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Seismic Performance Evaluation of RC Buildings with Regular And Irregular Floor Masses

G. Suresh[1], R. Arun[2]

[1]P. G. Student, Department of Civil Engineering, Sir Vishveshwaraiah Institute of Science and Technology, Madanapalle, Andhra Pradesh, India
[2]Asst. Professor, Department of Civil Engineering, Sir Vishveshwaraiah Institute of Science and Technology, Madanapalle, Andhra Pradesh, India

ABSTRACT

Mass irregularity is the presence of heavy mass on a floor or when one floor is much heavier than the others, e.g., heavy machinery or a swimming pool installed on an intermediate floor of a building. In this study the slab thickness i.e., floor mass is varying. Slab thickness is increased at alternative floors in mass irregular buildings. 0.15 m slab thickness is taken for the without mass irregular buildings and for mass irregular buildings slab thickness is taken as 0.30m.In light of these facts, it is imperative to seismically evaluate building with the present day knowledge to avoid the major destruction in the future earthquakes.

The dissertation work is concerned with the comparison of the seismic evaluation of RC buildings with and without mass irregularity, the method carried out in terms of equivalent static, response spectrum and pushover analysis according to IS 1893:2002(part1) code.G+2 to G+8 storey buildings are considered for the analysis. In this analysis for mass irregular buildings, the floor mass is varied at 2nd, 4th, 6th, 8th floor of all the buildings. The comparison of equivalent static response spectrum method and pushover analysis by using finite element software package SAP2000 version 14.0.0 is used to perform the modeling and analysis of G+2 to G+8 storey's buildings by considering the seismic zone V as per IS 1893:2002(part 1) code. For analysis various IS codes have been referred. For Gravity load combination IS 456:2000 and for 0.9, 1.2 and 1.5 seismic load combinations as per IS 1893:2002 (part 1) code is referred. In this study building model analysis carried out namely gravity, equivalent static, response spectrum & pushover analysis in longitudinal direction & transverse direction discussed and comparisons of codal values of the software analysis values. Results of these analyses are discussed in terms of the time period, storey displacement, storey drift and base shear. From this results it is concluded that time period, storey displacement, storey drift and base shear will be more in mass irregular buildings compare with the without mass irregular buildings.

Keywords : Heavy Mass, Heavy Machinery, Seismic Evaluation, Mass Irregular Buildings.

I. INTRODUCTION

E-commerce has become one of the vital parts of the modern life. Online payment is the supportive application for the payment of money for the products we buy. For the past years online security breach created a major problem and lots of money had been stolen. The proposed document deals by securing the payment through iris recognition [1]. This method also adds the method of using visual cryptography for securing the user credentials. This visual cryptography method was formerly invented by Moni Naor and Adi Shamir in 1994[6].

II. METHODS AND MATERIAL

Earthquakes are one of the most destructive of natural hazards. Earthquake occurs due to sudden transient motion of the ground as a result of release of elastic energy in a matter of few seconds. The impact of the event is most traumatic because it affects large area, occurs all on a sudden and unpredictable. They can cause large scale loss of life and property and disrupts essential services such as water supply, sewerage systems, communication and power, transport etc. They not only destroy villages, towns and cities but the aftermath leads to destabilize the economic and social structure of the nation. Seismic vibrations may cause settlement beneath buildings when soils consolidate or compact. Certain types of soils, such as alluvial or sandy silts are more likely to fail during an earthquake. The size of the earthquake can be measured by Magnitude (M) which was obtained by recording the data of motions on seismograms. But shaking of the ground will have different intensities at different locations for the same magnitude. This can be measured by MMI scale (Modified Mercalie Intensity).

The magnitude and intensities of earthquake varies from place to place causing low to severe destructive powers on engineered properties as well as giving rise to great economic losses and life threat. To overcome this issue several countries over the world started monitoring the records of ground motions in their regions and converting these data into seismic zone maps interms of PGA (Peak ground accelerations). These maps are regularly updated inorder to predict future earthquakes, which will be helpful for creation of safe and economical earthquake resistant structures.

When an earthquake does occur, there can be considerable variation in the levels of performance experienced by different buildings located on the same site as shown in fig 1.2. This variability can result from a number of factors, including random differences in the levels of workmanship, material strength, and condition of each structure, the amount and distribution of live load present at the time of the earthquake, the influence of mass and stiffness of structural and nonstructural components, the response of the soils beneath the buildings, and relatively minor differences in the character of the ground motion transmitted to the structures. Many of these factors are trying to identified or quantified at our current level of research works.

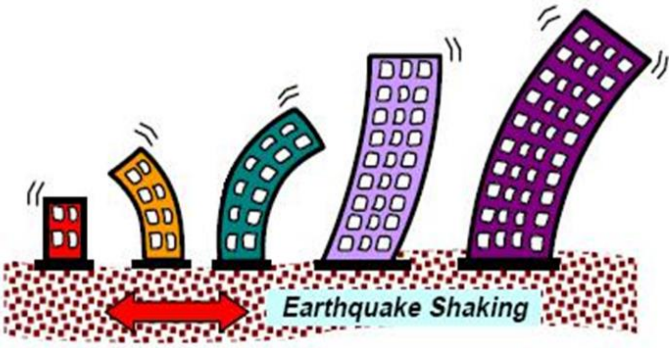


Figure 1 Seismic Response of Different Buildings

1.2 Floor Mass Irregularity:

Floor mass irregularity is the presence of heavy mass on a floor or when one floor is much heavier than the others, e.g., heavy machinery or a swimming pool installed on an intermediate floor of a building. In case of unavoidable situations or non-compliance the ratio of mass to stiffness of two adjacent storeyes should be made equal. Mass irregularities affect the dynamic response of the structure by increasing ductility demands at a few locations and lead to unexpected higher mode effects.

This exists when the weight of the structure at one level is substantially in excess of that at the levels immediately above or below it. This condition commonly occurs in industrial structures where heavy pieces of equipment are located at some levels. It also can occur in buildings that have levels with large mechanical rooms or storage areas.

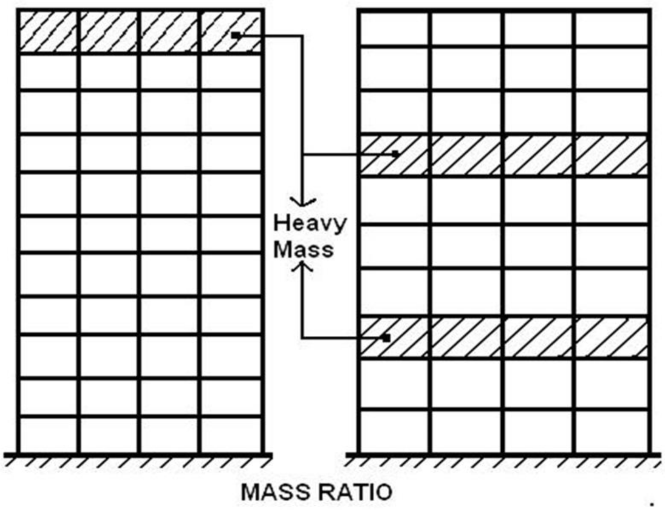


Figure 2. Mass Irregularity (IS 1893 part-I)

III. RESULTS AND DISCUSSION

A. Seismic Design Philosophy

The design philosophy adopted in the seismic code is to ensure that structures possess at least a minimum strength to

(i) Resist minor earthquakes (Design Basis Earthquake-DBE), which may occur frequently without damage.
(ii) Resist moderate earthquake (DBE) without significant structural damage through some non-structural damage.
(iii) Resist major earthquake (Maximum Considered Earthquake-MCE) without collapse.

Design Basis Earthquake (DBE) is defined as the maximum earthquake that reasonably can be expected to experience at the site once during lifetime of the structure. The earthquake corresponding to the ultimate safety requirements is often called as maximum considered earthquake (MCE). Generally, DBE is half of MCE.

B. Methods of Seismic Evaluation

Once the structural model has been selected, it is possible to perform analysis to determine the seismically induced forces in the structures. There are different methods of analysis provides different degrees of accuracy. Currently seismic evaluation of buildings can be divided into two categories

1. Qualitative Method
2. Analytical Method

The qualitative methods are based on the available background information of the structures, which involves the visual inspection report, some non-destructive test results etc. Whereas analytical methods involves the estimation of forces and behavior of the structures during the earthquakes depending on the available data. The methods in these categories are as shown in the below fig.

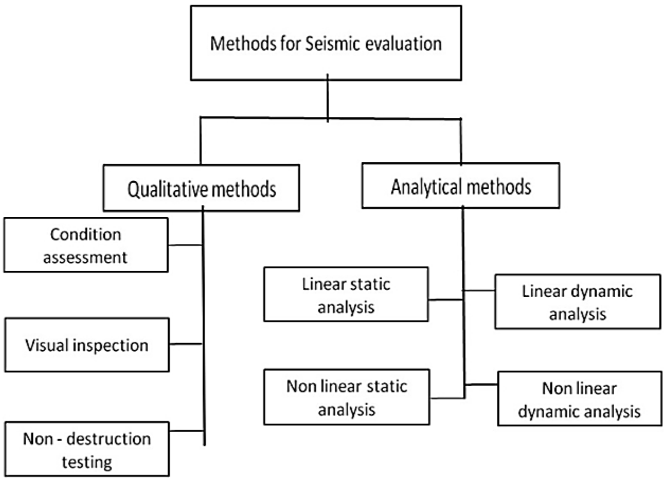


Figure 2. Flow Chart showing different methodology

C. Linear Dynamic Analysis by Response Spectrum Method

The response spectrum represents an envelope of upper bound responses based on several different ground motion records. For the purpose of the seismic analysis the design spectrum given in IS 1893 (Part 1):2002 is used. This spectrum is based on strong motion records of eight Indian earthquakes.

Following procedure is generally used for the response spectrum analysis which involves undamped free vibration of the entire building using established methods of mechanics.

1. Select the design spectrum
2. Determine the Eigen vales (ω^2) , Eigen vectors (Ø) and periods of vibration (T) using the basic equations of motion

$$M\ddot{X}^{t} + C\dot{X} + KX = 0$$

3. Read the level of response from the spectrum for the period of each of the modes considered.
4. Determination of Modal Participation Factor P_k for mode k is given below

$$P_k = \frac{\sum_{i=1}^{n} W_i \phi_{ik}}{\sum_{i=1}^{n} W_i \phi_{ik}^2}$$

5. Determination of Modal Mass M_k of mode k is given as follows

$$M_k = \frac{\left[\sum_{i=1}^{n} W_i \phi_{ik}\right]^2}{g \sum_{i=1}^{n} W_i \phi_{ik}^2}$$

6. Select number of modes k such that the sum total of modal masses of all modes considered is at least 90% of the total seismic mass.
7. Design Lateral Force Q_{ik} for floor i and mode k is given as follows:

$$Qik = AkØikPkWi$$

Where A_k is the design horizontal acceleration spectrum and W is the seismic weight of the building

8. Peak value of Design Lateral Force for floor i and storey shear forces in each mode can be obtained by one of the Modal Combination Rules

SRSS (Square Root of Sum of Squares) rule,

$$Q_i = \sqrt{\sum_{k=1}^{r} (Q_{ik})^2}$$

CQC (Complete Quadratic Combination) rule

$$Q_i = \sqrt{\sum_{j=1}^{r} \sum_{k=1}^{r} \lambda_{ij} \rho_{jk} \lambda_{ik}}$$

By this way convert the combined maximum response into shears and moments for use in design of the structure.

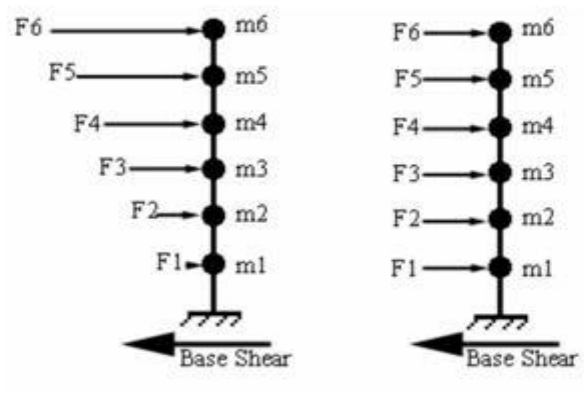


Figure 3. Conventional Lateral Load Distribution

The pushover or capacity curve represents the lateral displacements as the function of force applied to the structure. Location of hinges in various stages can be obtained from pushover curve as shown in fig 2.3.2 The range AB is elastic range, B to IO is the range of immediate occupancy, IO to LS is the range of life safety, and LS to CP is the range of collapse prevention. If all the hinges are within the CP limit then the structure is said to be safe. However, depending upon the importance of structure the hinges after IO range may also need to be retrofitted.

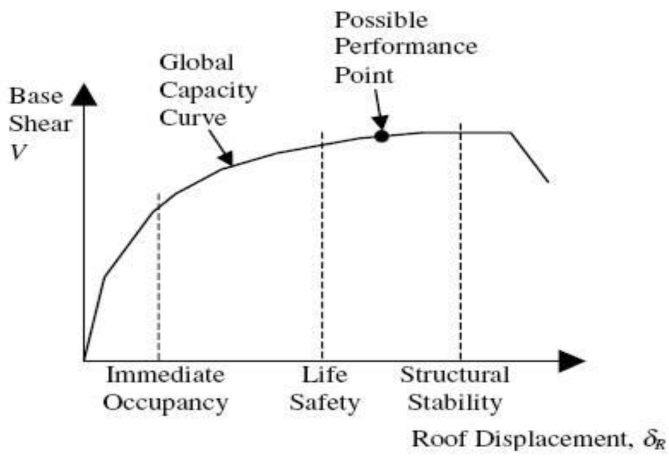
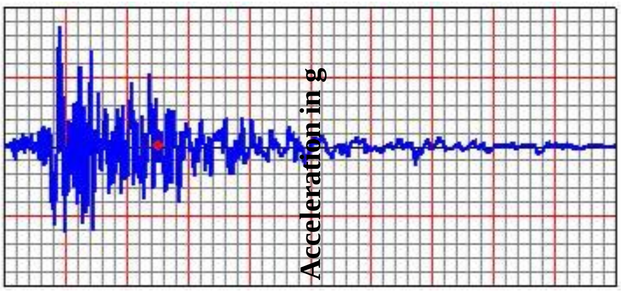


Figure 4. Building Capacity Curve

D. Nonlinear Dynamic Analysis

The Nonlinear Dynamic Procedure (NDP) is for seismic analysis of the building, a mathematical model directly incorporating the nonlinear load-deformation characteristics of individual components and elements of the building shall be subjected to earthquake shaking represented by ground motion time histories to obtain forces and displacements. Calculated displacements and internal forces shall be compared directly with acceptance criteria. With the NDP, the design displacements are not established using a target displacement, but instead are determined directly through dynamic analysis using ground motion time histories as show in fig 5.



Time in seconds

Figure 5. Typical Acceleration Time-History Record

E. Modeling And Analysis

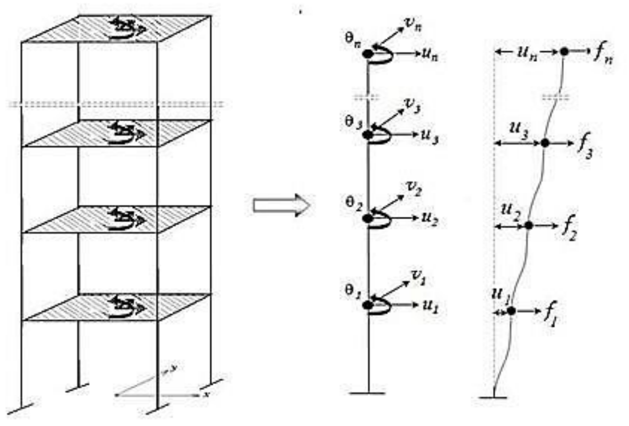


Figure 6. Building Model with 3DOFs per Floor

F. Example Buildings Studied

In the present study reinforced concrete moment resisting frame building of three storeyed, four storeyed, five storeyed, , six storeyed, seven storeyed, eight storeyed and nine storeyed are considered. The plan layout, elevations and 3D view of all storeyed buildings with and without floor mass irregularity are as shown in the below Figures. The different configurations of buildings are modeled by considering only mass of the infill i.e., stiffness of the infill is neglected in order to account the nonlinear behavior of seismic demands. The bottom storey height is kept 1.5m and height of 3.5m is kept for all other storeyes for all kind of building models. The building is considered to be located in the seismic zone V and intended for commercial purpose.

Model-I – Building without mass irregularity i.e., building assemblage of regular slab, beam, and column elements. (fig 6).

Model-II –Building with floor mass irregularity i.e., increase the slab thickness at alternative floors in building. (fig 6).

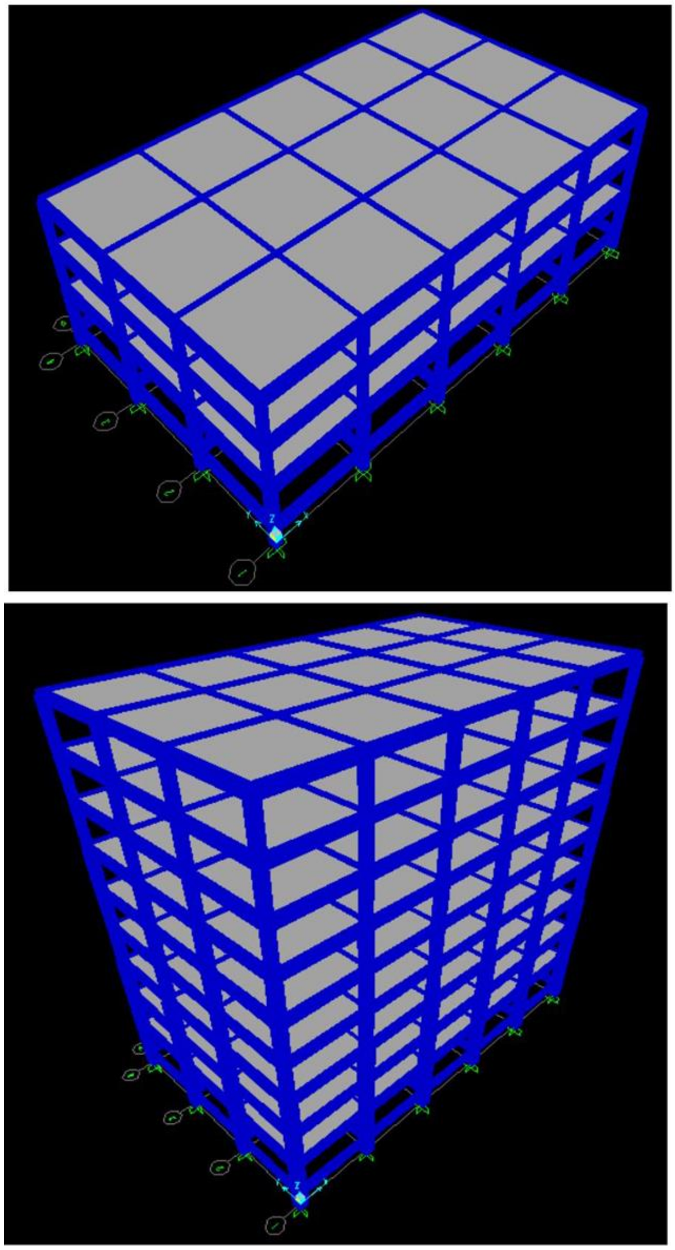


Figure 6. Three Dimensional view of 3 storey and 9 storey building

G. Load Combinations

The following load combinations are considered for the analysis and design as per IS: 1893-2002.

Table 1. Load combinations as per IS: 1893-2002 and IS: 875(Part3)-1987

Load Combination	Load Factors
Gravity analysis	1.5 (DL+LL)
Equivalent static analysis	1.2 (DL+ LL ± EQX) 1.2 (DL+ LL ± EQY) 1.5(DL±EQX) 1.5 (DL± EQY) 0.9DL±1.5EQX 0.9 DL± 1.5EQY
Response spectrum analys	1.2 (DL+ LL ± RSX) 1.2 (DL+ LL ± RSY) 1.5(DL±RSX) 1.5 (DL± RSY) 0.9DL±1.5RSX 0.9 DL± 1.5RSY

IV. CONCLUSION

The Present study is focused on the study of Seismic demands of different R.C buildings i.e., low rise, medium rise and high rise buildings using various analytical techniques for the seismic zone V medium soil. The Performance was studied in terms of time period, base shear, lateral displacements, storey drifts and eccentricity in linear analysis. Whereas performance point and hinge status in Nonlinear analysis. Also an attempt was made in pushover analysis to identify the correct lateral load pattern for all the buildings with mass irregularity and without.

1) The fundamental natural period of the structures increase due to the presence of mass irregularity in the buildings.
2) Base shear increases with the increase of floor mass of the building and it decreases for the buildings without mass irregularity.
3) Compared to the regular building the storey displacement will increase as the heavy mass at floor level increases in mass irregular buildings.
4) The storey drift will increases as the floor mass increases in building, due to mass irregularity of the buildings.
5) After studying mass irregularity at various floors, it is found that the worst situation is observed, when the floor mass is vary at 2nd , 4th , 6th and 8th floor of the buildings.
6) The performance level of all the models is found between life safety and collapse prevention level and the numbers of plastic hinges in the collapse prevention level at performance points for seismic designed buildings are same for all seismic load combination.
7) The obtained results show that the amount of information given by the linear analysis was limited up to certain extent. Whereas the nonlinear analysis provides the exact demand and strength of the building.
8) The number of plastic hinges for both buildings i.e., with and without mass irregular buildings are same, but the performance base force is less in the building with mass irregular than in without mass irregular with increases in performance displacement. Hence maximum displacement in mass irregular buildings.
9) The result shows that, the buildings with mass irregular are more vulnerable compared to buildings without mass irregularity.

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