STUDY OF IRREGULAR RC FRAME BUILDINGS UNDER SEISMIC

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ABSTRACT:
Buildings may be considered as asymmetric in plan or in elevation based on the distribution of mass and stiffness along each storey, throughout the height of the buildings. Most of the hilly regions of India are highly seismic. A building on hill slope differs in different way from other buildings. In this study, 3D analytical model of four and nine storied buildings have been generated for symmetric and asymmetric building models and analyzed using structural analysis tool “ETABS”. To study the effect of varying height of columns in ground storey due to sloping ground, the plan layout is kept similar for both buildings on plane and sloping ground. The analytical model of the building includes all important components that influence the mass, strength, stiffness and deformability of the structure.

Previous studies emphasize for proper planning and construction practices of multistoried buildings on sloping ground. However, in normal design practice the designers generally ignore the effect of vertical irregular elevation on the structural behavior of the building. The seismic forces are considered as per IS: 1893-2002. The structural analysis software ETABS is used to study the effect of sloping ground on building performance during earthquake. Seismic analysis has been done using Linear Static method. The analysis is carried out to evaluate the effect of vertical irregularity on structural forces. The horizontal reaction, bending moment in footings and axial force, bending moment in columns are critically analyzed to quantify the effects of various sloping ground. It has been observed that the footing columns of shorter height attract more forces, because of a considerable increase in their stiffness, which in turn increases the horizontal force (i.e. shear) and bending moment significantly. Thus, the section of these columns should be designed for modified forces due to the effect of sloping ground. The present study emphasizes the need for proper designing of structure resting on sloping ground.

In this Study, a multi- storey reinforced concrete building has been modelled and performed by using software ETABS with different plan shapes regular (Rectangular shaped ) and each shape has three different configurations like (setback building, step back building and set-step back building ) and plane dimension (40 x 40) m with nine stores resting on plan and on sloping ground (26.57°) with fixed length of short columns support for each models, the models have been conducted and analyzed in the ETABS pro program by using equivalent linear static method and response spectrum method for comparing and investigating the changes in structural behavior and the irregularity effect in plan and elevation on sloping ground. The result of the analysis for displacement and storey drift have been studied and compared with reference to the serviceability and the time period, storey shear, storey moment and storey torsion, have been studied and compared for different configurations structure models and it was presenting in graphical and tabular form.
1. INTRODUCTION

In the past, several major earthquakes have exposed the shortcomings in buildings, which leads to damage or collapse. It has been found that regular shaped buildings perform better during earthquakes. The structural irregularities cause non-uniform load distribution in various members of a building. There must be a continuous path for these inertial forces to be carried from the ground to the building weight locations. A gap in this transmission path results in failure of the structure at that location. There have been several studies on the irregularities, viz., (Jack P. Moehle, A. M. ASCE 2002), Seismic Response of Vertically Irregular Structures, seismic response of vertically irregular frames with pushover analysis (Chintanapakdee, Chopra, 2004) and evaluation of mass, strength and stiffness limits for regular buildings specified by UBC (Valmundsson and Nau, 1997), Seismic Response of RC Frame Buildings with Soft First Storeys (Arlekar Jaswant N, Jain Sudhir K. and Murty C.V.R, 1997) etc. In the present paper, response of a G+ 10-storeyed vertically irregular frame to lateral loads is studied for stiffness irregularity at fourth floor in the elevation. These irregularities are introduced by changing the properties of the members of the storey under consideration maintaining aspect ratio for vertically irregular frame Specified in I.S 1893:2002(part1) Guidelines. Stiffness irregularities include the height of the column increased on the fourth floor which is applied on vertically irregular frame. Effects on storey-shear forces, storey drifts and deflection of beams is studied.

1.1 Structural Irregularities

There are various types of irregularities in the buildings depending upon their location and scope, but mainly, they are divided into two groups—plan irregularities and vertical irregularities.

In the Study, the vertical irregularities are considered which are described as follows.

1.2 Vertical Geometric Irregularity

Geometric irregularity exists, when the horizontal dimension of the lateral force resisting system in any storey is more than 150% of that in an adjacent storey. The setback can also be visualized as a vertical re-entrant corner. The general solution of a setback problem is the total seismic separation in plan through separation section, so that the portion of building is free to vibrate independently.

1.3 Objective of the study

The present thesis work is aimed at evaluating hypothetical existing RC framed building with the following objectives:

1. Generation of 3D building model for both elastic and inelastic method of analyses.
2. Determination of deflections and storey drifts at each storey under seismic load.
4. To study on the influence of masonry infill on the overall behavior of structure when subjected to lateral seismic forces.
5. To study the effect of vertical irregularity on the fundamental natural period of the building and its effect on performance of the structure during earthquake for different building models selected.
6. To find out the damage distribution in the structure due to earthquake loading.
Chandrasekaran and Rao (2002) investigated analysis and the design of multi-storyed RCC buildings for seismicity. Reinforced concrete multi-storyed buildings are very complex to model as structural systems for analysis. Usually, they are modeled as two-dimensional or three-dimensional frame systems are in to plane and slope with different angles 5°, 10°, and 15°. Analyze multi-storyed buildings in the country for seismic forces and comparing the axial force, shear force, moment, nodal displacement, stress in beam and support reaction compared to current version of the IS: 1893–2002 to the last version IS: 1893–1984.

Birajdar B.G. (2004) presented the results from seismic analyses performed on 24 RC buildings with three different configurations like, Step back building; Step back Set back building and Set back building are presented. 3-D analysis including tensional effect has been carried out by using response spectrum method. The dynamic response properties i.e. fundamental time period, top storey displacement and, the base shear action induced in columns have been studied with reference to the suitability of a building configuration on sloping ground. It is observed that Step back Set back buildings are found to be more suitable on sloping ground.

A. Giordano (2008) The paper investigates the seismic response of plan irregular masonry building structures in order to evaluate the magnitude of torsional coupling and the applicability of 3D pushover analysis for assessing the behavior under earthquakes. As a test example a simple plan asymmetric two-storey masonry building is selected. The nonlinear dynamic response obtained under both several generated records and selected earthquake ground motions is initially compared with the one obtained for a symmetric building variant. Subsequently, the nonlinear dynamic analysis results are compared with the pushover analysis results. The pushover analyses are performed up to the maximum top displacement obtained by the nonlinear dynamic analyses (measured at the mass center), computed for each earthquake record separately. The deflection profiles and damage at the stiff and the flexible building sides are compared with the peak response obtained by nonlinear dynamic analysis.

Mr. Sandesh N. (2014) Most recent earthquakes have shown that the irregular distribution of mass, stiffness and strengths may cause serious damage in structural systems. Due to several reasons structures acquire asymmetry. Asymmetry in structures makes analysis of the seismic behavior very complicated. Seismic demand in peripheral elements is enhanced. Uniformity in load distribution gets disturbed. Torsional behaviour of asymmetric building is one of the most frequent causes of structural damage and failure during strong ground motions. The paper first concentrates in understanding the complex behaviour of structure under asymmetric form; a study on the influence of the torsional moment effects on the behaviour of structure is done by using Response spectrum method. Then a simplified nonlinear pushover analysis has been used to find structural descriptors required in seismic vulnerability assessment. Deformation demand for different story for low-medium rise framed building has been found by using software SAP2000.

Ashish R. (2015) Performance-based seismic design method is both efficient and effective to avoid future earthquake losses. Structural irregularities are important factors which decrease the
seismic performance of the structures. Buildings which have structural irregularities may experience different drifts of adjacent stories, excessive torsion, etc. according to irregularity type and fail during an earthquake. In this work, performance based seismic design of buildings with plan irregularity is studied using Standard pushover analysis and Modal pushover analysis. Also to check accuracy for both the methods Non-linear time history analysis is carried out. For present study, building models of (G+6) storey regular and irregular buildings of ‘L’ shaped, ‘C’ shaped and ‘T’ shaped are generated by a computer program ETABs (version 9.7.3). The buildings shape in plan is selected in such a way that the total area in plan remains same so that value of dead and live load remains almost same. Different parameters such as pushover curves, performance point, plastic hinges mechanism and torsion are studied. The results shows that the Standard pushover analysis gives same results as compare to Modal pushover analysis and time history analysis for regular building, but for irregular buildings modal pushover analysis gives better results due to consideration of higher mode effects. It is also concluded that torsion produced in irregular buildings are almost 20% more than the regular building so it is necessary to take the effects due to torsion for irregular buildings. Also the performance based seismic design obtained by above procedure satisfies the acceptance criteria for immediate occupancy and life safety limit states for given intensities of earthquake.

S.Varadharajan (2013) The present study summarizes the research works done in the past regarding different types of structural irregularities i.e. Plan and vertical irregularities. Criteria and limits specified for these irregularities as defined by different codes of practice (IS1893:2002, EC8:2004 etc.) have been discussed briefly. It was observed that the limits of both Plan and vertical irregularities prescribed by these codes were comparable. Different types of modeling approaches used have also been discussed briefly. The review of previous research works regarding different types of plan irregularities justified the preference of multistory building models over single storey building models and concept of balanced CV (Center of strength) – CR (Center of rigidity) location was found to be useful in controlling the seismic response parameters. Regarding the vertical irregularities it was found that strength irregularity had the maximum impact and mass irregularity had the minimum impact on seismic response. Regarding the analysis method MPA (Modal pushover analysis) method even after much improvement was found to be less accurate as compared to dynamic analysis.

3. METHODOLOGY

3.1 Method of Analysis

The method of analysis used for the present study is
1. Equivalent static method
2. Response spectrum method
3. Push over Analysis.

**Equivalent Static Method:** This method follows linear static procedure, in which the response of buildings is assumed in a linearly elastic manner. Analysis is carried out as per IS 1893:2002(PART1), total design lateral force or design base shear along any principal direction is given in terms of design horizontal seismic coefficient and seismic weight of the structure. Design horizontal coefficient depends on the zone factor of site, importance of the structure, response reduction factor of the lateral load resisting elements and
the fundamental natural time period of the structure.

**Response Spectrum Method:**
In this method linear dynamic analysis of the frame models are performed, the maximum response of the building is estimated directly from elastic or inelastic design spectrum characterizing the design earthquake for the site and considering the performance criteria of the building. The software solves the Eigen value problem of the model and calculates the fundamental natural period values. Hence the total earthquake loads are generated and its distribution along the height corresponds to the mass and stiffness distribution. The modeling and analysis is done using ETABS.

**Pushover analysis:** This is a performance based analysis and has aim in controlling the structural damage. In this analysis several built in hinge properties are included from FEMA 356 for concrete members. This analysis will be carried out by using nonlinear software ETABS 2013. This software is able to predict the displacement level and corresponding base shear where first yield of structure occurs. The main objective to perform this analysis is to find displacement vs. base shear graph.

**3.2 About the Structure:**
Two configurations: Rectangular shaped and for each configuration, shapes have been modeled:

**BASIC DATA FOR BUILDINGS MODEL:**
- Plan Dimension: (4x 40) m
- Height of each story: (3) m & one store is 5 m
- Number of stores: G+ 9 stores
- Length of each bay(in X-direction) : (4)m
- Length of each bay(in Y-direction) : (4)m
- Dimension of Column: (450 X 300) mm
- Dimension of Beam: (230 X300) mm
- Slab Thickness: (150) mm
- Walls Thickness: (230) mm thick brick masonry wall
- Grade of the concrete: M 25
- Grade of the steel : Fe415
- Type of Soil: Type II, Medium Soil
- Seismic Zone: II
- Building Frame Systems: Ordinary RC moment-resisting
- Live Load on Typical Floor: (2.0 ) KN/m2
- Wind speed: (44) m/s
- Support: Fixed.

**4. RESULTS AND DISCUSSION**
5. CONCLUSION

The following conclusions from this study are:

1. The performance of irregular plan shaped building with vertical irregularity could prove more vulnerable than the regular plan shaped building with vertical irregularity.

2. On plan ground, setback building attract less action forces as comparing with other configurations on sloping ground which make it more stable and it would not suffer more damages due to the lateral load action.

3. On sloping ground set-step back building attract less action forces as comparing with step back building but if the cutting cost of sloping ground is with acceptable limits then setback building may be preferred.

4. In step back building, the development of storey shear and moment and torsion were more than other configuration which found to be more vulnerable.

5. The effect of overall building torsion in step back and set-step back building was more than the setback building, as the building gets more unsymmetrical on sloping ground.

REFERENCE


Pushover Analysis of Seismic Performance Evaluation.


