EXPERIMENTAL STUDY OF RC FRAMED BUILDING ON SLOPING TOPOGRAPHY SUBJECTED TO SEISMIC FORCES

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Abstract - *Now-a-days there is shortage of plain land to build structures in faster developing cities, subsequently construction turned its face towards hilly areas. Construction of structure on hilly region is not easy as on plain ground. The behaviour of structures on hilly areas is totally different to that of constructed on flat ground. The buildings constructing on hilly regions are asymmetric and are irregular in lateral and vertical directions. Buildings are considered as irregular due to irregular distribution of mass, stiffness and geometry. Hilly regions are more prone to earthquake, the buildings must sustain all the loads coming on it. To strengthen the buildings lateral load resisting systems like shear walls, core walls, bracings are provided. Those buildings also show more deflection and story drifts compared to buildings on plain ground. In this work, analysis is carried out to evaluate the dynamic properties of building situated on flat ground and hilly areas. Here I considered a Twelve storied bare frame (step-back building) for experimental analysis. The sloping ground inclined at varying degrees like 0º, 27º and 40º. Different type of soil conditions like soft, medium and hard soils also considered for analysis. Then core wall is added to the structure followed by the infill wall for all sloping degrees and soil conditions. Modelling is done in ETABS software. Response spectrum analysis is carried out to know the response of the building and the results are compared in terms of story displacement, base shear, story drifts and fundamental time period and are tabulated.*

Key Words: Step-Back Building, Response Spectrum , Sloping Degree, Infill Wall, Core Wall, ETABS

1. INTRODUCTION

Earth is everything for all living creatures, since it gives food, shelter and water. But it is affected by certain natural calamities like earthquake, flood, volcanic eruptions etc., which will disturb living creatures. In this project work, I am focussing on the effects of earthquake on the medium rise structural systems, since there is a lot of scope for medium and high rise structures now-a-days. Earthquake is one of the most dangerous natural calamities. It is mainly classified into two and they are natural and man-made type. In natural type, earthquake occurs along the fault if two plates colloid each other, majority of energy get releases which is called seismic energy. The seismic energy moves in the form of waves and reaches to the earth surface. While considering the case of Man-made type of earthquake, it mainly occurs due to the activities like ground water extraction, building tall and heavy structures like multi storey buildings, dams reservoirs on the soft soil. With the process of extraction of water from ground will leads to the decline of water table level and it will destabilise the earth also. For the construction of tall structures , huge amount of concrete and steel will be used for the resistance of earthquake due to the reason more weightage is applied on that site and the collected water in the reservoir also be heavy, these all things will become burden to that site.

1.1 DEMAND OF CONSTRUCTION ON HILLY REGION

In this century there is insufficient plain land for the construction of buildings. As the job opportunities are more in faster developing cities so that people will migrate towards those cities. Almost all the existing plain land is covered with buildings, and the human tendency generated to find any other alternatives to live in the cities, so the picture of construction of buildings on hill slopes came into mind. For the design of buildings on hill slopes, standard codes are made based on the experience. According to that standard design, buildings started to stand on sloping ground. Increased cost of plain land is the another reason for the demand of construction formed in hilly areas. As the cities are developing day-by-day, demand for the land is increasing and the cost of land also increases. Hence people turned towards construction on hill slopes. The demands of multi-storey buildings on hilly areas are increased due to the rapid urbanisation. If earthquake occurs on sloping ground, destructions will be more. Buildings on the sloping ground will be affected more than the buildings on the flat ground and also the dynamic response of hill buildings will differ a lot from the plain ground buildings. While comparing the buildings on hilly areas and flat ground, hilly areas behave differently. These will show maximum storey displacement and storey drifts. High grade concrete and high strength steel are used to provide more strength to buildings. Shear walls, central core walls, bracings, outriggers are the structural resisting system also added to increase the strength of the building..

2. SCOPE OF THE PRESENT WORK

In this work, seismic analysis of RC framed building is done on flat ground and on sloping ground along with the inclination of sloping ground. The sloping ground is inclined at different degrees like 27º and 40ºby varying soil conditions for all the different sloping grounds, analysis will be done. Different types of soil considered are hard, medium and soft soils. Analysis is further carried out by providing core wall at different locations for in filled frames and bare frame building. The results like storey displacement, storey drift, fundamental natural period and base shear are compared for different type of buildings. The main objective of the study is focussed on inclination of the ground along with different soil conditions as it gives better understanding about buildings located on hilly areas, this type of study is not observed in the literature survey.

3. METHODOLOGY

To observe the behaviour of the buildings located on different type of soils and hilly terrains, 27 models were created using FEM based software ETABS. Some data should be considered before the initiation of any models

Table-1: Material Specifications

Sl. No.	Members	Sizes
1	Beam	250mmX500mm
2	Column 1	600mmX600mm
3	Column 2	800mmX800mm
4	Thickness of slab	150mm
5	Height of the floor	3m
6	Wall	230mm
7	Parapet wall	150mm
8	Core wall	230mm

Table-2: Seismic factors

Sl. No.	Zone	III
1	Zone factor, Z	0.16
2	Importance factor, I	1
3	Response reduction factor, R	5
4	Damping ratio, %	5

3.1 Description of Models

In the present work, step-back building is considered with G+ 12 storied is located at sloping ground which is inclined at various degrees like 0º, 27º and 40º. A bare frame is considered and for next model core wall is added, followed by adding infill wall load to the model. Further these models are analysed for different types of soil conditions like hard, medium and soft soil. The columns of the building are supported at different levels. Considering a storey height of 3m, total height of the building is 50m from the foundation.

Table-3 : Different types of models considered for Analysis

FOR HARD SOIL		
MODELS	**Slope Angle**	**Description of models**
Model 1	0º	Bare frame
Model 2	0º	Bare frame with core wall
Model 3	0º	Bare frame with core wall and infill
Model 4	27º	Bare frame
Model 5	27º	Bare frame with core wall
Model 6	27º	Bare frame with core wall and infill
Model 7	40º	Bare frame
Model 8	40º	Bare frame with core wall
Model 9	40º	Bare frame with core wall and infill
FOR MEDIUM SOIL		
Model 10	0º	Bare frame
Model 11	0º	Bare frame with core wall
Model 12	0º	Bare frame with core wall and infill
Model 13	27º	Bare frame
Model 14	27º	Bare frame with core wall
Model 15	27º	Bare frame with core wall and infill
Model 16	40º	Bare frame
Model 17	40º	Bare frame with core wall
Model 18	40º	Bare frame with core wall and infill
FOR SOFT SOIL		
Model 19	0º	Bare frame
Model 20	0º	Bare frame with core wall
Model 21	0º	Bare frame with core wall and infill
Model 22	27º	Bare frame
Model 23	27º	Bare frame with core wall
Model 24	27º	Bare frame with core wall and infill
Model 25	40º	Bare frame
Model 26	40º	Bare frame with core wall
Model 27	40º	Bare frame with core wall and infill

3.2 Building Configurations

Building configuration 1: In this type of configuration, bare frame is considered which is located at flat ground (0º). These models are analysed in different soil conditions like hard, medium and soft soils.

Fig-1: Model 1,Model 10 and Model 19

Building configuration 2: In this type of configuration, bare frame is considered which is located at sloping ground inclined at 27º. These models are analysed in different soil conditions like hard, medium and soft soils.

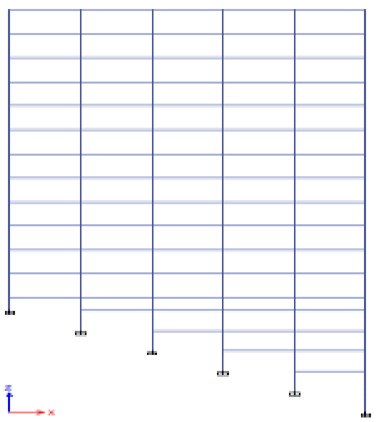

Fig-2: Model 4, Model 13 and Model 22

Building configuration 3: In this type of configuration, bare frame is considered which is located at sloping ground inclined at 40º. These models are analysed in different soil conditions like hard, medium and soft soils.

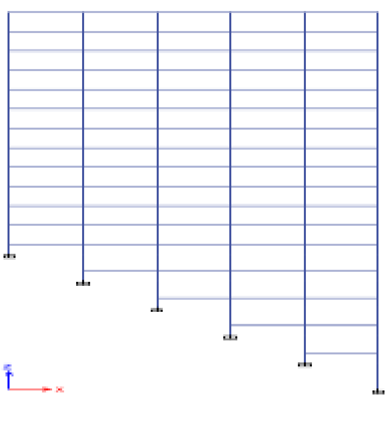

Fig-3: Model 7, Model 16 and Model 25

Building configuration 4: In this type of configuration, for bare frame core wall and infill are added and these are also located on flat ground (0º). These models are analysed for hard, medium and soft soils.

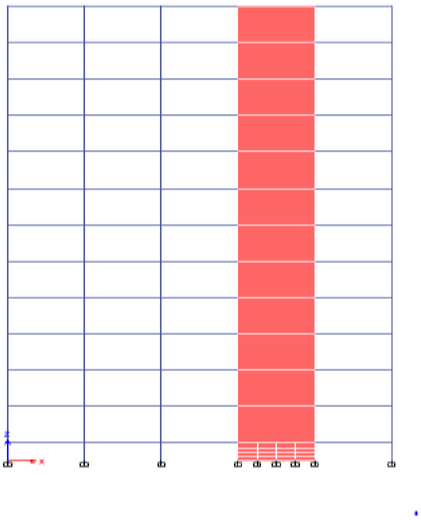

Fig-4: Model 2, Model 3, Model 11,Model 12, Model 20 and Model 21

Building configuration 5: In this type of configuration, for bare frame core wall and infill are added and these are also located on sloping ground inclined at 27º. These models are analysed for hard, medium and soft soils.

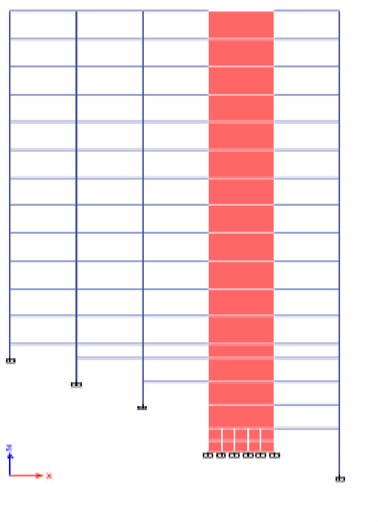

Fig-5: Model 5, Model 6, Model 14,Model 15, Model 23 and Model 24

Building configuration 6: In this type of configuration, for bare frame core wall and infill are added and these are also located on sloping ground inclined at 40º. These models are analysed for hard, medium and soft soils.

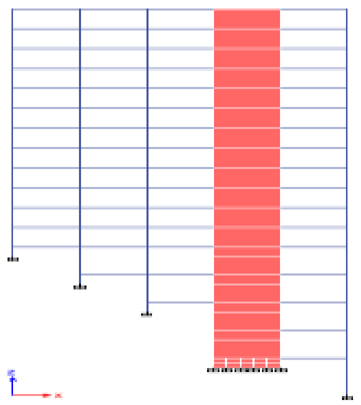

Fig-6: Model 8, Model 9, Model 17,Model 18, Model 26 and Model 27

Totally 27 models are prepared in ETABS. Response spectrum analysis is carried out to know the response of the building during earthquake like storey displacement, base shear, storey drift and fundamental time period.

4. RESULT AND DISCUSSIONS

Results of the dynamic analysis are compared for 27 models with different soil conditions.

4.1 Top Storey Displacement

Table-4 Top storey displacement (mm)

Soil type	Hard			Medium			Soft		
Degree	0º	27º	40º	0º	27º	40º	0º	27º	40º
Bare frame	19.6	24	26.2	26.7	31.1	34.7	32.8	37.2	40.9
Core wall	23.8	47.6	31.3	31.5	63.5	32.3	38.2	77.3	38.7
Core & infill	30.8	57.1	32.9	40.4	76	41	48.7	92.3	47.9
%	26	59	12	23	58.5	29	22	60	14.5

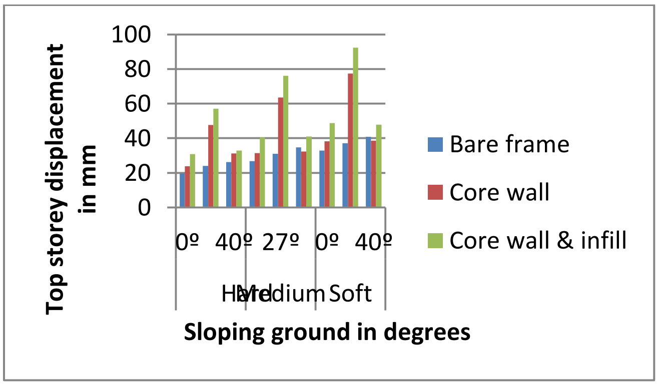

Chart-1: Top storey displacement

4.2 Base Shear

Table-5: Base shear in X direction(KN)

Soil type	Hard			Medium			Soft		
Degree	0º	27º	40º	0º	27º	40º	0º	27º	40º
Bare frame	1170	1153	1151.1	1470	1484.3	1531.1	1712.4	1748.7	1837
Core wall	1804.7	2914	1898.1	223	3964.1	2118.8	2672.8	4867.7	2601
Core wall & infill	2369.	3628	1903.4	286	4934.8	2468.6	3373.8	6059	3031
%	35	60	39	34	62	27	36	64	29

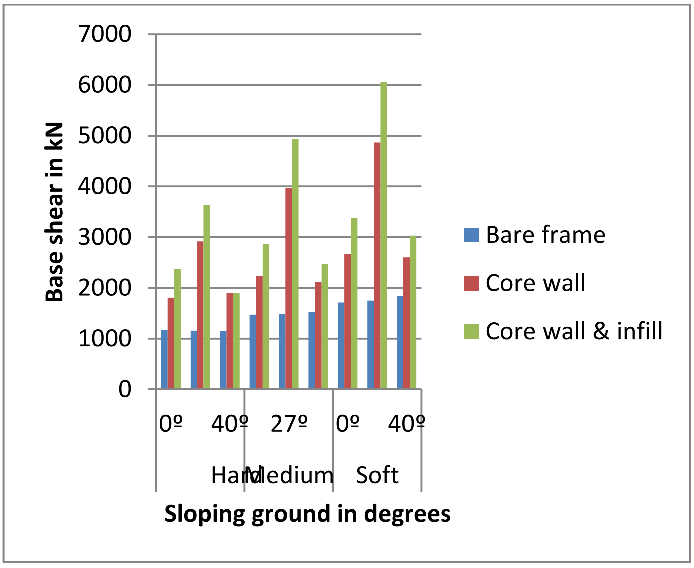

Chart-2: Base shear in X-direction

4.3 Time Period

Table-6: Time period of all the models

Soil type	Hard			Medium			Soft		
Degree	0º	27º	40º	0º	27º	40º	0º	27º	40º
Bare frame	1.686	1.773	1.802	1.686	1.773	1.802	1.686	1.773	1.802
Core wall	1.511	1.55	1.55	1.511	1.55	1.55	1.511	1.55	1.55
Core wall & infill	1.914	1.923	1.959	1.914	1.923	1.959	1.914	1.923	1.959
%	10	12	14	10	12	14	10	12	14

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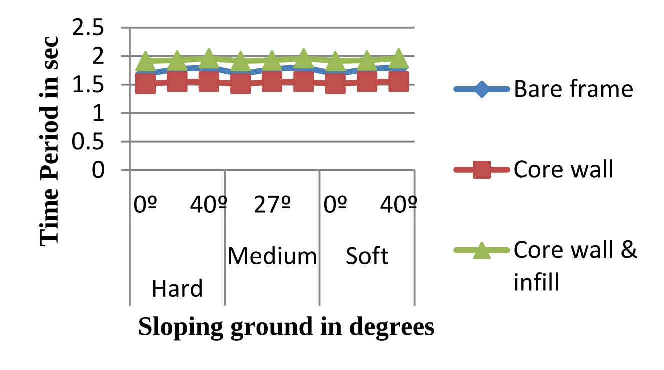
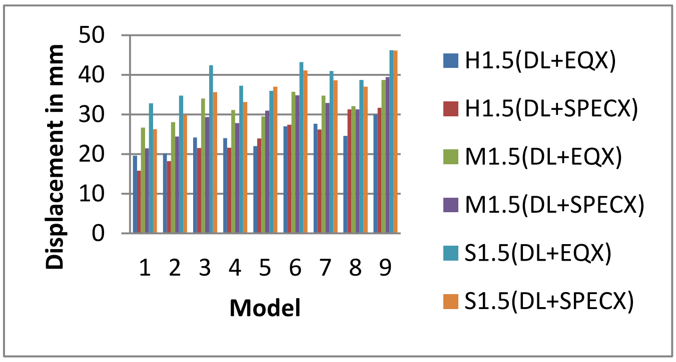


Chart-3: Time period of models

4.4 Storey Displacement

Table-7: Comparison of Maximum displacement in all the models

	Hard				Medium				Soft			
Model	1.5(DL+EQX)	1.5(DL+EQY)	1.5(DL+SPECX)	1.5(DL+SPECY)	1.5(DL+EQX)	1.5(DL+EQY)	1.5(DL+SPECX)	1.5(DL+SPECY)	1.5(DL+EQX)	1.5(DL+EQY)	1.5(DL+SPECX)	1.5(DL+SPECY)
1	19.6	19.6	15.8	15.8	26.7	26.7	21.4	21.4	32.8	32.8	26.3	26.3
2	20.1	23.8	18.2	22.6	28	31.5	24.4	28.9	34.7	38.2	29.8	34.3
3	24.2	30.8	21.5	29.1	34	40.4	29.3	36.5	42.4	48.7	35.6	42.8
4	24	20.4	21.6	19.7	31.1	27.8	27.8	26.8	37.2	34.1	33.1	32.8
5	22	47.6	23.9	26.2	29.5	63.5	30.9	33.2	35.9	77.3	37	39.3
6	27	57.1	27.4	29.5	35.7	76	34.8	37.1	43.2	92.3	41.1	43.6
7	27.6	21.1	26.2	21.9	34.7	28.6	32.9	29.7	40.9	35.2	38.6	36.4
8	24.6	23.6	31.3	25.5	32.1	30.7	31.3	32.3	38.7	36.9	37	38.2
9	30	29.3	31.7	32.9	38.7	37.3	39.4	41	46.2	44.4	46.1	47.9



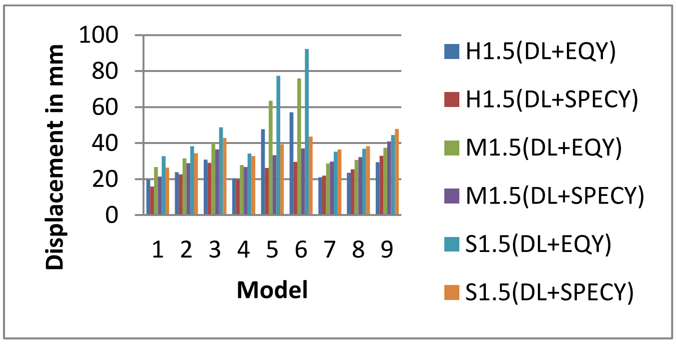


Chart-4: Comparison of displacement in X and Y direction

4.5 Storey Drift

Table 8-: Maximum value of storey drift

Model	Hard		Medium		Soft	
	Storey Drift	Storey	Storey Drift	Storey	Storey Drift	Storey
1	0.000707	4	0.000962	4	0.001181	4
2	0.000783	6	0.001044	6	0.001271	5
3	0.001018	5	0.001345	5	0.001628	5
4	0.000834	3	0.001092	3	0.001314	3
5	0.001565	4	0.002097	4	0.002555	4
6	0.001935	4	0.002587	4	0.003149	4
7	0.000943	3	0.001208	3	0.001437	3
8	0.000899	6	0.001027	4	0.001239	4
9	0.000956	4	0.001243	4	0.001489	4

From the above table, we can say that drift value increases with the increase in sloping ground and building configurations. In most of the models, drift is more in the 4^{th}storey. Drift value also increases as the soil condition changes from hard to soft soil.

5. CONCLUSIONS

In the present study, the experimental analysis with response spectrum of G+12 storied step back building is performed out to study the dynamic behaviour of building located on hill slope with and without core wall. Some of the important conclusions drawn from the study are,

1 Top storey displacement of the buildings is found to be increase with increase in the sloping angles.

2 Top storey displacement increases as the soil conditions of the site varies from hard to medium soil and it is found less in X-direction compared to Y-direction.

3 Comparing all 27 models, base shear of the zero degree inclined building is found to be more (bare frame, in filled frame, with and without core wall)

4 Base shear is found to be increasing gradually with hard, medium and soft soil for all the type of models.

5 Fundamental time period of the buildings is increased with a 2% with the increase in the angle of inclination.

6 Storey displacement for all the models are found to be increased with an increase in the inclination angle, again storey displacement is increased in filled building with respect to bare frame.

7 Storey displacement of the building is found to be more in infilled buildings with core wall.

8 Minimum value of displacement is found in zero degree bare frame and maximum value is found in 27 degree and 40 degree bare frame with core wall and infill structures.

9 Displacement of building varies as the soil at site varies. Displacement of soft soil building increases 23% than medium soil building.

10 Displacement of medium soil building increases 36 % than hard soil buildings.

11 Maximum value of storey drift is found at middle height of the building, on an average it is found in the 4thstorey in most of the models

12 Storey drift of the building located on hard soil is less compared to the buildings located on medium and soft soil. Drift value of the medium soil buildings increased to 10% than hard soil buildings and soft soil buildings increased 20% than medium soil buildings.

13 Storey drift of the building increases as the slanting degree increases with respect to horizontal and it also increases when core wall and infill load are added to the structure.

14 Storey drift is found to be less in the buildings located on hard soil compared to other type of soils.

- From the above conclusions made, it is clearly observed that bare frame, core wall building with and without infill load behaves better with zero degree inclination. The response of all these buildings are good by considering hard soil strata compared to other type of soil strata.

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