A STUDY ON SEISMIC ANALYSIS OF RC FRAMED STRUCTURES ON VARYING SLOPE ANGLES WITH & WITHOUT SHEAR WALLS

Vinayakumar R[1], Chetan Gonni S[2]

[1]Post Graduate in Structural Engineering, BIET College, Davanagere
[2]Asst. Professor, M. Tech Structural Engineering, BIET College, Davanagere-577004, India

---

Abstract - *The structures are usually constructed on flat ground, however, due to the lack of flat grounds usually hilly regions for construction task have been preferred. Since, construction of framed structures on sloping grounds gives variety of structural performance than the flat grounds, since these structures are unequal in universe consequently, attract huge amount of shear force and torsional moments and shows unsymmetrical distribution due to differing in column lengths. In this existing study, performance of G+10 building on varying sloping angle i.e. 0^0,11.25^0, 22.5^0, 45^0 to be studied for without and with shear walls at corners (Case 1) and both corner & edges (Case2) for a seismic intensity of 0.24 (Zone IV). The modeling and analysis of the RC framed structures has been done by using ETABS. To study the effect of varying column length in bottom storey by increasing sloping angle by both equivalent static and response spectrum analysis as per Indian standards codes. The results to be obtain in form of Base Shear, Story Shear, Story Displacement, Story Drift ratios for all cases of with shear walls (Case 1 & Case 2) and without shear walls for all the incremental slope angles have been studied.*

Key Words: Slope Angle, Shear Walls, Base Shear, Story Shear, Story Displacement, Story Drift and ETABS.

1. INTRODUCTION

Since past years ago, huge quantity of material bunch combined to made Earth. This bunch of materials exhibits huge quantity of heat and slowly as the earth warmed down, the massive and medium material sink to the center and delicate or weightless materials climbed to the top. The converted earth made up of the inner core of the radius 1290 km, the outer core of thickness 2200 km, the mantle of thickness 2900 km and crust of thickness 5 to 40 km. These layers of cores induced by some variety of materials such as, inner core which is solid type of the core and it consists of massive metals like nickel and iron as the constituents and outer core which is liquid in form as the constituents as material, similarly main constituents of material for the mantle core is ability to flow and the crust constitutes the weightless or delicate materials like basalt and granites. In which the core has estimated temperature about 2500^0C as a pressure about 4 million atmosphere and density about 13.5 gm/c which is in contrast to 25^0C at 1 atmosphere and 1.5 gm/cc on the surface of the earth.

1.1 CONSTRUCTION ON SLOPING GROUND

Usually constructions of buildings on sloping ground are unequal in nature, due to this unequal nature design of these buildings are difficult on slopes and undulations on grounds. But at present generation growth of the population in this universe is tremendously increasing, which affects the basic requirements of the constructional activities like transportation and shortage in the availability of land, by considering all of these affects peoples are rapidly focused on sloped land like hill stations for their constructions, but construction on sloped grounds are rejected for constructional activities due to difficulty in transportation and effect of slopes on the structures. During the past earthquakes on hilly regions like sloped buildings undergo huge damage which directly cause the failure of the structure by collapsing, because building constructed on sloped grounds have varying column heights at the bottom stories, which leads to short columns more prone to seismic activity than the long columns.

1.2 OBJECTIVE OF THE STUDY

The objectives of the present study on seismic analysis of RC framed structure on the sloping ground for with and without shear wall are as follows:

1. To develop the RC framed structures on sloping ground having G+10 stories with an earthquake intensity of zone IV.
2. To develop the models by varying column length at the bottom story by increasing sloping angels such as 0^0 (Plane Surface), 11.25^0, 22.5^0, 45^0, respectively for without shear wall and with shear walls at corners and edges of the building with various cases which are listed in the next chapter (Chapter-3).
3. To perform the analysis of the developed RC frame models by ESA & RSA as per IS 1893-2002.
4. To obtain the seismic parameters such as base shear, story shear, time periods, story displacement and story drift by both ESA & RSA.

2. DATA FOR DEVELOPING THE MODEL

1. For analysis of RC framed structure on varying sloping angles for 0^0(plane surface), 11.25^0, 22.5^0 and 45^0 for with shear wall and without shear wall at corners and edge positions, can be studied by

developing 12 models of G+10 story with a plan dimensions along X & Y axis, story heights and structural components which are beams, Columns, Slabs and Shear walls considered for the analysis of frame structures by the dimensions with the materials properties which are Grade of concrete and Grade of steel have been listed on Fallowing Table.

Table -1: Building Parameters for Analysis

SL NO.	PARAMETERS	REMARKS
1	Plan Dimension	14 X 17.5 m
2	No. of Stories	G + 10
3	Story Height	3.2m
4	Plinth Beam Height	1.75m
5	Size of Column	700 X 700 mm
6	Size of Beam	300 X 300 mm
7	Slab Depth	150 mm
8	Shear wall Thickness	200 mm
9	Grade of Concrete	M30
10	Grade of Steel	Fe 500, Fe 415

2. Seismic parameters which are used for analyzing the framed structures are considered as per IS 1893-2002 (part 1) are listed below.

Table -2: Seismic Parameters for Analysis

SL NO.	PARAMETERS	REMARKS
1	Seismic Zone	IV (Severe)
2	Zone Factor	0.24
3	Soil Type	TYPE II
4	Importance Factor	1
5	Building Frame System	SMRF
6	Response Reduction Factor	5
7	Damping Ratio	5%

2.1 LOAD CALCULATIONS FOR DEVELOP THE MODLES

a. Loads on slab:

1. Live load = 4 KN/m^2.
2. Floor finish,

12mm vitrified tile = 0.012 x 24 = 0.29 KN/m^2.
20mm backing mortar = 0.02 x 20.4 (density of cement plaster) = 0.408 KN/m^2.
12 mm thick ceiling plaster = 0.25 KN/m^2.
TOTAL = 0.948 KN/m^2.
Say, Floor finish = 1.5 KN/m^2.
Floor finish on ground floor for parking = 2 KN/m^2.
Floor finish on terrace,
Water proof plaster = 0.150 KN/m^2.
12mm ceiling plaster = 0.25 KN/m^2.
Total = 0.4 KN/m^2.
By considering extra load due water proofing as 2.6 KN/m^2.
Then, Total floor finish on terrace = 3 KN/m^2.

b. Load on beam:
Loads on Beams are self-weight and wall loads, self-weight of the beam is determined automatically by ETABS and wall loads can be assigned by manual calculation results which is calculated below.

Wall load calculations for beam,
Thickness of wall considered,
For exterior wall thickness =230mm.
For interior wall thickness =150mm.
Density of brick = 20 N/mm^2.
Height of parapet wall for terrace = 1.5m.

Exterior wall load calculation,
= 0.230 x (3.2-0.450) x 20 + 0.04 x (3.2-0.450) x 20.4
= 14.9 KN/m.

Interior wall load calculation,
= 0.150 x (3.2-0.450) x 20 + 0.04 x (3.2-0.450) x 20.4
= 10.5 KN/m.

Parapet wall load on terrace,
= 0.230 x 1.5 x 20 + 0.04 x 1.5 x 20.4
= 8.12KN/m.

2.2 MODELLING TO 45^0 SLOPE ANGLE & ANALYSIS

a. Bottom Length Calculations: Sloping angle consider for model 4 is 45^0, and considering 1.5m as first column length, and remaining columns length can be calculated by, Tan 45^0 = 1, 1st column length=1.5m.

b. Fundamental natural period Calculation:
1. Without shear wall for both along X-direction and Y-direction,
$T_a = 0.075*h^{0.75}$, Where h = 50.7 m.
$T_a = 0.075*50.7^{0.75} = 1.42$ s.
2. With shear for both case 1 and case 2,
$T_a = 0.09*h$ / SQRT(d), Where h = 50.7 m and
d = 14m along X axis and d = 17.5m along Y axis
Along X-direction, $T_a = 0.09*50.7$/ SQRT (14) =1.21 s.
Along Y-direction, $T_a = 0.09*50.7$/ SQRT (17.5) =1.09 s.

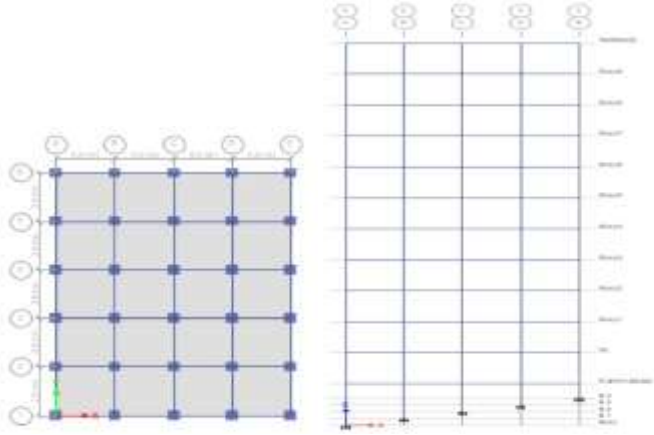

Fig -1: Plan & Elevation for model with slope angle of 45^0 without Shear walls.

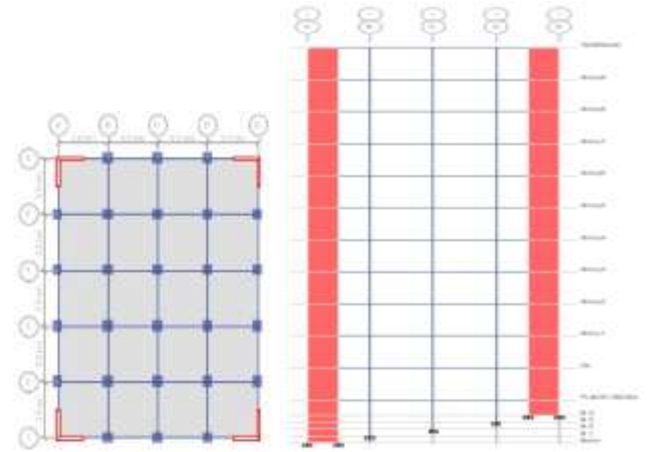

Fig -2: Plan & Elevation for model with slope angle of 45^0 with Shear walls at corners.

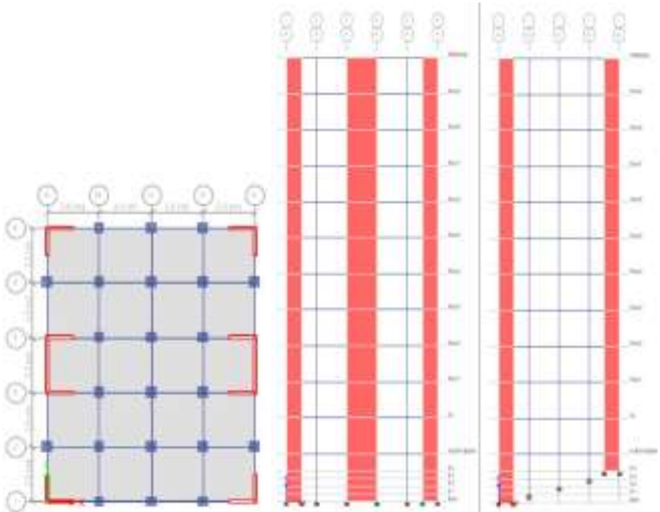

Fig -3: Plan & Elevation for model with slope angle of 45^0 with Shear walls at corners and edges.

3. RESULTS & DISCUSSION

3.1 STORY SHEAR

It is defined as the lateral force acting on each story in horizontal direction during earthquake, and the maximum lateral shear should always maximum at the base of the building which is termed as the Base shear.

Table -3: Maximum Story Shear for ESA along X & Y Axis

Models	without shear wall	with shear walls	
		Case 1	Case 2
Model 1	1794.2652	2465.2067	2399.0397
Model 2	1708.6446	2295.3614	2236.1435
Model 3	1639.0969	2150.8793	2096.8158
Model 4	1459.3972	1842.1166	1766.3322

Chart -1: Maximum Story Shear for ESA

Table -4: Maximum Story Shear for RSA along X & Y Axis

Models	without shear wall	with shear walls	
		Case 1	Case 2
Model 1	1794.2625	2465.1963	2399.0393
Model 2	1708.6402	2295.3544	2236.1358
Model 3	1639.0922	2150.8723	2096.8049
Model 4	1459.3919	1842.1151	1766.3289

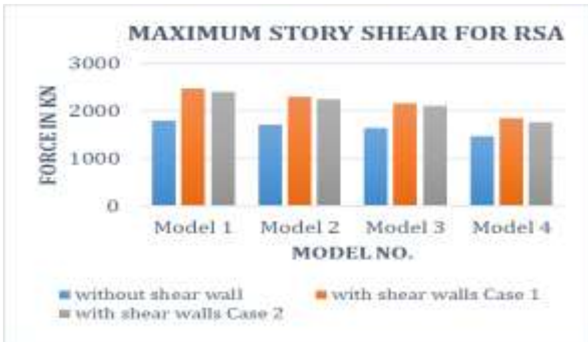

Chart -2: Maximum Story Shear for RSA

From Chart 1 & 2 represents the maximum story shear results for varying slope angles of all the models with shear walls (Case 1 & Case 2) and without shear walls for both ESA & RSA along X & Y direction, Maximum story shear for Model 1 shows maximum values.

3.2 STORY DISPLACEMENT

The lateral displacement of each story due to the lateral forces from base of the building or structures is known as story displacement. Story displacement results for the structures with various cases for all the models as tabulated below.

Table -5: Maximum Story Displacement for ESA along X & Y Axis

Models	without shear wall	with shear walls	
		Case 1	Case 2
Model 1	34.71	32.42	23.08
Model 2	64.6	56.01	36.13
Model 3	63.33	54.76	34.32
Model 4	57.57	48.34	30.84

Chart -3: Maximum Story Displacement for ESA

Table -6: Maximum Story Displacement for RSA along X & Y Axis

Models	without shear wall	with shear walls	
		Case 1	Case 2
Model 1	28.068	26.684	19.186
Model 2	53.395	45.758	29.703
Model 3	55.86	46.41	31.51
Model 4	54.98	43.5	30.84

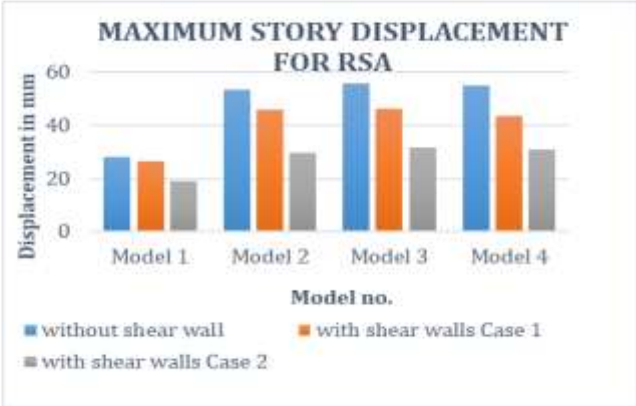

Chart -4: Maximum Story Displacement for RSA

From Chart 3 & 4 represents the maximum story displacement results for varying slope angles of all the models with shear walls (Case 1 & Case 2) and without shear walls for both ESA & RSA along X & Y direction, Maximum story displacement for model 2 shows maximum values.

3.3 STORY DRIFT

It is defined as the drift of the one story with respect to the below story of the building and story drift limitation as per IS 1893-2002 is 0.004 times the story height. The story drift results for the structures with various cases for all the models as tabulated below.

Table -7: Maximum Story Drift for ESA along X & Y Axis

Models	without shear wall	with shear walls	
		Case 1	Case 2
Model 1	0.001287	0.001137	0.000791
Model 2	0.002379	0.001888	0.001227
Model 3	0.002248	0.001788	0.00114
Model 4	0.00193	0.001516	0.000941

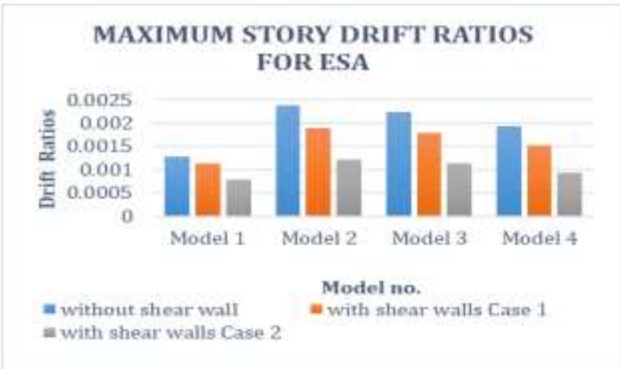

Chart -5: Maximum Story Drift Ratios for ESA

Table -8: Maximum Story Drift for ESA along X & Y Axis

Models	without shear wall	with shear walls	
		Case 1	Case 2
Model 1	0.001128	0.000977	0.000671
Model 2	0.002044	0.001591	0.001011
Model 3	0.002067	0.001548	0.000966
Model 4	0.001918	0.001374	0.000882

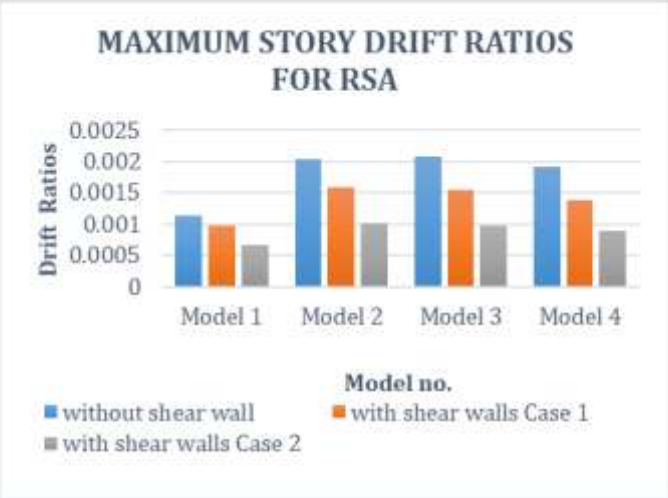

Chart -6: Maximum Story Drift Ratios for RSA

From Chart 5 & 6 represents the maximum story drift results for varying slope angles of all the models with shear walls (Case 1 & Case 2) and without shear walls for both ESA & RSA along X & Y direction, Maximum story drift for all the models are within the limits as per IS 1893-2002 (Part 1) which is 0.004 times of the story height.

3. CONCLUSIONS

In this present study, seismic analysis of RC framed structures on varying slope angles for with and without shear wall have been modelled and analysis is done for ESA & RSA with ETABS and the results which are obtained is time period, base shear, story shear, story displacement and story drift. From the analysis results, the following conclusions have been made as fallows,

i. From the story shear results it has been observed that for both ESA & RSA as the angle of slope increase base shear of the structures decreases to 5% - 12% and the shear walls at corners having maximum base shear than the shear walls at both corners and edges.
ii. From the both ESA & RSA it has been observed that story shear values are goes on decreases at the top story and the slope angle increases story shear values decreases and shear walls at the corners have maximum story shear than the shear walls at both corners and edges.
iii. Story displacement is observed to be maximum for ESA than the RSA for all models and it is maximum at the top story, as the slope angle varies displacement of the stories increases, but in case of model 4 it shows less displacement than the other models and it is observed to be displacement is maximum along Y-direction than the X-direction for both ESA and RSA analysis, they should be in allowable permissible limits, Displacement for the shear walls at corners positions have been observed to be maximum than the shear walls at both corners and edges positions, hence shear walls at both corners and edges positions are to be suitable location for structures on sloping ground.
iv. The story drift is observed to be maximum for ESA than the RSA for all the models, drift values increases as the slope angle increases, but in case of model 4 it shows less values than the other models and for the shear walls at corners having maximum story drift than the shear walls at both corners and edges positions of the structures, and it has been observed that for all the models story drift ratios are within permissible limits as per IS 1893-2002 (Part 1) clause 7.11.1.
v. From the present study, shear walls at both corners and edges positions gave lesser values in the results of time period, base shear, story shear, displacement and drift for all the models within the limitations provided from the IS 1893-2002 (Part 1), Hence shear walls at both corners and edges positions are to be suitable location for structures on sloping ground and safe against the seismic forces.

REFERENCES

[1] Likhitharadhya Y R and Praveen J V, *"Seismic analysis of multi storey building resting in flat ground and sloping ground"*, International journal of innovative research in science, Volume 05, Issue 06, Page 9786-9794, June 2016.

[2] Miss. Pratiksha Thombre and Dr.S.G. Makarande, *"Seismic analysis of building resting on sloping ground"*, Journal of emerging technologies and innovative research (JETIR), Volume 03, Issue 06, Page 296-300, June 2016.

[3] M.G. Kalyanshetti, *"Seismic analysis of building resting on sloping ground with varying number if bays and hill slopes"*, International journal of engineering research & technology (IJERT), Volume 02, Issue 12, Dec 2013.

[4] Naveen Kumar S M and Vasipalli Vamsi Krishna Reddy, *"Analysis and comparison of step back RC frame building on sloping strata and plain strata"*, International journal

for research trends and innovative (IRJTI), Volume 02, Issue 09, Page 61-69, 2017.

[5] Rahul Manoj sing Pawar and S.B. Sohani, *"Analysis of setback step back building resting on sloping ground"*, International journal of scientific development and research (IJSDR), Volume 02, Issue 06, Page 577-584, June 2017.

[6] Roser J Robert and Ranjana M. Ghate*, "Seismic analysis of multistoried RCC building on sloping ground"*, International journal for research in emerging science and technology, Volume 03, Issue 12, Page 40-45, Dec-2016.

[7] Ravindra Navale and Dr. Sandeep Hake, et al., *"Analysis of unsymmetrical building resting on sloping ground by dividing in 2D frame"*, International research journal of engineering and technology (IRJET), Volume 04, Issue 07, Page 943-946, July 2017.

[8] Shivanand.B and H.S. Vidyadhara, *"Design of 3D RC frame on sloping ground"*, International journal of research in engineering and technology (IJRET), Volume 03, Issue 08, Page 307-317, Aug 2014.

[9] Umakant Arya and Aslam Hussain, et al*., "Wind analysis of building frames on sloping ground"*, International journal of scientific and research publications, Volume 04, Issue 05, May 2014.

[10] Vinod Kumar and H.S. Vidyadhar*, "Analysis of 3D RC frame on sloping ground"*, International research journal of engineering and technology (IRJET), Volume 04, Issue 09, Page 1176-1184. Sep 2017.

[11] Zaid Mohammad and Abdul Baqi, et al., *"Seismic response of RC framed building resting on hill slopes",* Science direct procedia engineering 173, Page 1792-1799, 2016.

BIOGRAPHIES

VINAYAKUMAR R
Post Graduate Student
Dept. of Civil Engineering
BIET College, Davanagere.

CHETAN GONNI S
Asst. Professor
Dept. of Civil Engineering
BIET College, Davanagere.