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STATIC LINEAR AND NONLINEAR ANALYSIS OF RC BUILDINGS ON VARYING HILL SLOPES

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Abstract: *The group of people involved in constructing the building facilities, including owner, architect, structural engineer, contractor and local authorities, contribute to the overall planning, selection of structural system, and to its configuration. This may lead to building structures with irregular distributions in their mass, stiffness and strength along the height of building. When such buildings are located in a high seismic zone, the structural engineer's role becomes more challenging. Therefore, the structural engineer needs to have a thorough understanding of the seismic response of irregular structures. In recent past, several studies have been carried out to evaluate the response of irregular buildings.*

Earthquake field investigations repeatedly confirm that irregular structures suffer more damage than their regular counterparts. This is recognized in seismic design codes, and restrictions on abrupt changes in mass and stiffness are imposed. Irregularities in dimensions affect the distribution of stiffness, and in turn affect capacity, while mass irregularities tend to influence the imposed demand. Elevation irregularities have been observed to cause story failures due to non- uniform distribution of demand-to-supply ratios along the height. Plan irregularities, on the other hand, cause non-uniform demand-to-capacity ratios amongst the columns within a single floor. The structure chosen for study is a 4, 5 storied commercial complex building. The building is located in seismic zone IV on a rock soil site. Three dimensional mathematical models for the same are generated in ETABS software. For all structural elements, M40 grade of concrete is used. The floor diaphragms are assumed to be rigid. Seismic loads were considered acting along either of the two principal directions. Using ETABS a4, 5 storey RC structure with typical ground slope is chosen in between 0° and 25°and building that which produce less torsion effect for set-back and step-back with irregular configuration in horizontal and vertical direction is modeled and analyzed.

KEYWORDS: Setback and stepback buildings, Pushover analysis ,target Displacement.

1. INTRODUCTION

In multi-storeyed framed buildings, damage from earthquake ground motion generally initiates at locations of structural weaknesses present in the lateral load resisting frames. This behaviour of multi-storey framed buildings during strong earthquake motions depends on the distribution of mass, stiffness, and strength in both the horizontal and vertical planes of buildings. In some cases, these weaknesses may be created by discontinuities in stiffness, strength or mass between adjacent storeys. Such discontinuities between storeys are often associated with sudden variations in the frame geometry along the height. There are many examples of failure of buildings in past earthquakes due to such vertical discontinuities. Structural engineers have developed confidence in the design of buildings in which the distributions of mass, stiffness and strength are more or less uniform. But there is a less confidence about the design of structures having irregular geometrical configurations.

A common type of vertical geometrical irregularity in building structures arises is the presence of setbacks and step back i.e. the presence of abrupt reduction of the lateral dimension of the building at specific levels of the elevation at top and bottom . This building category is known as 'setback and step back building'. This building form is becoming increasingly popular in modern multi-storey building construction mainly because of its functional and aesthetic architecture. In particular, such a setback formprovides for adequate daylight and ventilation for thelower storeys in an urban locality with closely spaced tall buildings.

2. OBJECTIVES

The objective of this work is to study the linear, non-linear behavior and performance of building frame on sloping ground depends on various hill slopes and number of stories. The objective of study is as follows:

[1]. To study the variation of base shear, displacement, drifts with respect to variation in various hill slopes.

[2]. To study the target displacement in various hilly slopes and finding the angle that subjected to less torsion and which is safe in increasing the height of building.

3. ANALYSIS METHODS

Static Analysis of Buildings Using Is 1893 (Part 1)-2002

Design Seismic Base Shear- The total design lateral force or design seismic base shear (Vb) along any principal direction of the building shall be determined by the following expression

$$VB = Ah\ W$$

Where

Ah = Design horizontal seismic coefficient.

W = Seismic weight of the building

Seismic Weight of Building:

The seismic weight of each floor is its full dead load plus appropriate amount of imposed load. While computing the seismic weight of each floor, the weight of columns and walls in any storey shall be equally distributed to the floors above and below the storey. The seismic weight of the whole building is the sum of the seismic weights of all the floors. Any weight supported in between the storey shall be distributed to the floors above and below in inverse proportion to its distance from the floors.

Fundamental Natural Time Period:

The fundamental natural time period (Ta) calculates from the expression from clause.7.6.1 of is 1893:2002 is as follows

$$T_a = 0.09h/\sqrt{d}$$

Where h is the height of thr building ,in meters,d base dimension of the building along the plinth level,in m, along the considered of the lateral force

Distribution of Design Force:

The design base shear, VB computed above shall be distributed along the height of the building as per the following expression

Pushover Analysis

After assigning all properties of the models, the displacement –controlled pushover analysis of the models are carried out. The models are pushed in monotonically increasing order until target displacement is reached or structure loses equilibrium. The program includes several built-in default hinge properties that are based on average values from ATC-40 for concrete members and average values from FEMA-273 for steel members.

Locate the pushover hinges on model. ETABS provides hinge properties and recommends PMM hinges for columns and M3 hinges for beam as described in FEMA-356.

Define pushover load cases. IN ETABS more than one pushover load case can be run in the same analysis

4. GENERAL DETAILS OF BUILDING

Table -1: Details of Building

No of Storey	4 Storey,5Storey
Storey Height	Floor to Floor Height=3.5mts
	Plinth Height=1.75mts
Building frame system	OMRF
The concrete floors are modeled as	Rigid
Building use	Commercial Building
Foundation type	Stepped
Seismic Zone	IV
Soil Type	ROCK
Grade of concrete	M40
Grade of steel	415N/mm^2
Youngs Modulus of M40 concrete,Ec	5000√fck
Density of concrete	25KN/m^3
Poison's ratio (of concrete)	0.2
Density of Brick masonary	19N/mm^2
Thick ness of Slab	0.12mts
All beam Size	For 4 storied=0.23*0.45mts
	For 5 storied=0.30*0.45mts
All Column Size	For 4 storied=0.23*0.50mts
	For 5 storied=0.30*0.50mts
Thickness of wall	Full brick wall=0.230mts
	Half brick wall=0.115mts
Floorfinishes	1.5KN/m^2
Live load	3KN/m^2

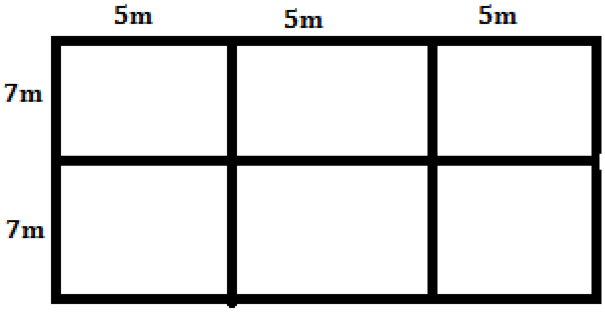
Table -2: load cases for pushover analysis

Pushover cases	Names	Loads	Controlled by
1	Gravity	DL+0.25 LL	Forces Displacements
2	PUSH X	EQX	
3	PUSHY	EQ	Displacements

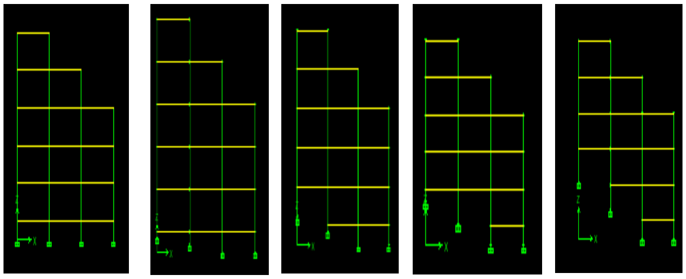
Table-3: Earthquake Parameters

Time period T	$0.09h/\sqrt{d}$
Importance factor-I	1
Sa/g	1/T
Response Reduction Factor(R)	3

5 . SKETCHES & RESULTS

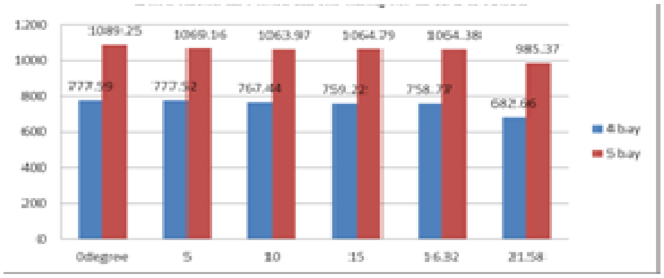


plan of building

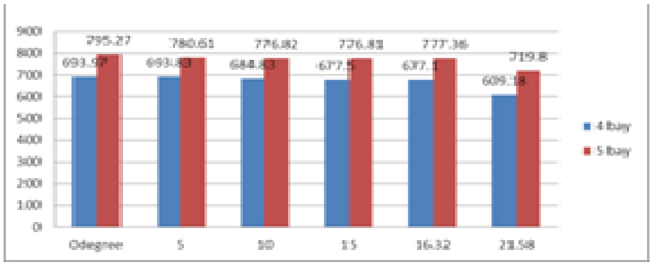


5-bay 0^0 , 5^0 , 10^0 , 16.32^0 , 21.58^0

BASE SHEAR



Base shaer in static linear analysis in x-direction



Base shear in static linear analysis in y-direction

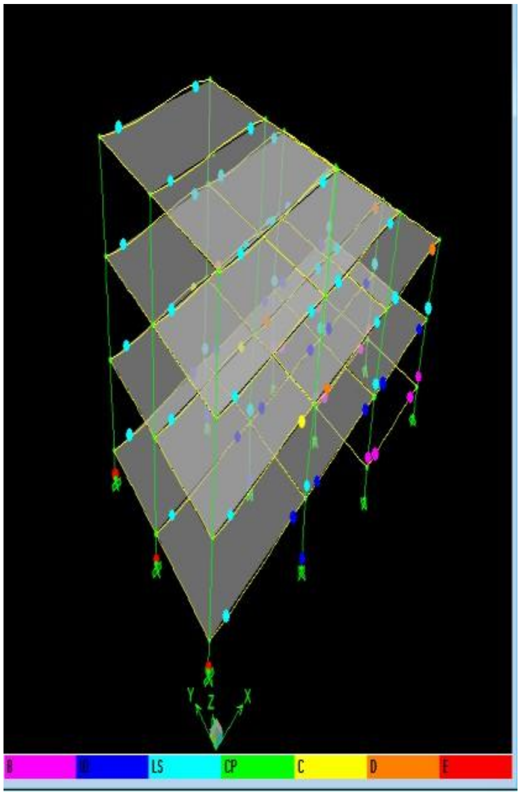
TABLES FROM NONLINEAR STATIC ANALYSIS

x-direction

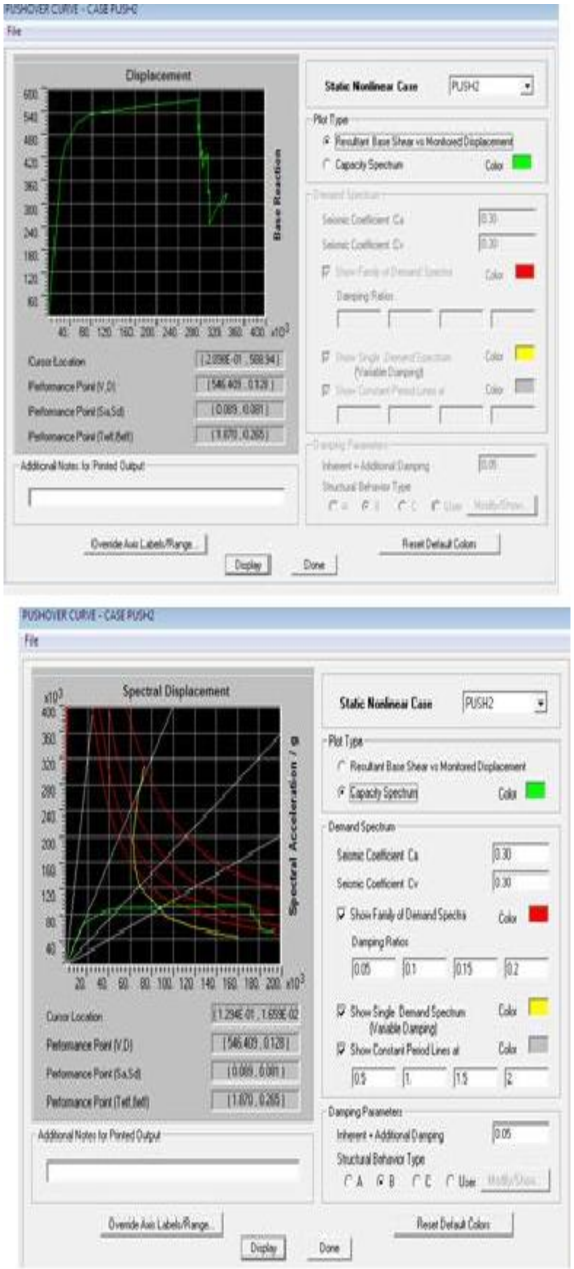
models	target displacement	base shear	performance level	no of hinges
0^0	128	546.406	LS-CP	382
5^0	126	546.5862	LS-CP	382
10^0	119	569.034	C-D	356
15^0	105	603.184	LS-CP	330
16.32^0	96	612.650	LS-CP	330
21.58^0	101	596.305	C-D	304

y-direction

models	target displacement	base shear	performance level	no of hinges
0^0	141	646.88	LS-CP	474
5^0	137	646.8	LS-CP	474
10^0	133	657.660	A-B	448
15^0	123	698.460	LS-CP	422
16.32^0	114	703.851	LS-CP	422
21.58^0	121	702.473	D-E	396



HINGES IN X-DIRECTION


PUSHOVER CURVE - CASE PUSH2

Static Nonlinear Case: PUSH2

Plot Type: ● Resultant Base Shear vs Monitored Displacement ○ Capacity Spectrum

Seismic Coefficient Ca: 0.30
Seismic Coefficient Cv: 0.30

Cursor Location: (2.098E-01 , 588.94)
Performance Point (V,D): (546.409 , 0.128)
Performance Point (Sa,Sd): (0.089 , 0.081)
Performance Point (Teff,Beff): (1.870 , 0.265)

Inherent + Additional Damping: 0.05

PUSHOVER CURVE - CASE PUSH2

Static Nonlinear Case: PUSH2

Plot Type: ○ Resultant Base Shear vs Monitored Displacement ● Capacity Spectrum

Demand Spectrum
Seismic Coefficient Ca: 0.30
Seismic Coefficient Cv: 0.30
☑ Show Family of Demand Spectra
Damping Ratios: 0.05, 0.1, 0.15, 0.2
☑ Show Single Demand Spectrum (Variable Damping)
☑ Show Constant Period Lines at: 0.5, 1., 1.5, 2.

Damping Parameters
Inherent + Additional Damping: 0.05
Structural Behavior Type: ○ A ● B ○ C ○ User

Cursor Location: (1.294E-01 , 1.659E-02)
Performance Point (V,D): (546.409 , 0.128)
Performance Point (Sa,Sd): (0.089 , 0.081)
Performance Point (Teff,Beff): (1.870 , 0.265)

PUSH OVER CURVE AND DEAND CURVE

CONCLUSION

- The performance of reinforced concrete frames was investigated using the static linear analysis , pushover analysis .These are the conclusions drawn from the analysis
- The pushover analysis is a relatively simple way to explore the nonlinear behavior of buildings.
- The results obtained in terms of plastic hinges gave an insight into the real behavior of the structures.
- Thus, the performance of pushover analysis depends upon of choice of material models included in the study.
- In step back and set back frames, it is observed that extreme left columns, which are on the higher side of the sloping ground and are short, are most affected. So, special attention is required while detailing and designing these short columns.
- The number of plastic hinges formation in buildings on sloping ground are more in longitudinal direction as compared to transverse direction because of the effect of asymmetry along longitudinal direction.
- The performance of the buildings on sloping ground suggests an increased vulnerability of the structure with formation of column hinges at base level and beam hinges at each storey level at performance point .
- For the buildings studied, it is found that the plastic hinges are less in case of buildings resting on sloping ground as the slope increases. Most of these elements are in the range of LS-CP and some of the elements lie in the range of C-D which indicates failure of elements lies in the range of collapse point increases the seismic vulnerability of the structure and such elements which are in LS-CP state requires retrofitting.
- From this study we observed that as the storey height increases the base shear and displacement also increases. But according to the performance of structure for slope at an angle of 21.58 degree it suggests up to four storey as the height increases it leads to collapse state
- As the height increases storey drifts also increases.
- From this analysis the observations are as the angle of slope increases base shear increases and target displacement decreases.
- The base shear acts more in longitudinal direction than in transverse direction.

- From this we observed that for 16.32 degrees slope are safe upto 5- bay .But as the bay increases more no of hinges are to be formed and subjected to collapse region.

- In static linear analysis we observed that as the angle of slope increases storey shear decreases and base shear decreases.

- As the angle of slope increases displacement and drifts decreases.

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