ANALYSIS OF MULTI STORE SYMMETRICAL BUILDING IN ZONE-II ON SLOPING GROUND UP TO FAILURE USING ETABS

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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 Nonlinear”. 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.

To study the effect of infill during earthquake, seismic analysis zone –II using both linear dynamics (response spectrum method) as well as nonlinear static procedure (pushover) has been performed.

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 sloping ground on the structural behavior of the building. The seismic analysis of a G+7 storey RCC building on varying slope angles i.e., 7.50 and 150 is studied and compared with the same on the flat ground. The seismic forces are considered as per IS: 1893-2002. The structural analysis software E Tabs 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 sloping ground 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.

Keywords: Sloping ground, Seismic forces, RCC Building, Structural analysis, E Tabs etc.

INTERDUCTION

Multistoried R.C. framed buildings are getting popular in hilly areas because of increase in land cost and under unavoidable circumstances due to shortage of land in urban areas. Thus,
many of them are constructed on hilly slopes. Setback multistoried buildings are frequent over level grounds whereas stepback buildings are quite common on hilly slopes. Combinations of stepback and setback buildings are also common on hilly slopes. At the location of setback stress concentration is expected when the building is subjected to earthquake excitation. These are generally not symmetrical due to setback and/or stepback and result into severe torsion under an earthquake excitation. Current building code suggests detailed dynamic analysis for these types of buildings.

Buildings in hilly areas are irregular and asymmetric and therefore are subjected to severe torsion in addition to lateral forces under the action of earthquake forces. Many buildings on hill slopes are supported by columns of different heights. The shorter columns attract more forces as the stiffness of the short columns is more and undergo damage when subjected to earthquakes. Buildings in hilly areas are subjected to lateral earth pressure at various levels in addition to other normal loads as specified on building on level grounds. Building loads transmitted at the foundation level to a slope create problem of slope instability and may result into collapse of the building. The soil profile is non uniform on the hilly slopes and result into total collapse of the building. The bearing capacity, cohesion, angle of internal friction, etc. may bedifferent at different levels. It may result into unequal settlement of foundations and local failure of the slope.

Simplified approaches for the seismic evaluation of structures, which account for the inelastic behavior, generally use the results of static collapse analysis to define the global inelastic Performance of the structure. Currently, for this purpose, the nonlinear static procedure (NSP) which is described in FEMA-273/356 and ATC-40 (Applied Technology Council, 1996) documents are used. Seismic demands are computed by nonlinear static analysis of the structure subjected to monotonically increasing lateral forces with an invariant height-wise distribution until a predetermined target displacement is reached.
Nonlinear static (pushover) analysis can provide an insight into the structural aspects, which control performance during severe earthquakes. The analysis provides data on the strength and ductility of the structure, which cannot be obtained by elastic analysis. By pushover analysis, the base shear versus top displacement curve of the structure, usually called capacity curve, is obtained. To evaluate whether a structure is adequate to sustain a certain level of seismic loads, its capacity has to be compared with the requirements corresponding to a scenario event.

In pushover analyses, both the force distribution and target displacement are based on very restrictive assumptions, i.e. at time-independent displacement shape. Thus, it is in principle inaccurate for structures where higher mode effects are significant, and it may not detect the structural weaknesses that may be generated when the structures dynamic characteristics change after the formation of the first local plastic mechanism. One practical possibility to partly overcome the limitations imposed by pushover analysis is to assume two or three different displacements shapes (local patterns).

Earthquake is the most disastrous due to its unpredictability and huge power of devastation. Earthquakes themselves do not kill people, rather the colossal loss of human lives and properties occur due to the destruction of structures. Building structures collapse during severe earthquakes, and cause direct loss of human lives. Numerous research works have been directed worldwide in last few decades to investigate the cause of failure of different types of buildings under severe seismic excitations. Massive destruction of high-rise as well as low-rise buildings in recent devastating earthquakes proves that in developing counties like India, such investigation is the need of the hour. Hence, seismic behavior of asymmetric building structures has become a topic of worldwide active research. Many investigations have been conducted on elastic and inelastic seismic behavior of asymmetric systems to find out the cause of seismic vulnerability of such structures. The purpose of the paper is to perform linear static analysis of medium height RC buildings and investigate the changes in structural behavior due to consideration of sloping ground.

An important feature in building configuration is its regularity and symmetry in the plane and elevation. Buildings on hill slope are highly irregular and asymmetric in plan and elevation.
One of the major contributors to structural damage during strong earthquake is the discontinuities and irregularities in the load path or load transfer.

The lateral load such as earthquake is to be classified as live horizontal force acting on the structure depending on the building’s geographic location, height, shape and structural materials. A building with an irregular configuration may be designed to meet all code requirements but it will not perform well as compared to a building with a regular configuration.

LITERATURE REVIEW

Chen and Constantinou (1998) studied that the practical system deliberately introduces flexibility to the sloping ground storey of structures was described. The system utilizes Teflon sliders to carry a portion of the superstructure. Energy dissipation is provided by the ground story ductile columns and by the Teflon sliders. Utilizing this concept the seismic response characteristics of a multistory frame are analyzed and discussed. The results show that it is possible to provide safely to the superstructure while maintaining the stability of the ground storey.

Chandrasekaran and Rao (2002) investigated analysis and the design of multi-storied RCC buildings for seismicity. Reinforced concrete multi-storied 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 plane and slope with different angles 5, 10, and 15. Analyze multistoried 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.

Kadid A. and Boumrkik A. (2005) studied experimental pushover analysis was carried out with a study the performance of framed buildings under future expected earthquakes. Sloping
ground are consider the three framed buildings with 5, 8 and 12 stories respectively were analyzed. The results obtained in these three buildings and compare the axial force, bending moment, nodal displacement, base shear and shaws that properly designed frames will perform well under seismic codes. Some of the conclusions made by the authors are the pushover analysis is a relatively simple way to explore the linear and non linear behavior of Buildings.

METHODS OF ANALYSIS AND RESULT OF STRUCTURE

METHODOLOGY

Code-based procedure for seismic analysis

Main features of seismic method of analysis according to IS1893 (Part 1): 2002 are described as follows

- Equivalent Static Analysis (Linear Static)
- Response Spectrum Analysis (Linear Dynamic)
- Time History Analysis (Nonlinear Dynamic)
- Pushover Analysis (Nonlinear Static)

Suitable methods of analysis are provided in codes of practice; in general, the more complex and tall the building, the more stringent the analysis that is required.

Regular buildings up to around 15 storeys in height can usually be designed using equivalent static analysis; tall buildings or those with significant irregularities in elevation or plan require modal response spectrum analysis.

Equivalent static analysis

All design against earthquake effects must consider the dynamic nature of the load. However, for simple regular structures, analysis by equivalent linear static methods is often sufficient. This is permitted in most codes of practice for regular, low- to medium-rise buildings and begins with an estimate of peak earthquake load calculated as a function of the parameters given in the code.

Response spectrum analysis

It is a dynamic method of analysis. In the calculation of structural response the structure should be so represented by means of an analytical or computational model that reasonable and rational results can be obtained by its behavior, when response spectrum method is used with modal analysis procedure. At least 3 modes of response of the structure should be considered except in those cases where it can be shown qualitatively that either third mode or the second mode produces negligible response. The model maxima should be combined using the square root of the sum of the squares of the individual
model values. With the advent of powerful desktop computers, this type of analysis has become the norm. It involves calculating the principal elastic modes of vibration of a structure. The maximum responses in each mode are then calculated from a response spectrum and these are summed by appropriate methods to produce the overall maximum response. There are computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and member forces in structural systems. The method involves the calculation of only the maximum values of the displacements and member forces in each mode of vibration using smooth design spectra that are the average of several earthquake motions.

Table 3.1: Zone wise basic wind speeds in m/s

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<tr>
<th>Zone</th>
<th>Basic wind speed (m/sec)</th>
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<td>I</td>
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The major advantages of modal response spectrum analysis (RSA), compared with the more complex time-history analysis are as follows.

1. The size of the problem is reduced to finding only the maximum response of a limited number of modes of the structure, rather than calculating the entire time history of responses during the earthquake. This makes the problem much more tractable in terms both of processing time and (equally significant) size of computer output.

2. Examination of the mode shapes and periods of a structure gives the designer a good feel for its dynamic response.

3. The use of smoothed envelope spectra makes the analysis independent of the characteristics of a particular earthquake record.

4. RSA can very often be useful as a preliminary analysis, to check the reasonableness of results produced by linear and non-linear time-history analysis.

**Time-history analysis**

In this analysis dynamic response of the building will be calculated at each time intervals. This analysis can be carried out by taking recorded ground motion data from past earthquake database. A linear time-history analysis of this type overcomes all the disadvantages of Response spectrum analysis, provided non-linear behavior is not involved. The method involves significantly greater
computational effort than the corresponding Response spectrum analysis and at least three representative earthquake motions must be considered to allow for the uncertainty in precise frequency content of the design motions at a site. With current computing power and software, the task of performing the number crunching and then handling the large amount of data produced has become a non specialist task.

![Seismic zone map of India](image)

**Figure - 3.2: Seismic zone map of India**

### 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. Pushover analysis is a simplified, static, nonlinear analysis under a predefined pattern of permanent vertical loads and gradually increasing lateral loads. Typically the first pushover load case is used to apply gravity load and then subsequent lateral pushover load cases are specified to start from the final conditions of the gravity pushover. Typically a gravity load pushover is force controlled and lateral pushovers are displacement controlled. Load is applied incrementally to frameworks until a collapse mechanism is reached. Thus it enables determination of collapse load and ductility capacity on a building frame. Plastic rotation is monitored, and a lateral inelastic force versus displacement response for the complete structure is analytically computed.

For the present dynamic analysis, response spectrum analysis method is used in the FE based software ETABS. This analysis is carried out according to the code IS 1893-2002 (part1). Here type of soil, seismic zone factor should be entered from IS 1893-2002(part1). The standard response spectra for type of soil considered is applied to building for the analysis in ETAB5v9.7.4 software.

### LOADS CONSIDERED:

Loads on a structure are generally two types.

1. Gravity loads and
2. Lateral loads

**Gravity loads:**

Gravity loads are the vertical forces that act on a structure. The weight of the structure, human occupancy and snow are all types of loads that need to have a complete load path to the ground.

**DEAD LOADS:**

All permanent constructions of the structure form the dead loads. The dead load comprises of the weights of walls, partitions floor finishes, false ceilings, false floors and the other permanent constructions in the buildings. The dead load loads may be calculated from the dimensions of various members and their unit weights. the unit weights of plain concrete and reinforced concrete made with sand and gravel or crushed natural stone aggregate may be taken as 24 kN/m³ and 25 kN/m³ respectively.

**Imposed loads:**

All permanent constructions of the structure form the dead loads. The dead load comprises of the weights of walls, partitions floor finishes, false ceilings, false floors and the other permanent constructions in the buildings. The dead load loads may be calculated from the dimensions of various members and their unit weights. the unit weights of plain concrete and reinforced concrete made with sand and gravel or crushed natural stone aggregate may be taken as 24 kN/m³ and 25 kN/m³ respectively.

**Lateral loads:**

Lateral loads are the horizontal forces that act on a structure. Wind loads and earthquake loads are the main lateral loads act on structures.

**WIND LOADS**

Basic wind speed zones in India are classified as six zones as per IS 875 part - 3-1987.

**ANALYSIS AND RESULT IS E-TABS**

**ETABS**

*Structural Design Software for Structural Analysis Professionals:*

ETABS is the present day leading design software in the market. Many design company’s use this software for their project design purpose. The innovative and revolutionary new ETABS is the ultimate integrated software package for the structural analysis and design of buildings. Incorporating 40 years of continuous research and development, this latest ETABS offers unmatched 3D object based modeling and visualization tools, blazingly fast linear and nonlinear analytical power, sophisticated and
comprehensive design capabilities for a wide-range of materials, and insightful graphic displays, reports, and schematic drawings that allow users to quickly and easily decipher and understand analysis and design results.

From the start of design conception through the production of schematic drawings, ETABS integrates every aspect of the engineering design process. Creation of models has never been easier - intuitive drawing commands allow for the rapid generation of floor and elevation framing. CAD drawings can be converted directly into ETABS models or used as templates onto which ETABS objects may be overlaid. The state-of-the-art SAP Fire 64-bit solver allows extremely large and complex models to be rapidly analyzed, and supports nonlinear modeling techniques such as construction sequencing and time effects (e.g., creep and shrinkage). Design of steel and concrete frames (with automated optimization), composite beams, composite columns, steel joists, and concrete and masonry shear walls is included, as is the capacity check for steel connections and base plates. Models may be realistically rendered, and all results can be shown directly on the structure. Comprehensive and customizable reports are available for all analysis and design output, and schematic construction drawings of framing plans, schedules, details, and cross-sections may be generated for concrete and steel structures.

ETABS is the structural engineer's software choice for steel, concrete, timber, aluminum and cold-formed steel structure design of low and high-rise buildings, culverts, petrochemical plants, tunnels, bridges, piles, aquatic structures and much more.

**Structural Software can Offer the following.**

- State-of-the art 2D/3D graphical environment with standard MS Windows functionality.
- Full range of structural analysis including static, P-delta, pushover, response spectrum, time history, cable (linear and non-linear), buckling and steel, concrete and timber design.
- Concurrent engineering-based user environment for model development, analysis, design, visualization, and verification.
- Object-oriented intuitive 2D/3D CAD model generation.
- Supports truss and beam members, plates, solids, linear and non-linear cables, and curvilinear beams.
- Advanced automatic load generation facilities for wind, area, floor, and moving loads.
- Customizable
- Structural templates for creating a model.
- Toggle display of loads, supports, properties, joints, members, etc.
• Isometric and perspective views with 3D shapes.
• Joint, member/element, mesh generation with flexible user-controlled numbering scheme.
• Rectangular and cylindrical coordinate systems with mix and match capabilities.

Advantages of ETABS structural analysis software:

We revolutionized the concurrent use of spreadsheets, a 3D CAD graphical modeler, and a text-based input language editor. With over 40 step-by-step movie tutorials and hundreds of examples and verification problems, even a novice user can become productive in a matter of days.

ETABS is a solution for all types of structures and includes tools designed to aid specific structural engineering tasks. For example, for the bridge engineer, ETABS.beava incorporates a powerful influence surface generator to assist in locating vehicles for maximum effects.

ETABS software is mainly made for modeling, analysis and design of buildings.

Various advantages in the ETABS are listed below.

1. Fundamental to ETABS modeling is the generalization that multi-story buildings typically consist of identical or similar floor plans that repeat in the vertical direction.

2. ETABS has feature known as similar story. By which similar storeys can be edited and modeled simultaneously. Due to which building is modeled very speedily.

3. Basic or advanced systems under static or dynamic conditions may be evaluated using ETABS.

4. ETABS can perform various seismic coefficients, Response Spectrum, Static Non-linear, Time History, Construction sequence and many more analysis with good graphics.

5. Once modeling is complete, ETABS automatically generates and assigns code-based loading conditions for gravity, seismic, wind, and thermal forces. Users may specify an unlimited number of load cases and combinations.

6. ETABS can do optimization of steel section.

7. ETABS has a facility to design composite beam and composite deck.

Procedure for modeling of building using ETABS:

1. Open ETABSV9.7.4 and select grid only.

2. Define storey data like storey height, storey number and spacing in x and y directions.

3. Define code preference from option menu.

4. Define material properties of concrete and steel from the define menu.

5. Define section properties from frame section in define menu for columns, beams etc.

6. Define slab section from define menu.

7. Give supports conditions

8. Create areas for slabs.
BASIC DATA FOR BUILDINGS MODEL:

- Height of each storey: (3) m
- Number of storeys: 7 storey's
- Dimension of Column: (600 X 600) mm
- Dimension of Beam: (230 X 495) mm
- Slab Thickness: (150) mm
- Walls Thickness: (230) mm thick brick masonry wall
- Grade of the concrete: M 25, M30
- 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
Fig: displacement due to dead load

Fig: Moment of column

Fig: share force column

Fig: share fore dead load
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


