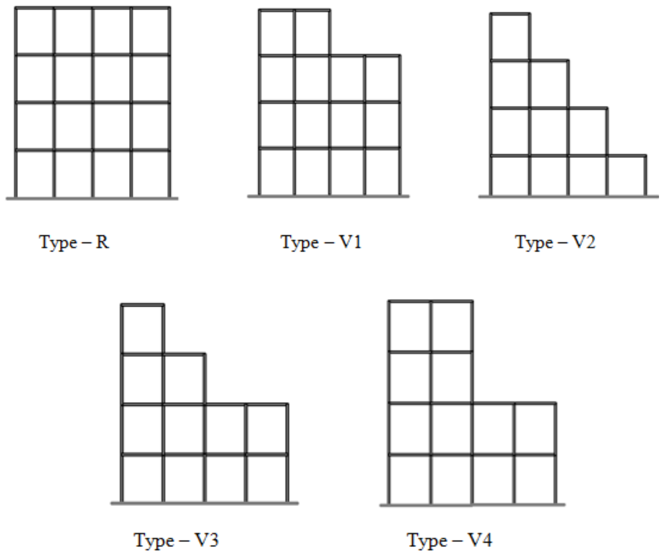

Fig -1: Typical building configuration for four-storey building variant

The method used in this study is *Seismic coefficient method* which is an equivalent static analysis considering a design seismic coefficient. Gravity (dead and imposed) load and seismic load corresponding to seismic zone IV of IS 1893:2002 are considered for the design. Ordinary moment resisting frame is considered in all the cases having response reduction factor (RF) as 3.
All building frames are assumed to be located on medium soil. All buildings are general type structure. Damping ratio is taken as 5%.The various seismic parameters are summarized below in the table 3.2.

Seismic parameter	*Value*
Zone factor	0.24
Response reduction factor(RF)	3
Importance factor(I)	1
Rock & soil site factor	2
Damping ratio	.05
Type of structure	1

Table1: Parameters taken in Seismic Analysis

The slab thickness is taken as 150 mm for all the buildings. All Infill walls are considered to be the external with thickness of 200 mm. The parapet wall is assumed to be of 200 mm thickness and of 1m height for all the selected buildings. The unit weight of brick is taken as 20Kn/m³and concrete as 25kN/m³.All supports are taken as fixed. The structures are modeled by using computer software Staad.Pro V8i.The floor load is taken as 4.75kN/m² including floor finish load. The live load of 3kN/m² is assumed in all the cases. Total 15 load cases are taken according to the Indian codes. The various load case details including 1893 load X1,1893 load Z1,dead load(member load, self weight,& floor load) , live load and other 11 load cases are generated based on Indian codes. All load cases are generated according to the Indian codes. Wind load combinations are not considered in this study.

Building Type	*Beam dimension(mm)*	*Column dimension(mm)*
4-storey building	200 ×400	300 × 300
8-storey building	300 × 600	350 × 350
12-storey building	500 × 700	450 × 450
16-storey building	500 ×700	500 × 500

Table 2: Dimensions of beams and columns for different building

4. RESULTS AND DISCUSSIONS

The seismic parameters which are considered for this study are shear force, bending moment storey drift, storey displacement and sectional displacement. The critical maximum values are taken in all the cases. The Z directional shear force and bending moment are considered. The storey drift and maximum storey nodal displacement of both the horizontal direction X & Z are noted down. The aim of the study is to find out the variation of these parameters among five frame configurations. Initially these results are compared for same storey height, then after conclusion will be made considering all storey heights. The critical values are being taken that are maximum among the all load cases. The seismic performance and behavior of any building frames can easily be predicted based on studying these parameters.

This section focuses on the comparison between four bay and eight bay frames based on seismic parameters described in the previous chapter. A comparative study is done storey wise which are shown with the help of graphs.

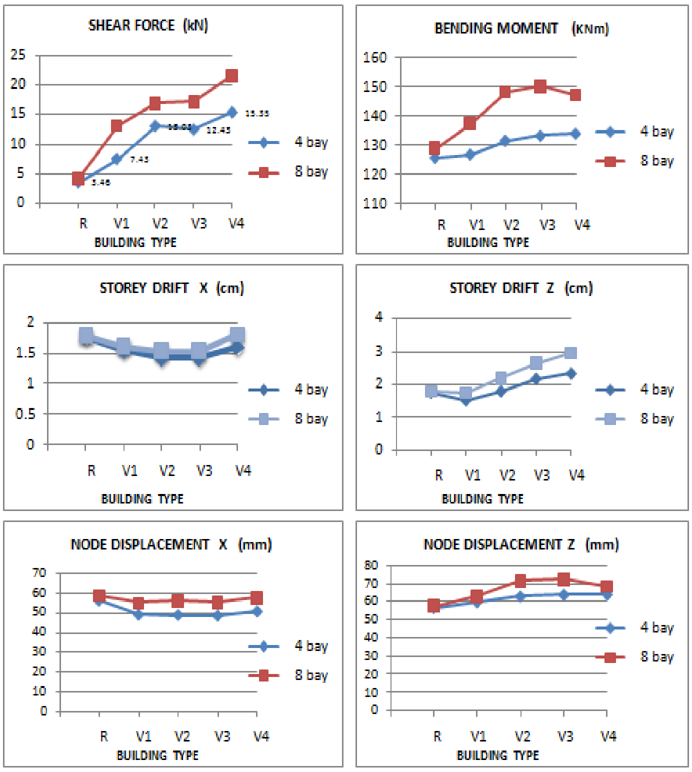

Fig -2: Comparison Of Critical Seismic Parameters 4 STOREY

Four bay frames have less critical bending moment than eight bay frames for both four storey and eight storey building. There is not much change for the bending moment of regular frames. The shear force and bending moment of building are considered in Z directions only.

The critical inter storey drift are taken in both X and Z directions. From graph we see that the drift lines of 4 bay and 8 bay frames in X direction is almost coinciding for both four storey and eight storey building. Regular building configurations have exactly same value of drift. The irregular frames V4-4-8 and V4-8-8 have slightly more drift in X direction than there corresponding configurations. Now let us consider the storey drift in Z direction, the scenario is something different. It is observed that the 8 bay frames posses higher values of drift than there corresponding 4 bay frames for both the storey height. Also the regular frames R-4-4 and R-4-8 have nearly same storey drift. The similar is observed for frames R-8-4 and R-8-8.
Considering the fourth seismic parameter node displacement, it is seen that the storey displacement of 8 bay frames in both the horizontal directions is more than the 4 bay frames. The regular frames have almost same displacement in both the cases and in both directions. The similar conclusions can be drawn for node displacement for eight storey RCC building frame in Z direction for both

the bay number. But the opposite result are obtained for X directional displacement. Initially it is seen that the frames have same displacement but as we move on further, the four bay building frames comprises more node displacement than their corresponding eight bay frames.

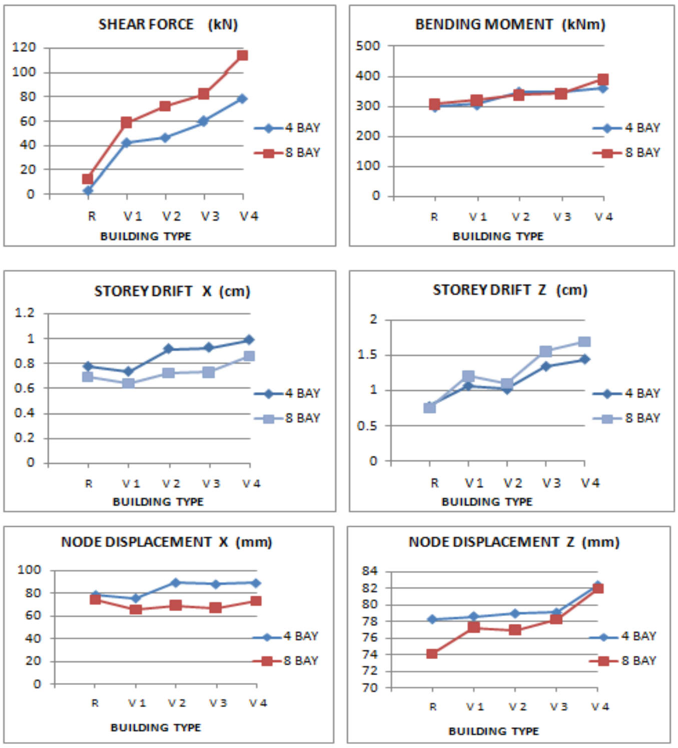

Fig -3: Comparison Of Critical Seismic Parameters 12 STOREY

5. CONCLUSIONS

The comparison of results have been done storey wise for each bay and then bay wise for same building height. It is concluded that as the amount of setback increases the shear force also increases. The fluctuation of critical shear force from regular to vertical geometric irregular is very high

Based on the work presented in this thesis following point-wise conclusions can be drawn:

1) It is concluded that as the amount of setback increases, the critical shear force also increases. The regular building frames possess very low shear force compared to setback irregular frames.

2) The critical bending moment of irregular frames is more than the regular frame for all building heights. This is due to decrease in stiffness of building frames due to setbacks. Thus there is need for providing more reinforcement for irregular frames.

3) It is seen that the critical seismic parameter of 4 *bay* building frames up to eight storey building height is less than corresponding 8 *bay* building frames . Therefore 4 bay building is appropriate for lower building heights.

4) For higher storey building (twelve & sixteen storey) 8 *bay* configurations should be preferred because they have generally lesser values of critical seismic parameters than 4 *bay*. Thus this study demonstrated that with the increase in number of bays the seismic performance of both regular and setback building improves.

5) The seismic performance of regular frame R is found to be better than corresponding irregular frames in nearly all the cases. Therefore it should be constructed to minimize the seismic effects. Among setback frames, Type V1 building configuration is found superior than others.

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