PUSH OVER ANALYSIS OF UNSYMETRICAL BUILDING ON SLOPING GROUND

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ABSTRACT

The current design standards and building codes provide limited prescriptive or performance based guidance on analysis and design of structures. The existing building can become seismically deficient since seismic design code requirements are constantly upgraded and advancement in engineering knowledge. An essential and critical component of evolving performance-based design methodologies is the accurate estimation of seismic demand parameters.

Nonlinear static procedures (NSPs) are now widely used in engineering practice to predict seismic demands in building structures. The analysis is carried out up to failure, thus it enables determination of collapse load and ductility capacity. ATC-40 and FEMA- 356 have well-documented limitations in terms of their inability to account for higher mode effects and the modal variations resulting from elastic behaviour.

This paper deals with the push over analysis of unsymmetric building on a sloping ground subjected to live, dead and also earthquake loads in an incremental way. Different buildings of single storey constructed on a plane ground and also on a sloped ground with slope of 30 degrees inclination and also three storied are considered for analysis. All the buildings are considered with symmetry and also asymmetry in plan with difference in bay size.

The analysis is carried out using SAP-2000 and STAAD PRO software.

KEYWORDS: Pushover Analysis, Symmetrical and Unsymmetrical Structures

INTRODUCTION

BACKGROUND

The nonlinear static procedure or pushover analysis is increasingly used to establish the estimations of seismic demands for building structures Since structures exhibits nonlinear behavior during earthquakes, using the nonlinear analysis is inevitable to observe whether the structure is meeting the desirable performance or not. During the last decade, performance based design (PBD) procedure has become one of the most important research area in the earthquake engineering

The pushover procedure consists of two parts. First, a target displacement for the building is established. The target displacement is an estimation of the top displacement of the building when exposed to the design earthquake excitation. Then a pushover analysis is carried out on the building until the top displacement of the building equals to the target displacement and the second one force controlled type in which the total amount of force acting is estimated and applied to the structure and the analysis is carried out.

In order to consider the torsion effects in the nonlinear static analysis of the asymmetric buildings is carried out by defining the target displacement for each resisting element until failure. The base shear is applied in incremental order until the target displacement is reached. This helps us to know the max base shear the structure can with stand for the member within the displacement limits.

OBJECTIVES OF THE STUDY

The main objective of the thesis is to consider the effect of the changes in the structures modal properties of asymmetric-plan buildings during the pushover analysis and the application of the displacement based adaptive pushover procedure. Different single and multi-storied structures on plane and sloping grounds are considered in the study. The nonlinear analysis is carried out for all the structures and is compared. Various modes subjected to different failures are located according to different zones, (Immediate occupancy (IO), Life Safety (LS) and Collapse Prevention (CP)).

SCOPE OF STUDY

Linear static analysis for symmetric structures as per the design methods of IS code provisions.

Linear static analysis for asymmetric structures as per the design methods of IS code provisions.

Nonlinear static analysis of symmetric structures.

Nonlinear static analysis of asymmetric structures on sloping ground.

Pushover curves are obtained for the different cases and the maximum base shear is obtained.

Conclude the comparison between the symmetric and asymmetric structures subjected to linear static and nonlinear static analysis.

METHODOLOGY

The analysis part of structures is carried out in ETABS, SAP and STAAD. Results obtained in all the cases are compared with remaining two cases and found satisfactory results, so as to carry out the analysis in ETABS and SAP.

Critical beams and columns are identified for all the structures by carrying out the linear analysis of the structure using ETABS software.

Nodes corresponding to different zones (<IO, (LS-CP),>CP) are identified by carrying out the non linear static analysis of the structures using SAP2000 software.

Pushover curves for all the case are obtained (Base shear Vs Displacement) and the maximum base shear is identified beyond the elastic limit.

Maximum base shear of different structures with and without irregularities are identified and compared.

Nonlinear analysis is carried out for structures with irregularities in both plan and elevation which undergo torsion effect due to vertical irregularity. The various results obtained from the analysis part is presented in paper.

LITERATURE REVIEW

INTRODUCTION

To carry out the thesis I have done on nonlinear static analysis of irregular buildings information is received by going through various journals and published papers by various authors which is very helpful for me in carrying out my project successfully. The literature is obtained from various journals and papers on nonlinear analysis of structures and various analysis and many other papers related to my thesis subject are reviewed for carrying out this thesis.

ATC-40: Seismic Evaluation and Retrofit of Concrete Buildings

The Applied Technology Council (ATC) is a non-profit, tax exempt corporation established in 1971 through the efforts of the Structural Engineers Association of California. ATC is guided by a Board of Directors consisting of representatives appointed by the American Society of Civil Engineers, the Structural Engineers Association of California, the Western States Council of Structural Engineers Associations, and four at large representatives concerned with the practice of structural engineering.

The purpose of ATC is to assist the design practitioner in structural engineering in the task of keeping abreast of and effectively using technological developments. ATC also identifies and encourages needed research and developes consensus opinions on structural engineering issues in a nonproprietary format.

This document is organized into two volumes. Volume one contains the main body of the evaluation and retrofit methodology, presented in 13 chapters, with a glossary and a list of references. This volume contains all of the parts of the document required for the evaluation and retrofit of buildings. Volume two consists of appendices containing supporting material related to the methodlogy.

FEMA 356: Prestandard and Commentary For The Seismic Rehabilitation of The Buildings

The preparation of this prestandard was originally undertaken with two principle and complimentary objectives. The first was to encourage the wider application of the NEHRP Guidelines for the Seismic Rehabilitation of Buildings, FEMA 273, by converting it into mandatory language. Design professionals and building officials thus would have at their disposal a more resistant to earthquake. This volume fully meets this first objective.

The second objective was to provide a basis for a nationally recognised, ANSI-approved standard that would further help in disseminating and incorporating the approaches and technology of the prestandard into the mainstream of the design and construction practices in the United States.

Seismic Analysis of Buildings

Dhiman Basu1 and Sudhir K. Jain2

The issue of static seismic analysis of such buildings for torsional provisions of codes has not been addressed in the literature. The concept of center of rigidity needs to be formulated for buildings with flexible floor diaphragms. In this paper, the definition of center of rigidity for rigid floor diaphragm buildings has been extended to unsymmetrical buildings with flexible floors. A superposition-based analysis procedure is proposed to implement code-specified torsional provisions for buildings with flexible floor diaphragms.

In this paper we developed a framework for analysis of such buildings following usual codal requirements for torsion. The building is assumed to have a single wing only, i.e., buildings with multiple wings ~e.g., L, V, Y, etc. shaped are not considered

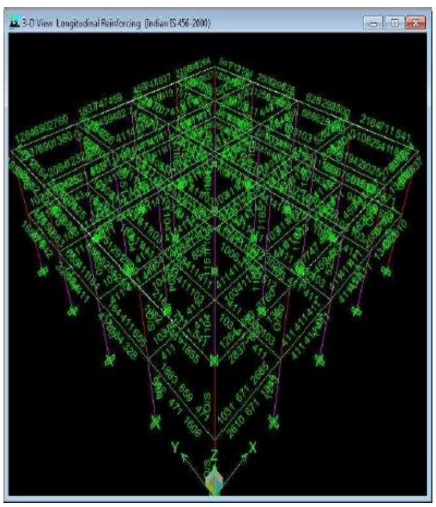


fig: Single floored regular symmetric plan building.

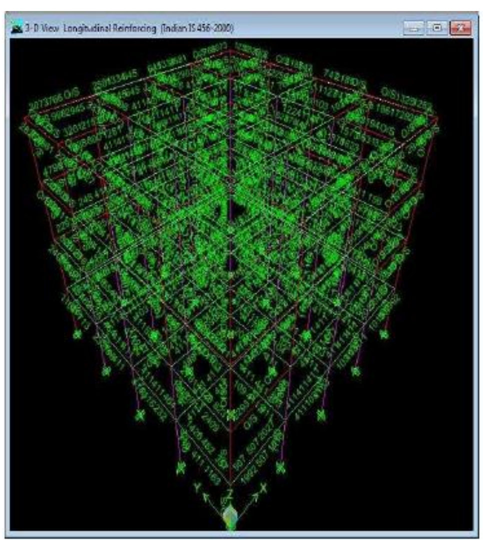


Fig:Three floored regular symmetric plan building

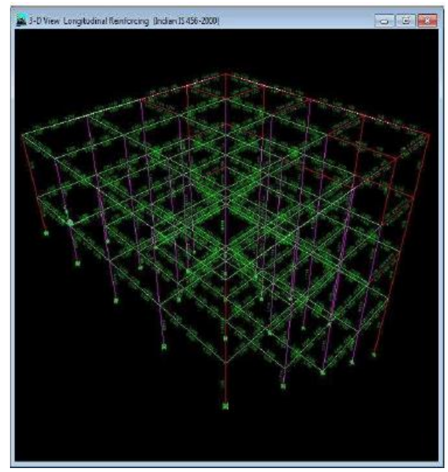
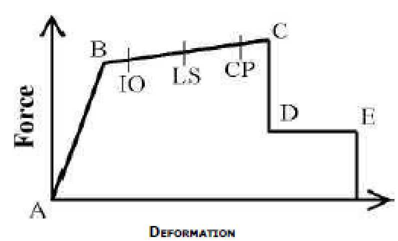


Fig:Single floored symmetric plan building on sloped ground.

Non-Linear Static Analysis of Structure

INTRODUCTION :

In the previous figures we have seen the failure beams and columns of different cases subjected to linear static analysis.



Now we run the non-linear static analysis of the structures which are considered in the previous cases and the different nodes subjected to failure and belonging to various regions are specified in different colours.

- In the figures below different nodes subjecting to different levels of elastic zone are represented with respective colors mentioned at the bottom of the figures.

The elastic zone is categorized into three parts likely

•Immediate Occupancy (IO)

•Life safety (LS)

•Collapse prevention (CP)

- The Immediate Occupancy to Life Safety zone (IO- LS) is mentioned in dark blue in colour, Life Safety to Collapse Prevention zone (LS- CP) is mentioned in light blue in colour and Collapse Prevention zone is mentioned in green colour
- All the nodes beyond Collapse Prevention zone are mentioned in yellow, orange and red colours depending on their severity and the nodes below Immediate Occupancy zone are mentioned in pink colour.

COMPARISION OF PUSHOVER CURVES:

Pushover or nonlinear static analysis is carried out for all the cases considered in the thesis and finally pushover curves are obtained.

Pushover curves are obtained with Displacement on X-axis and Base reaction on Y -axis.

Depending on the pushover curves comparisions are carried out between:

•Symmetric 1 floor building and symmetric sloped building.

•Symmetric 3 floor building and Asymmetric 3 floor building.

•Asymmetrical 1 floor building and asymmetric sloped building.

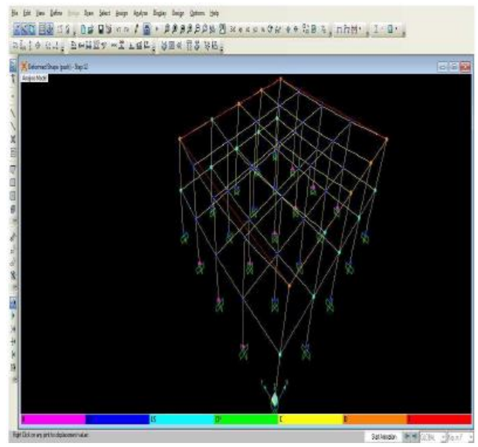


Fig:Single floored regular symmetric plan building

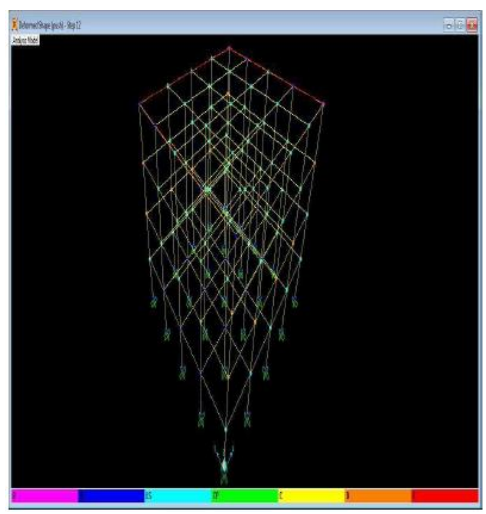


Fig:Three floored regular symmetric plan building

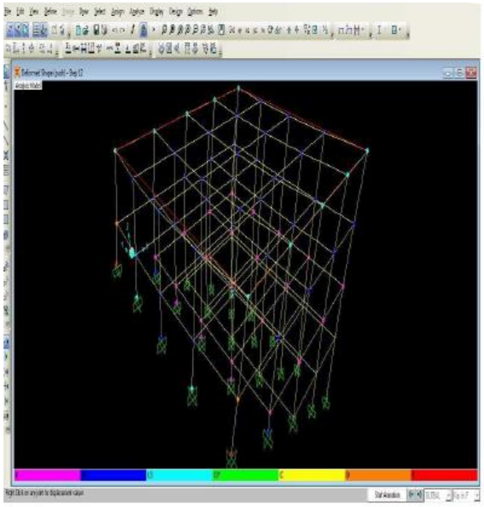


Fig:Single floored symmetric plan building on sloping ground

Comparision 1:

In the first comparision we compare the pushover values obtained from the graph between Symmetric 1 floor building on regular and slope grounds.

•The maximum displacement that the symmetric 1 floor building can withstand up to the elastic limit is 105x10-3m and the base reaction for this displacement is 3.14x103KN.

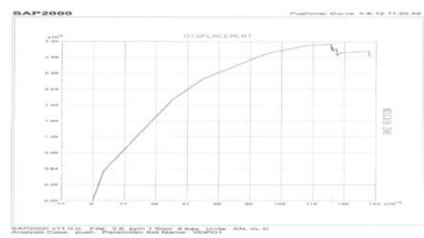
•The maximum displacement that the symmetric sloped 1 floor building can withstand up to the elastic limit is 125x10-3m and the base reaction for this displacement is 2.86x103KN.

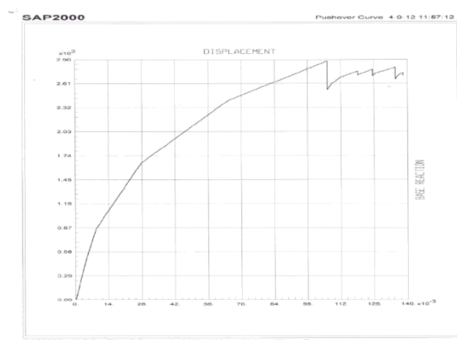
Structure	Displacement	Base Reaction
Symmetric 1 floor building	$125x10^{-3}$m	$3.14x10^{3}$KN
Symmetric building on sloped ground	$105x10^{-3}$m	$2.86x10^{3}$KN

In the above comparison we can find that a single storied building on a sloping ground can resist a maximum base shear of 2.86x103KN with a maximum displacement of 105x10-3m.

Whereas in the second structure we considered i.e. a symmetric 1 floor building the structure can resist a maximum base shear of 3.14x103KN for a maximum displacement of 125x10-3m.

The symmetric structure can resist larger base shear of 0.28x103KN than the structure on the sloping ground and also can withstand more displacement of 20x10-3m more than the structure on the sloping ground.





CONCLUSIONS:

From the thesis which I have carried out the following are the conclusions that I have obtained.

- All the outermost columns of all the structures are subjected to failure during the linear analysis of all the considered structures.

- In three floored structures all the beams connecting the outermost corners are subjected to failure.
- In case of buildings on sloped ground large numbers of beams and columns have failed due to in equality of the structure as the structure is less stiff on the longer edge.
- In Nonlinear static analysis for single storied symmetric and asymmetric structures the corner nodes of the top floor lie in the region beyond the Collapse Prevention zone.
- In Nonlinear static analysis of structures on sloping ground the nodes at the shortest edge are subjected to the maximum severity due to short column effect.
- For a 3 floored structure as the asymmetry increased the resistance to base shear reduced for same displacement and asymmetric structure reached maximum displacement for less base shear resistance.
- The symmetric regular structure can resist larger base shear of 0.28x103KN than the structure on the sloping ground and also can withstand displacement of 20x10-3m more than the structure on the sloping ground.
- A symmetric 3 floored structure can resist 1.31x103KN more base shear than that of a asymmetric 3 floored structure upto elastic limit and also displacement is 100x10-3m larger for asymmetric building to that of symmetric building.
- An asymmetric regular structure can resist larger base shear of 0.39x103KN than the structure on the sloping ground and also can withstand displacement of 25x10-3m more than the structure on the sloping ground.
- The final conclusion from the thesis is Nonlinear static analysis of various structures with irregulaties in both plan and elevation are carried out and found out from the obtained pushover curves that the structures with vertical irregularities are more critical than compared to plan asymmetry when compared to normal regular symmetric structures.

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