Effect of Irregularities on Seismic Performance of High Rise Structures

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Abstract: This Paper describes about effect of mass irregularity in regular and irregular high rise structure under seismic loads. These Irregularities refer to abrupt change of geometry, mass, strength and stiffness as well. This leads to uneven distribution of forces and their corresponding deformation over the height of structure. Performing dynamic analysis and comparing the responses of Mass irregularity taken at various stories of regular and irregular buildings. Various aspects such as Modal periods, Modal frequencies, Story drifts, and Response of Time history graphs are drawn while these structures are subjected to Mass irregularity and seismic loads.

Keywords—Irregularities, High rise structure, Non-linear Dynamic Analysis, Modal periods & frequencies etc.,

I Introduction

The word earthquake is used to express any seismic occurrence whether natural or caused by human that can produce seismic influence around any area. Earthquakes are caused generally by rapture of geological falls inside the earth, but also by other events such as volcanic movement, landslides, mine blasts, atomic test. Irregularities referring to sudden change of strength, stiffness, geometry and mass. This results in irregular distribution of forces or deformation over the height of the building. The behaviour of these types of buildings is something different. There is need of more work to be done in this regard. So, this research work is an attempted to reach on more accurate conclusion to be reduce their effect on the structure

1.1 Earth Quake: Shaking of the ground due to sudden release of energy and 95% of earthquakes are caused by plate tectonics. 5% of earthquakes are caused due to other disturbances like volcanic eruptions, rock falls, landslides and explosions

1.2 Structure Irregularities: The irregularity in the building structures may be due to irregular distributions in their mass, strength & stiffness along the height of building when such buildings are constructed in high seismic zones, the analysis and design becomes more complicated. The types of irregularities are.

a) Stiffness Irregularity
b) Mass Irregularity
c) Geometry Irregularity

As this project is dealing with Dynamic analysis for mass irregularity and geometry irregular structures of high rise building. (Where as dynamic analysis is one of the part in seismic analysis).
1.3 Mass Irregularity: Mass irregularity shall be considered to exit where the seismic weight of any story is more than 150 percent of that of its adjacent stores. In case of roof irregularity need not to be considered.

Fig 1 indicates stiffness irregularity

1.4 Geometry Irregularity: A structure is considered to be geometry irregular when the horizontal dimension of the lateral force resisting system in any story is more than 150 percent of that in its adjacent story.

Fig 2 represents types of Geometric Irregularity

1.5 Seismic Analysis: Analysis of earthquake vibrations and its crust. Subsets of Seismic Analysis-
   a) Static Analysis
      a) Linear Static
      b) Non Linear Static
   b) Dynamic Analysis
      a) Linear Dynamic
      b) Non Linear Dynamic

1.6 Non-Linear Dynamic Analysis: Time history analysis is also called as nonlinear dynamic analysis. This method is adopted when the time history is recorded of a particular location is available. In time history analysis, the maximum seismic response of a building is determined with respect to the ground motion records.

1.7 Linear Dynamic analysis: Linear dynamic analysis can be performed by response spectrum method. Response spectrum analysis is a method which is used to find the structural response to non-deterministic and transit dynamic events. This method provides maximum seismic response of a building by measuring the natural mode of vibration.

1.8 Response spectrum analysis: The response spectrum is the best method to perform the dynamic analysis of seismic resistant building without having the time history data this method is best suited to determine peak seismic response of the building and also to find the accurate results for structural design. The maximum response is plotted against undamped natural frequency. The response spectrum is determined by time or frequency domain analysis and then for a given time period maximum response is picked in this method. The maximum response or maximum design base shear is calculated using the formula
\[ V = k \times x_{\text{max}} \]
Where,
\[ V = \text{maximum base shear.} \]
\[ k = \text{stiffness}. \]
\[ x_{\text{max}} = \text{maximum displacement} \]

2. OBJECTIVES

- To study the nonlinear dynamic response in Geometric structures and Non Geometric structures.
- To study the variations in modal periods and frequencies when structures subjected to dynamic loads.
- To study the effect of mass irregularity at different stories when exposed to the nonlinear dynamic response of structures.
- Compare the nonlinear dynamic response of a regular structure to irregular structures when both the structures subjected to mass irregularity.

3. METHODOLOGY

Methodology used in this project to analyze the high rise structural behaviour of regular and geometry irregular with mass irregularity is:

- Selection and design plan of building before heading towards software design
- Plan the high rise structure according to NBC
- Manual Calculations are necessary to give value inputs to build structure
- Modeling and result analysis in ETABS
- Comparison of analysis and its behavior patterns in various aspects, as we are going to discuss it further going deep in topic

| Specifications                      |
|-------------------------------------|
| No. of stories                      | G+18                        |
| Storey height                       | 3m                          |

| Material properties                |
|------------------------------------|
| Grade of Concrete                  | M40                         |
| Grade of steel                     | Fe 500                      |
| Beam dimensions                    | 300*600 mm                  |
| Column Dimensions                  | 1000*1000mm, 800*800mm, 600*600 mm |
| Thickness of slab                  | 120mm                       |
| Thickness of wall                  | 230mm                       |
| Zone factor, Z                     | 0.36                        |
| Importance factor, I               | 1.00                        |
| Response reduction factor, R       | 5.00                        |
| Thickness of slab                  | 120mm                       |
| Thickness of wall                  | 230mm                       |
3.1 Models for Analysis

Regular Structure Models:
- Regular Structure with Mass irregularity at 6\textsuperscript{th} Floor (R6MR)
- Regular Structure with Mass irregularity at 12\textsuperscript{th} Floor (R12MR)
- Regular Structure with Mass irregularity at 18\textsuperscript{th} Floor (R18MR)
- Regular Structure with Mass Irregularity at 6\textsuperscript{th} 12\textsuperscript{th} 18\textsuperscript{th} Floor (R)

Geometry Irregular Structure Models:
- Geometry irregularity with mass irregularity at 6\textsuperscript{th} floor (GIR6MR)
- Geometry irregularity with mass irregularity at 12\textsuperscript{th} floor (GIR12MR)
- Geometry irregularity with mass irregularity at 18\textsuperscript{th} floor (GIR18MR)
- Geometry irregularity with mass irregularity at 6\textsuperscript{th} 12\textsuperscript{th} 18\textsuperscript{th} floor (GIR)

Fig 3 shows regular building with mass irregularity

Fig 4 shows geometric irregular building with mass irregularity
Non linear dynamic analysis have performed to predict the responses of the structure, modal analysis has been simulated in order to verify the natural modes and frequencies and observations has been taken into consideration for storey drifts.

4. Results and discussion

4.1 Modal Time Periods & Frequencies
Comparison of time period and frequency of regular model with variations of mass irregularity at various levels of the high rise structure.

Graph 1 indicates modal time periods

As time period increases frequency decreases.

Comparison of time period and frequency of Geometric irregular model with variations of mass irregularity at various levels of the high rise structure.

Graph 2 specifies modal time period for geometric irregular structure

4.2 Storey Drifts
Maximum drift is observed at regular building at 18th floor mass irregularity and minimum drift at regular building at 6th, that may be caused due to excess mass mounted at the top storey.
Comparison of storey drifts in X and Y direction of geometric irregular structure with variations of mass at 6, 12, 18th floors.

Graph 3 depicts storey drifts in X & Y direction for regular models.

Graph 4 describes storey drifts in X direction for geometric irregular structure.

Graph 5 shows storey drifts in Y direction for geometric irregular structure.
Graph 6 describes storey drifts in X direction for all models.

Graph 7 represents storey drifts in Y direction for all models.

Graph 8 indicates the time period for all models.
Graph 9 shows the response of regular structure @ 18th floor.

Graph 10 illustrates the response of geometric irregular structure @ 18th floor.

From graph 9 & 10, the responses have been observed that, a non geometric structure shows less resistance under seismic loads.

5. Observations of the study

5.1 Modal frequencies and time period:

• In comparison with both structure regular and geometry irregular high rise structure modal periods and frequencies followed the same trend, from 6th floor to 18th floor enhancement of the time period is observed.

• Maximum time period is observed when mass irregularity is developed on the 18th floor of the both models.

• First mode values are considered as it indicates primitive response of the structure.

• As mass of the structure of structure increases frequency decreases.

• Taking into consideration development of mass irregular in the geometric irregular structure time period varies in between 8.47 to 9.00 sec.
In regular structure, time period varies in between 8.16 to 8.82sec.

5.2 Storey drifts

When two models Regular, Geometry Irregular are compared, maximum storey drifts are observed in GIR i.e., 9mm drift is observed in the Y direction.

In R models, the maximum drift observed is about 0.46mm in both X & Y directions.

In GIR models, maximum drift is 6mm and 9mm in X & Y directions respectively.

5.3 Responses in Time History Analysis

In R model optimum non linear responses are observed in the graph between pseudo spectral acceleration (mm/sec^2) with period (sec), the response of time history in X direction is max 8.828e10 mm/sec^2 at a period of 1.59 sec and is max 6.13e10 mm/sec^2 at a period of 1.59 sec.

In GIR model peak non linear responses are observed in the graph between pseudo spectral acceleration (mm/sec^2) with period (sec), the response of time history at 18th floor is max 9.00e10 mm/sec^2 at a period of 2.9 sec in X direction and 9.00e10 mm/sec^2 at a period of 2.33 sec in Y direction.

By studying the non linear responses of R models, mass irregularity at 6th floor has less response; hence we can conclude that increased mass makes the model rigid at base level and exhibit greater resistance to fail.

By analyzing the time history responses of GIR models, mass irregularity at 12th floor has less response, since the model is stepped, mass changes from 12th onwards, it acts as a tuned mass damper.

6. Conclusions

From the all the parameters considered in R & GIR models, when the center of gravity and center mass coincides; mass irregularity does not cause major change in frequency reduction. Increments in masses at lower stories make the model much stiffer and exhibit resistance. Here mass it acts as a damper.

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