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NONLINEAR STATIC ANALYSIS OF BUILDING USING ETABS

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ABSTRACT
This project is concerned with the effects of various vertical irregularities on the seismic response of a structure. From past earthquakes it is proved that many of structure are totally or partially damaged due to earthquake. So, it is necessary to determine seismic responses of such buildings. There are different techniques of seismic analysis of structure. Pushover analysis is one of the important techniques for structural seismic analysis generally the evaluated structural response is non-linear in nature. In this project work seismic analysis of RCC buildings with mass irregularity at different floor level are carried out. This project highlights the effect of mass irregularity on different floor in RCC buildings with pushover analysis is done by using etabs software.

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. Earthquakes have the potential for causing the greatest damages, among all the natural hazards. Since earthquake forces are random in nature & unpredictable. During an earthquake, the damage in a structure generally initiates at location of the structural weakness present in the building systems. These weaknesses trigger further structural deterioration which leads to the structural collapse which is due to geometry, mass discontinuity and stiffness of structure. The structures having this discontinuity are known as Irregular structures. These structures constitute a large portion of the modern 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. As per IS 1893, 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 hence structural engineer needs to have a thorough understanding of the seismic response of irregular structures. 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. There are two types of irregularities-

1. **Plan Irregularities**
2. **Vertical Irregularities**.

Vertical Irregularities are mainly of five types-

a) Stiffness Irregularity — Soft Storey-A soft storey is one in which the lateral stiffness is less than 70 percent of the storey above or less than 80 percent of the average lateral stiffness of the three storeys above.

b) Stiffness Irregularity — Extreme Soft Storey-An extreme soft storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the three storeys above.

ii) Mass Irregularity-Mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent storeys. In case of roofs irregularity need not be considered.

iii) Vertical Geometric Irregularity- A structure is considered to be Vertical geometric irregular when the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey.

iv) In-Plane Discontinuity in Vertical Elements Resisting Lateral Force-An in-plane offset of the lateral force resisting elements greater than the length of those elements.

v) Discontinuity in Capacity — Weak Storey-A weak storey is one in which the storey lateral strength is less than 80 percent of that in the storey above.

Vol 10, Issue 3, May /2019
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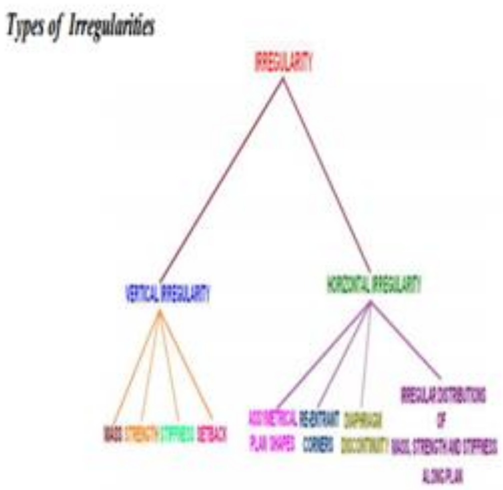

As per IS 1893, Part 1 Linear static analysis of structures can be used for regular structures of limited height as in this process lateral forces are calculated as per code based fundamental time period of the structure. Linear dynamic analysis are an improvement over linear static analysis, as this analysis produces the effect of the higher modes of vibration and the actual distribution of forces in the elastic range in a better way.

II.LITERATURE REVIEW

Afarani and Nicknam (2012) observed the behaviour of the vertically irregular building under seismic loads by Incremental Dynamic Analysis. They have dealing with eight stories regular building having 2 bays with 4 m width in y direction has and 4 bays with 3 m width in x direction with 3 m storey height is considered. They considered Dead load as 2 ton/m is distributed on beams. To avoid torsional effects they considered symmetric building and steel moment resisting frames which are designed according to IBC 2006 and ANSI/AISC 360-05
Eighteen ground motion records from Pacific Earthquake Engineering Research Centre (PEER) database are collected from Far-Field with distance more than 10 km from site and have Richter magnitudes of 5 to 8 on firm soil. The building is modelled in SeismoStruct-V5 software as a nonlinear dynamic analysis .Steel is modelled as Elastic Perfectly Plastic (EPP) hysteresis without experience of local and lateral buckling and the connections were failure according to FEMA 440. Maximum inter story drift ratios and first mode spectral acceleration are calculated by Incremental dynamic analysis and IDA curved are plotted to get the collapse points. The analysis of the building is focused on the collapse prevention limit state of the structures. Fragility curves are generated by using Cumulative Distribution Function through the lognormal distribution through collapse points.
The fragility analysis for an irregular RC building under bidirectional earthquake loading has studied by Jeong and Elnashai (2006). For the consideration of the irregularities in structure, the torsion and bidirectional response are utilized as 3D structural response features to represent the damage states of the building irregularities is presented through a reference derivation. A three story RC frame is taken with asymmetric in plan with thickness of slab is 150 mm and beam depth is 500 mm to study the damage assessments. The sectional dimension of C6 is 750×250 mm whereas all other columns are 250×250 mm. Fragility curves are generated by calculating the damage measure with spatial (3D) damage index by statistical manipulation methods and lognormal distributions for response variables Earthquake records consist are of two orthogonal components (Longitudinal and Transverse) of horizontal accelerations and are modified from the natural records to be compatible with a smooth code spectrum.
PGAs are taken from a range of 0.05 to 0.4g with a step of 0.05g. For accurate damage assessment of buildings is exhibiting torsion, Planar decomposition method is used where the building is decomposed into planar frame and analysed. The parameters such as top displacement, inter-story drift or a damage index are found out from numerical simulations results. The total damage index is calculated for the planar frames from the backbone envelope curve as a combination of damage due to in-plane monotonic displacement and strength reduction. Coefficient of variation (COV) is found be the ratio of standard deviation to mean value of damage index.
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

Vol 10, Issue 3, May /2019
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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.

III.RELIABILITY ASSESSMENT OF RC FRAMES

The fragility curves derived so far represent the probability that the maximum interstorey drift in the frames will exceed inter-storey drift capacity corresponding to a particular performance level, if subjected to earthquake of given intensity in terms of effective PGA. In order to estimate the actual probability of failure and the reliability, which is inversely related to probability of failure, the fragility curves shall be combined with seismic hazard curve at the region selected in the study. The hazard curve should adequately represent the seismicity of the particular area for which the structure has been designed. For the present study, hazard curves of the Manipur region is selected, comes under seismic zone v, for the building is also designed. Hazard curve of a site, where an earthquake of 1.05g would be associated with approximately 2500 year return period or 2% probability of exceedance in 50 years. The probability of failure of the structure is found out by numerical integration. The reliability index is calculated as the inverse of the standard normal distribution. ISO 2394 (1988) recommends the Target Reliability Indices requirement for each performance level (consequences of failure) for each relative cost of measures. Target reliability values as per ISO 2394: 1988 are chosen for the present study to assess the reliability

ASSESSMENT OF SEISMIC RELIABILITY FOR DIFFERENT HAZARD SCENARIOS

The fragility curves developed in the previous Chapter shall be combined with the hazard curve of the region for which the building is designed. Seismic hazard P [A = a], is described by the annual probabilities of specific levels of earthquake motion. In this study, hazard curve developed for Manipur is selected. Limit state probabilities can be calculated by considering a series of (increasingly severe) limit states, LSi, through the expression:

$$P[LS_i] = \sum_a P[LS_i \mid A = a] P[A = a]$$

According to Cornell et. al (2002) A point estimate of the limit state probability for state i can be obtained by convolving the fragility FR(x) with the derivative of the seismic hazard curve, GA(x), thus removing the conditioning on acceleration as per Eq.

$$P[LS_i] = \int F_R(x) \frac{dG_A}{dx} dx$$

The probability of failure is evaluated by numerical integration of Eq. The numerical integration is explained graphically in the Figure . The hazard curve and the fragility curve are divided into small strips parallel to vertical axis. The slope of the hazard curve is multiplied by the ordinate of the fragility curve for each strip, and the summation of all the strips is carried out to evaluate the probability of failure.

IV.RESULTS AND DISCUSSION

BUILDING DESCRIPTION

In the earlier versions of IS 1893 (BIS, 1962, 1966, 1970, 1975, 1984), there was no provision of vertical irregularity in building frames. However, in the recent version of IS 1893 (Part 1)-2002 (BIS,2002), irregular configuration of buildings has been defined explicitly hence the problem considered for the current study is taken in reference to IS 1893-part 1:2002.This G+10 building frame is considered as a regular structure have been analyzed using Pushover Analysis Method. The configuration of frames is as given below.

Frame-1: This is the regular plan of the building with no irregularities and 11 storeys.

Frame-2: This is the irregular plan of the building with ground storey as soft storey.

Frame-3: This frame carries heavier loading on the 8th floor i.e. swimming pool has been introduced hence making building mass irregular.

Frame-4: Frame with swimming pool at its 10th floor making building irregular.

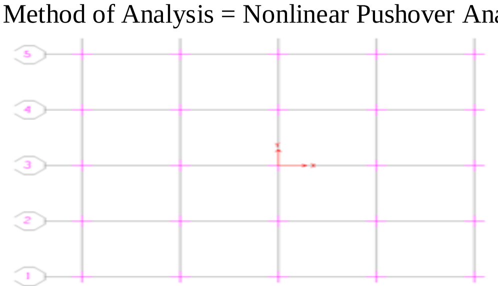
The data assumed for the problem to be analysing in ETABS are as follows

Table Section Properties

Columns Designation	Size (mm)	Beams Designation	Size (mm)
C1	350 X 700	B1	230 X 300
C2	350 X 700	B2	230 X 350
C3	350 X 700		

Section Properties

Building = (G + 10) storey
Slab thickness = 120 mm
Live Load on floor = 3 KN/m2
Live Load on terrace = 1.5 KN/m2
Storey Height = 3 m
Software Used = ETABS v14.2.4
Method of Analysis = Nonlinear Pushover Analysis



Plan of Regular building

V.CONCLUSION

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From above table & various pushover curves of regular & irregular frames it is seen that the yield force is more in case of regular structure & less in case of irregular structure while the yield displacement value is also more in regular structure & less in irregular structure. Therefore it has been concluded that irregular structure cannot sustain more force as compared to regular structure hence structure becomes damage.

Also the analysis proves that irregularities are harmful for the structures and it is important to have simpler and regular shapes of frames as well as uniform load distribution around the building. Therefore, as far as possible irregularities in a building must be avoided. But, if Irregularities have to be introduce for any reason , they must be designed properly.

SCOPE OF FUTURE WORKS

- A study on limited to reinforced concrete multi-storey framed buildings that are regular in plan and irregular in elevation. also can be extended to buildings having irregularity in plan. This involves analysis of three dimensional building frames that accounts for torsional effects. Also, similar studies can be carried out on steel framed building
- Vertically irregular buildings with basement, shear walls and plinth beams are not considered in this study. The present methodology can be extended to such buildings also.
- Soil - structure interaction effects are neglected in the present study. It will be interesting to study the response of the vertically irregular buildings considering the soil - structure interaction.

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