Analysis of Irregular Structures Using ETABS Software

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***Abstract*—Due to availability of affordable computers and specialized analysis software, the analysis and design of structures for static forces is now a routine event. Dynamic analysis, on the other hand, is a time-consuming process which needs additional input relating to the mass of the structure and an understanding of structural dynamics for evaluating analytical results. RC frame buildings are the most popular type of construction in large metropolitan India and are subject to a variety of factors during their lifetime, including static forces owing to dead and live loads and dynamic forces due to wind and earthquake. During an earthquake, the failure of a structure starts at its weakest points. This weak point in the structure may arises due to its discontinuity in their mass, stiffness and geometry of structure. The systems which having this discontinuity are termed as irregular systems. A substantial portion of the city's infrastructure is comprised of irregular structures. Vertical irregularities are one of the major causes of system failures during earthquakes. The effect of vertically irregularities on the seismic performance of the structure will become extremely important. The irregularity within the building structures is due to irregular distributions in their mass, strength and stiffness along its height of the building. So, the analysis can be done in Staad Pro software, ETABS software SAP 2000 software and Tekla software. As ETABS is widely used software in the country, it is one of the powerful and best software's for structural analysis. Validation of the ETABS software has been done with respect of paper, comparison of Storey overturning moment, storey drift, Storey displacements, storey shear and modal mass participation ratios has been done**

Key Words: Storey Building, Reinforced concrete, Storey Drift, Storey shear, Storey Stiffness, Storey displacements, Overturning moment.

1. INTRODUCTION

Earthquakes are generated by tectonic movement in the crust of a planet. When tectonic plates collide, one plate rides on top of the other, causing earthquakes and volcanoes. The earthquakes are generated by vibrations in the earth's crust that radiate in all directions from the disturbance's source. Some earthquakes are man-made, while others are natural. However, it is undeniable that all earthquakes are triggered by an imbalance in the earth's crust. One of the most recent earthquakes occurred in Nepal, which sits on the boundary between the two enormous tectonic plates that clashed to form the Himalayas. Continual convergence also results in earthquakes. As depicted in the figure 1.1, in Nepal damaged homes in Kathmandu, damaged World Heritage sites, and caused fatal avalanches around Mount Everest. The magnitude of the quake was around 7.8

Fig 1: Nepal Earthquake

1.1 Seismic zones

A seismic zone is the area where earthquakes may have a common root. It may also refer to the area on a map for which a common rate of areal seismicity is assumed while computing probabilistic ground motions. The seismic zoning map of the country was initially published by the Geological Survey of India (G. S. I.) in 1935, with subsequent modifications. The basic basis for this map was the level of devastation sustained by various regions of India. This map displays the four distinct seismic zones of India, each indicated by a different colour. The following are the several seismic zones of the country, as depicted on the map: Zone II is reportedly the least seismically active zone. It is situated inside the moderate seismic zone. This is considered the seismically active zone IV. Zone V is the most seismically active zone. This map helps people in preparing for a natural disaster like earthquake. An Indian seismic zoning map assists one in identifying the lowest, moderate as well as highest hazardous or earthquake prone areas in India. Even such maps are looked into before constructing any high rise building so as to check the level of seismology in any particular area. This in turn results in saving life in the long run. The figure 1.2 shows the seismic mapping zone.

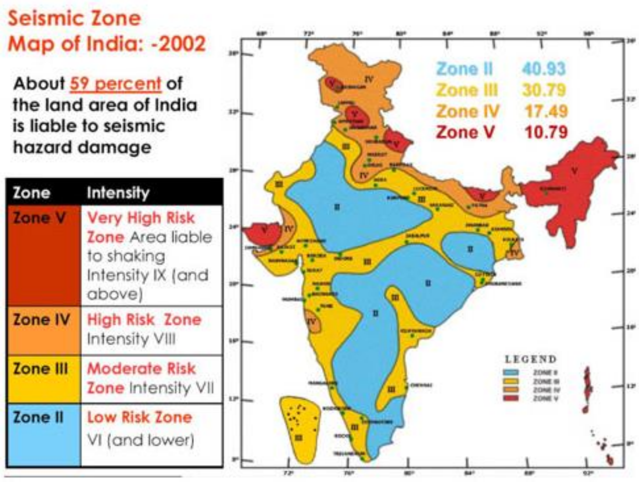

Fig 2: seismic mapping zone of India

1.2 Irregularities

Modern architecture is distinguished by its irregular design and vertical configurations. Irregularity in structures indicates a lack of symmetry, which implies vital eccentricity between the building's mass and stiffness centres, resulting in a negative coupled lateral response. In addition, higher degrees of engineering and designer effort are required to effectively design and analyse an irregular building, whereas a poor designer will design and analyse an unsafe structure by ignoring numerous parameters. To effectively design and analyses an irregular building, significant engineering and designer effort is required. In order to improve the dynamic response of irregular structures in the event of an earthquake, an additional, meticulous structural analysis is required

During earthquakes, vertical irregularities are one of the leading causes of structural failure. For example, the most notable structures that collapsed were those with soft storeys. Consequently, the effect of vertical irregularities on the seismic performance of structures becomes crucial. Changes in stiffness and mass along the building's height distinguish these structures' dynamic properties from those of a typical structure. According to the IS 1893 definition of vertically irregular structures, the irregularity in building structures is caused by irregular distributions of mass, strength, and stiffness along the building's height. When such structures are constructed in seismically active regions, the analysis and design become more complex.

During an earthquake, structural failure may occur at a structure's weak spot. This point of weakness is actually caused by a discontinuity in the structure's, stiffness, and their geometry. These discontinuous came to be known as irregular systems. Large sections of the city's infrastructure are made up of irregular structures. Unpredictable nature is one of the key causes of system failures during earthquakes. In the coming future, irregularities in the seismic performance of systems will have a drastic impact. Peak-wise fluctuations in stiffness and mass distinguish the dynamic properties of such structures from those of a supporting element. The irregularity in the building structures may be a result of mass, strength, and stiffness distributions along the building's height that are not regular. While such structures are constructed in high seismic zones, the analysis and design become more complex.

During earthquakes, vertical irregularities are one of the primary causes of structural collapse. For example, the most notable structures which collapsed are those with the soft storeys. Therefore, the effect of vertical irregularities on the seismic performance of structures becomes important. Changes in stiffness and mass along the building's height separate these structures' dynamic properties from those of a typical structure. According to the IS 1893 definition of vertically irregular buildings, the irregularity in building structures is created by irregular distributions of mass, strength, and stiffness along the building's height. When such buildings are constructed in earthquake - prone areas, the analysis and design become more complicated. There are mainly major two types of irregularities in the structure these are as follows

1. Vertical Irregularities
2. Plan Irregularities

1.2.1 VERTICAL IRREGULARITIES ARE MAINLY OF FIVE TYPES

a) Stiffness Irregularity (soft storey) — The lateral stiffness of a soft storey 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 storeys) — The lateral stiffness of a soft storey is less than 60 percent of the storey above or less than 70 percent of the average lateral stiffness of the three storeys above.

ii) Mass Irregularity- The presence of mass irregularity is confirmed whenever the seismic weight of any storey reaches 200 percent of that of its adjoining storeys. Regarding roofing, irregularity need not be taken into account.

iii) Vertical Geometric Irregularity- A structure is considered vertically geometrically irregular when the horizontal dimension of the lateral force resisting system in any storey exceed 150 percent of that in the storey adjacent to it.

iv) In-Plane Discontinuity in Vertical Elements Resisting Lateral Force- A higher in-plane offset of the parts that resist lateral force than their length.

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

According to IS 1893 Part 1 As lateral forces are computed in accordance with the code-based time period of the structure, linear static analysis of structures is suited for regular structures of limited height. Linear dynamic analysis is better over linear static analysis since it provides a more accurate picture of the higher modes of vibration and the actual distribution of forces in the elastic range. Design-based earthquake (DBE) is used to design buildings, although the actual forces acting on the structure are substantially larger. So, in higher seismic zones Ductility based design approach is preferred as ductility of the structure narrows the gap. The primary objective in designing an earthquake resistant structure is to ensure that the building has enough ductility to withstand the earthquake forces, which it will be subjected to during an earthquake. In essence, all loads, including the self-weight of the structure, are dynamic since at one point in time they did not exist. Dynamic analysis is differentiated from static analysis is based on whether the applied action has enough acceleration compared to the structure's natural frequency. Therefore, structural dynamics is a type of structural analysis which studies the behavior of structures subjected to dynamic (high acceleration) loading. People, wind, waves, traffic, earthquakes, and blasts all examples of active loads. Each structure is vulnerable to dynamic loading.

1.3 Method of analysis

1.3.1 seismic analysis

Seismic analysis is one of the major tools in earthquake engineering which is mainly used to understand the seismic response of structure. In the past the buildings were designed only for the gravity. seismic analysis is a recent development. It is a component of structural analysis and structural design in regions where earthquakes are widespread. There are various methods for evaluating earthquakes. Some of them were used in the project are as follows

- Response Spectrum Analysis
- Time History Analysis

Response spectrum method: Multiple modes of vibration of a structure can be used in this concept. This analysis can be applied in numerous building regulations for all constructions except simple & complex structures. The vibration of a building is defined as the combination of many various modes that correspond to "harmonics" in a vibrating string. Employing computer-aided structural analysis, various mode shapes for the structure are generated. For each mode shape, design spectrum responses are evaluated, using characteristics such as modal participation mass and modal frequency, and then they are combined to produce an evaluation of the structure's total responses.

Time history analysis: This is referred to as Time history analysis. It is a key technique for seismic structural analysis, especially when the assessed structural response is nonlinear. To execute such a study, a structure being analyzed must have a representative earthquake time history. Time history analysis is a step-by-step investigation of the time-varying dynamic response of a structure to a specific loading. Employing time history analysis, the seismic response of a structure under the dynamic loading of a representative earthquake is calculated.

2 METHODOLOGY

The problem has been identified through the review of literature. the identified problem and suitability of proper methodology for the solution was found out through software simulation and analysis. In this research analysis of irregular structure has done through ETABS software. For the proper working of software validation was done for one of the journal articles. Parametric study includes analysis of regular structure, structure on sloping ground and vertical irregular structure under sloping ground has been done through response spec trum analysis. Comparison of result like base shear, overturning moment, storey displacement, storey shear, Centre of stiffness, Centre of load, Centre of gravity has been done for the above-mentioned structure. A sample flowchart is indicated below fig 2.1.

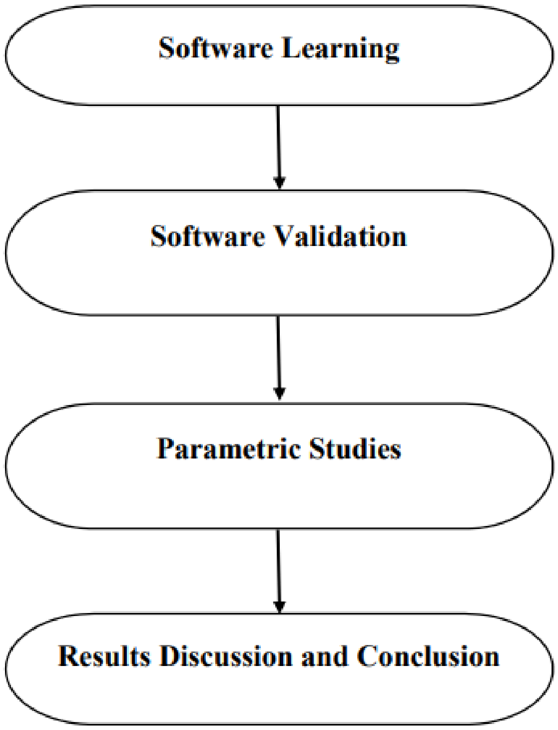

Fig 2.1 flowchart of methodology

2.1 ETABS software: ETABS is an engineering software product that caters to multi-story building analysis and design. Modelling tools and templates, code-based load prescriptions, analysis methods and solution techniques, all coordinate with the grid-like geometry unique to this class of structure. Basic or advanced systems under static or dynamic conditions may be evaluated using ETABS. For a sophisticated assessment of seismic performance, modal and direct integration time-history analyses may couple with P-Delta and Large Displacement effects. Nonlinear links and concentrated PMM or fibre hinges may capture material nonlinearity under monotonic or hysteretic behavior. Intuitive and integrated features make applications of any complexity practical to implement. Interoperability with a series of design and documentation platforms makes ETABS a coordinated and productive tool for designs which range from simple 2D frames to elaborate modern high-rises.

2.1.1 The modeling of structural systems Fundamental to ETABS modelling is the assumption that most multi-story buildings contain identical or similar floor designs that are repeated vertically. The below are modelling characteristics that streamline analytical-model generation and simulate advanced seismic systems:

- Customized section geometry and constitutive behaviour
- Templates for global-system and local-element modelling
- Classification of frame and shell objects
- Assignment of links for modelling isolators, dampers, and other complex seismic systems
- Nonlinear hinge characteristic
- Automatic and manual meshing options
- Editing and assignment features for plan, elevation, and 3D views

2.1.2 The three processes is analysis, loading, and design After the modelling phase is finished, ETABS will automatically develop and assign loading conditions that are according to the relevant codes for gravity, seismic, wind, and thermal forces. Users have the ability to specify an unlimited number of load and their combination per load case. After that, the analysis capabilities provide more advanced nonlinear methodologies for the characterization of static pushover and dynamic response. Analysis of modal factors, response spectra, or time histories are all examples of dynamic factors. The design features, when provided with an encompassing specification, will automatically size elements and systems, design reinforcing schemes, and otherwise optimize the structure depending on desired performance metrics.

2.1.3 Output: In addition, both the output and display formats are friendly to users. Diagrams of moment, shear, and axial forces, shown in two-dimensional and three-dimensional views with matching data sets, can be grouped into reports that can be customized easily. Additionally, included are detailed section cuts that illustrate the many different local response measures. Global perspectives that show displaced configurations that are static, as well as video animations that show how responses have changed over time, are also provided in this software.

2.1.4 Analysis of the response spectrum: The term "response spectrum analysis" refers to a linear-dynamic statistical analysis technique. This technique is used to predict the expected maximum seismic response of a primarily elastic structure by measuring the contribution of each natural mode of vibration to the overall vibration. Response-spectrum analysis gives insight into dynamic behavior by measuring pseudo-spectral acceleration, velocity, or displacement as a function of structural period for a particular time history and damping level. This gives the analyst information about how the system behaves dynamically. Enveloping response spectra in such a way that a smooth curve depicts the peak response for each realization of the structural period is something that is doable and can be done. The process of design decision-making can benefit from response-spectrum analysis because it establishes a connection between the choice of structural type and dynamic performance. Those with shorter periods are subjected to more acceleration, whereas structures with longer periods are subjected to greater displacement. It is important to keep in mind the structural performance objectives all during the preliminary design and response-spectrum analysis processes.

3 MODELLING AND ANALYSIS

The basic objective of structural analysis of building structures is to determine the distribution of internal forces and moments across the entire or a portion of a structure and to determine the key design conditions at all sections. Commonly, the geometry is idealized by assuming the structure to be made of linear and two-dimensional elements. ETABS is used to obtain the modal features.

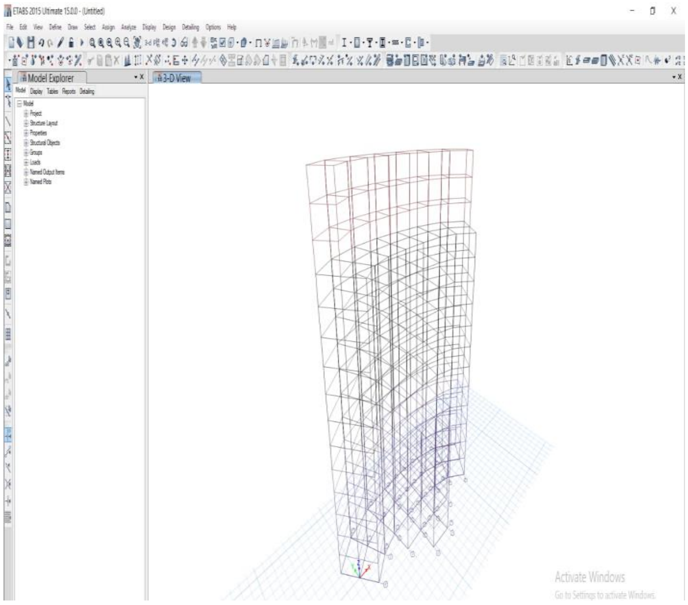

TABLE 1: MATERIAL PROPERTIES

Dimensions	Values
Length	32m
Width	45m
Stories Height	15
Support conditions	Fixed
Storey height	3m
Concrete grade used	20Mpa
Steel grade used	Fe415
Size of columns up to 5 storey	600mm x 600mm
Size of columns from 6-15 storey	450mm x 450mm
Size of beams	450mm x 450mm
Height of parapet wall	1m
Thickness of main wall	200mm
Thickness of parapet wall	100mm

TABLE 2: LOAD DETAILS OF THE MODEL

Loads	Values
Wall load	14 KN/m
Wall load (of Parapet wall at top floor):	2.00 KN/m
Live load	1 KN/m2
Floor load	4 KN/m2
Roof load	2 KN/m2
Seismic Load	
Seismic zone	v
Soil type	ii
Importance factor	1
Response reduction factor	5

3.1Analysis of Irregular structure on plane ground

TABLE 3: MATERIAL PROPERTIES

Dimensions	Values
Length	32m
Width	45m
Stories Height	15
Support conditions	Fixed
Storey height	3m
Concrete grade used	20Mpa
Steel grade used	Fe415
Size of columns up to 5 storey	600mm x 600mm
Size of columns from 6-15 storey	450mm x 450mm
Size of beams	450mm x 450mm
Height of parapet wall	1m
main wall thickness	200mm
parapet wall thickness	100mm

3.1Analysis of Irregular structure on sloping ground (1:25)

TABLE 4: MATERIAL PROPERTIES

Dimensions	Values
Length	32m
Width	45m
Stories Height	15
Support conditions	Fixed
Storey height	3m
Concrete grade used	20Mpa
Steel grade used	Fe415
Size of columns from 1-5 storey	600mm x 600mm
Size of columns from 6-15 storey	450mm x 450mm
Size of beams	450mm x 450mm
Height of parapet wall	1m
Main wall thickness	200mm
parapet wall thickness	100mm
Slopes (1:25)	Deduction in height 200mm

4 RESULTS

TABLE 4.1 MAXIMUM DISPLACEMENT (MM)

Model	Displacement in X direction,	Displacement in Y direction
Flat surface	49.08	53.25
Sloped surface	45.33	48.58

TABLE: 4.2 STOREY SHEAR (KN)

Model	Storey Shear in X direction,	Storey Shear in Y direction
Flat surface	8019.76	6586.57
Sloped surface	9540.33	7837.13

TABLE: 4.3 STOREY STIFFNESS(KN/M)

Model	Storey Stiffness in X direction,	Storey Stiffness in Y direction,
Flat surface	9850078	8518682
Sloped surface	8518682	2592627

5 CONCLUSIONS

The displacements, shear and stiffness of building in flat surface as well as sloped surface (1:25) of different stories is successfully evaluated with the help of this software. The comparative study should be done after further analysis and preparations.

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