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Effect of Variable Ground Slope on Lateral Strength of Wall-Frame Structure

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Abstract: The current era is a modern age. In today's era of rising urbanization has become condition of making multistorey building in adverse conditions like in mountainous region. As Earthquake is a natural disaster and can put lethal impact on hilly regions, to reduce the impact of the earthquake some earthquake resistant techniques comes into existence. The shear wall is one of them which provided lateral strength and stiffness to building against earthquake and wind forces. In the present paper 4 model of G+5 story concrete wall-frame building taken with identical position of shear wall, model one is a conventional building on flat ground and remaining three models built at ground slope of 22º, 27º and 31º respectively. The effluence caused by earthquake force act along slope direction has been studied in all four models. The story shear has taken as measure of study and all the external conditions are identical, except size of shear wall and ground slope. Linear static analysis has been done using SAP: 2000 software.
Keywords: Seismic load, shear wall, sloppy ground, rigid frame structure and sap: 2000.

I. INTRODUCTION

Erath crust is a very rugged place; it is made of massive mountains of rocks and ice. Our surface also contains flat plains and forest hills. It has busy cities and ocean floors. The trouble is our crust is cracked, the cracks extended below the sea and across the land. These faults are caused by our crust's tectonic plates being ripped apart and crushed together when those tectonic forces reach at the breaking point earthquake comes in existence. When Earthquake occurs under the sea generate most feared result of all, and then tsunami comes in existence. The destruction from earthquakes is tragically high each year.

The surface of the earth is like a Gipson puzzle and it's not a single piece of land but approximately 20 pieces of a single land the constantly move each one of land parts are called tectonic plate. So whenever that plate hits or slide passed another plates the earthquake is caused. The surface where this plates slip is called fault or the fault plane and the place where the earthquake originate is called the hypocentre and place where it occurs on the earth surface is called the epicentre. There are three types of earthquakes first convergent boundaries here one tectonic plate is forced over another during an earthquake which causes a thrust fault many hills and mountain have been formed due to the convergent boundaries. In divergent boundary plates are drifted apart each other forming a rift zone, this kind gives birth to new ocean floors. In transform fault the plates are sleep each other and this also called strike Slips Mountains are also the structure caused by tectonic actions. Human has been forced to flee due to rapid urbanization and population crisis and for this reason unexpected structures are being built in these areas too. Thirty years ago we could not imagine a multi-story building in the mountainous region. In today's times this hypothesis is also taking existence

Slanting of land in the hilly areas is a huge problem but when it subjected to seismic action it becomes lethal. Be a natural disaster like the earthquake in such regions can cause major destruction could be much more damage to multi-story which increase the loss of properties and life. So this is necessary for multi-story building that in mountain areas there should some anti-seismic techniques in buildings to protect against the effects of earthquakes.

Shear wall is one of those anti-seismic techniques which is employed in the vertical direction along the building and reduces the influence of lateral force on building. The concrete frame structure with shear wall is called as wall-frame structure.

II. THE ACTION OF WALL- FRAME STRUCTURE

The term shear wall refers to a wall that opposes lateral wind or earthquake loads acting parallel to the plane of the wall in addition to gravity loads from the floor and roof adjacent to the wall. Since plastic hinges are made in beams and columns, not in shear walls therefor shear wall system is more reliable. A great advantage of the shear wall is that it reduces the lateral sway of the building

The shear mode deformation in a rigid frame, flexural mode deformation in the shear wall and interaction deformation in frame and shear wall have given in the fig (1). It shows that how both of them compensates deformation of each other and reduce the overall deflection of the building by reversal action of deformation
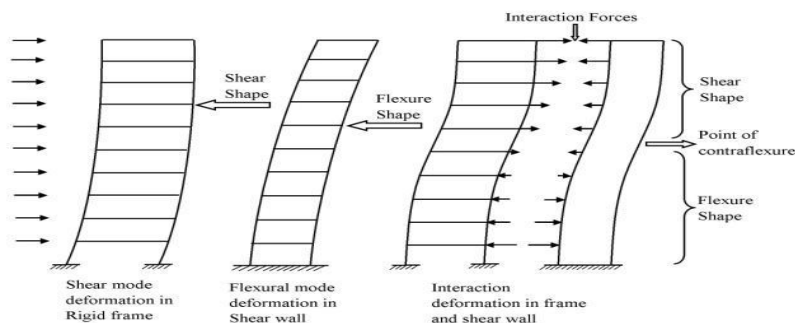
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Fig. 1 the Action of Shear Wall-Frame Structure

III. GEOMETRY AND DETAILING OF SHEAR WALL

All paragraphs must be indented. All Shear walls are oblong in cross-section i.e. the one dimension of the section is much longer than the other one. Here this paper using three different sizes as 0.25m*0.5m, .0.25m*1m and 0.25m*1.5m shear walls having longer dimension is along the X direction as shown below in fig(2).

They are designed as per procedure is given in code IS-456: 2000. According to is-13920:1993, clause 9.1.2, the minimum thickness of the shear wall should be 150mm. This paper takes 250mm thick wall. The shear wall starts from the foundation and continues throughout the height of the building. M_{20} grade of concrete and Fe_{500} grade of steel has been used. The steel rebar is provided in the shear wall with 60mm spacing in longitudinal, the minimum area of reinforcement to be provided should be 0.0025times of the cross-section for the shear walls. Across the wall cross-sections, the vertical reinforcement should be distributed uniformly.

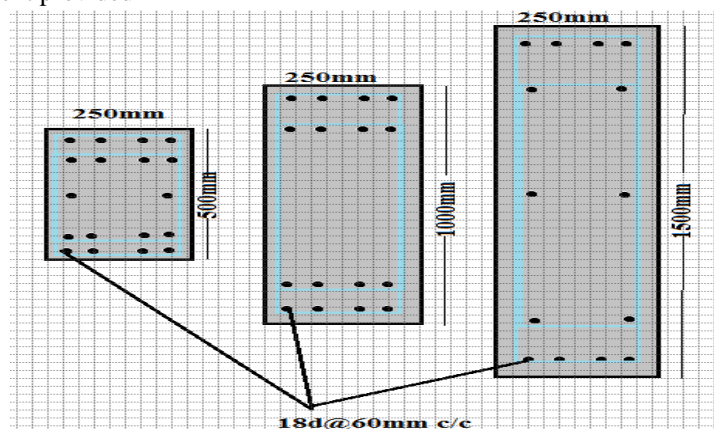The required area of reinforcement provided

Fig. 2 Cross-Sectional Details Of All Three Shear Walls

IV. MODELING AND ANALYSIS

Following work deals with the analysis of a G+5 building resting on slopping ground of different slope angles of 22°, 27° and 31° degrees respectively. The main task is to found effectiveness of shear wall in the frame at different slope angles. The presented building subjected to gravity and seismic loads of combination accordance to IS-456-2000.

Following steps are involving in modelling shown as below.

1) *Step 1:* The selection of seismic zone and geometry of building: building geometry is symmetric in plan shown in fig and building situated at seismic zone V with zone factor (Z) is 0.36.
2) *Step 2:* Application of primary load and combination of load: the load combination is taken according to IS-456-2000 and IS-1893, 2002.
3) *Step 3:* Modelling of G+5 story building by using software SAP: 2000
4) *Step 4:* Analysis of model for all load combinations.
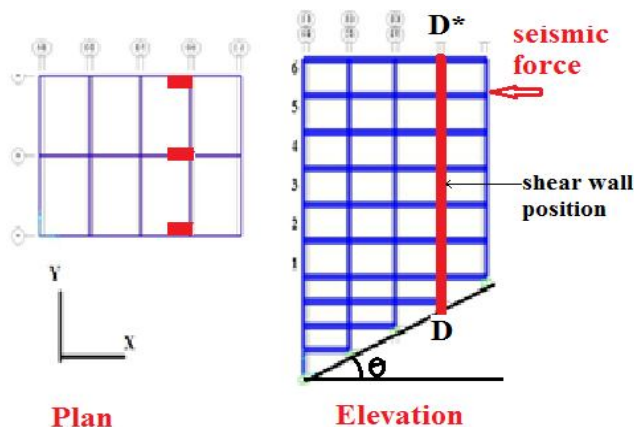5) *Step 5:* A comparative study of outputs (story shear)

Fig. 3 Plan and Side View of Common Model

A common building frame has been given in fig (3) in which shear wall (with 3 different sizes 0.25m*0.5m, 0.25m*1.0m and 0.25m*1.5m) has been applied at second position of column from right column i.e. DD* location. Besides that shear wall is not applied at any location.

TABLE I
Primary And Secondary Loads

| SN	SPECIFICATIONS	SIZE
1	Plan dimension	20m*12m
2	Length in X-direction	20m (4 bays)
3	Length in Y-direction	12m (2 bays)
4	Height in Z- direction	18m
5	Floor to floor height	3m
6	The total height of the building (G+5)	18m
7	Slab thickness	125mm
8	Soil type (as per IS: 1893-2000)	II
9	Importance factor	1
10	Seismic zone factor	0.36
11	Grade of concrete	M20
12	Grade of steel	Fe500
13	Floor beam size	0.3m*0.5m
14	Column size	0.35m*0.35m
15	Load combination	1.5DL + 1.5EQX

Table 2
Specifications Of Building Model

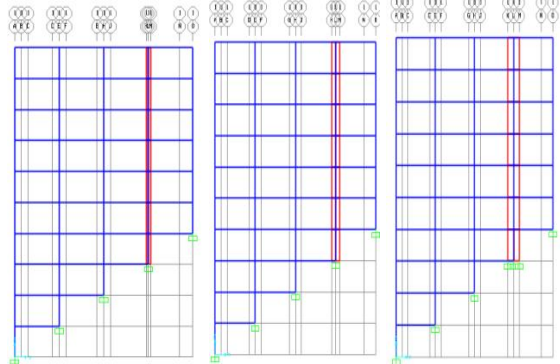| SN	LOAD APPLIED	MAGNITUDE
1	Self-weight of beam	3.75 KN/m
2	Self -weight of partition wall	12.5 KN/m
3	Self- the weight of the slab	3.125 KN/m^2
4	Self – the weight of parapet wall	5.52 KN/m
5	Live load	2.5 KN/m^2
6	Earthquake load in X-direction	As per IS: 1893- 2002
7	Earthquake load in Y-direction	As per IS: 1893- 2002
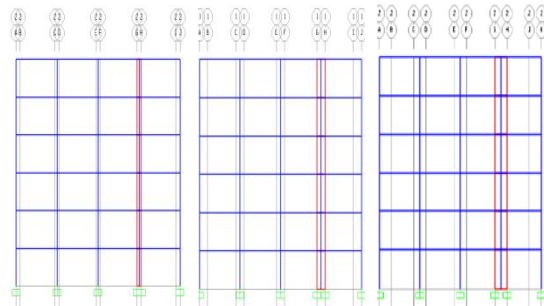
Model 1: (Flat Ground)
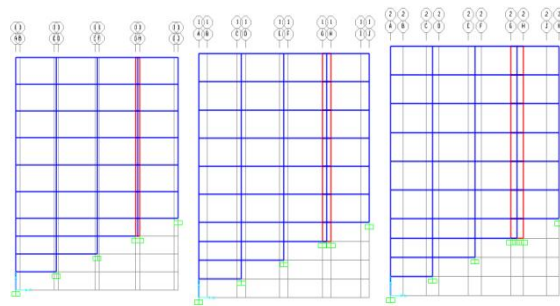
Model 2: (22° Ground Slope)
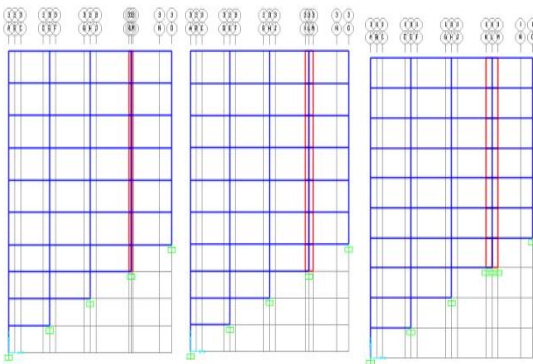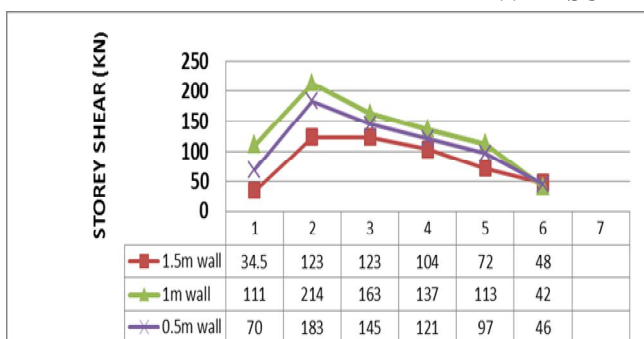

Model 3: (27° Ground Slope)

Model 4: (31 ° Ground Slope)

There are four models in the present figure shown above. Each model have relatively variable ground slope as specified below
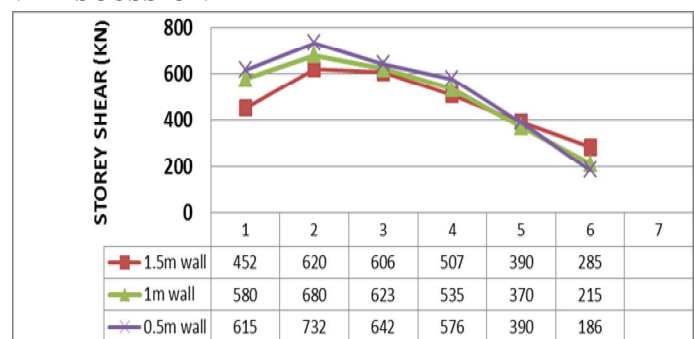
1) *Model (1):* Building frame with shear wall of constant thickness 0.25m and variable width 0.5m, 1.0m and 1.5m respectively at specified location on flat ground.
2) *Model (2):* Building frame with shear wall of constant thickness 0.25m and variable width 0.5m, 1.0m and 1.5m respectively at specified location on ground slope of 22° degrees.
3) *Model (3):* Building frame with shear wall of constant thickness 0.25m and variable width 0.5m, 1.0m and 1.5m respectively at specified location on ground slope of 27° degrees.
4) *Model (4):* Building frame with shear wall of constant thickness 0.25m and variable width 0.5m, 1.0m and 1.5m respectively at specified location on ground slope of 31° degrees. All four models have identical G+5 floors and shear wall position. Only the size of shear wall and slope of ground is varies in all four models. In the analysis the seismic force assumed to be applied toward direction of downward slope because it generates worst effect in term of story shear.

This paper use story shear as important factor, because previous studies emphasize that the building on sloping terrain subjected to seismic load have collapse in story shear. Presented building height is below than 21 meters that's why story drift criteria eliminate. The analysis of building is based on linear static approach it's also called equivalent static analysis approach.

V. RESULT AND DISCUSSION

	1	2	3	4	5	6	7
1.5m wall	34.5	123	123	104	72	48	
1m wall	111	214	163	137	113	42	
0.5m wall	70	183	145	121	97	46	

Graph .1

	1	2	3	4	5	6	7
1.5m wall	452	620	606	507	390	285	
1m wall	580	680	623	535	370	215	
0.5m wall	615	732	642	576	390	186	

Graph .2

STOREY SHEAR (KN)	1	2	3	4	5	6	7
1.5m wall	437	600	579	494	367	265	
1m wall	559	660	596	523	348	198	
0.5m wall	594	708	613	563	367	175	

Graph .3

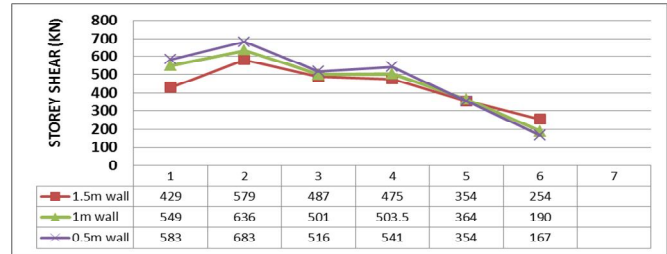| STOREY SHEAR (KN)	1	2	3	4	5	6	7
1.5m wall	429	579	487	475	354	254	
1m wall	549	636	501	503.5	364	190	
0.5m wall	583	683	516	541	354	167	

Graph .4

1) Graph (1) is output result of model (1) in form of story shear
2) Graph (2) is output result of model (2) in form of story shear
3) Graph (3) is output result of model (3) in form of story shear
4) Graph (4) is output result of model (4) in form of story shear

The relation between story shear at different stories for 3 different size of shear wall has shown above in all four graphs. Following outputs (story shear) are based on worst load combination

On comparing carefully the appropriate results, it is clear that the variation in story shear with different stories (0 to 5th) is changes variably. The building on flat ground (model-1) have less story shear induced and model (2), (3) and (4) have noticeable results. When ground slope has 22º (model-2) and 27º (model-3) the variation in story shear was gradual and certain but as ground slope reaches to 31º (model-4), the story shear was relatively less but uncertain. Finally on discussing, the appropriate location of shear wall is effectively working in all three models (i.e. model (1), (2)and (3)) and out of these three models, model (4) is more effective and efficient for greater slope criteria.

VI. CONCLUSION

A. A Story shear encountered for model (1) (i.e. flat ground condition) is very less and have extreme safe for story shear criteria.
B. 9% reduction has been estimated in average story shear in model (4) with respect to model (2).
C. 4% reduction has been estimated in average story shear in model (3) with respect to model (2).
D. 15.2% and 5.4% reduction in average story shear of lower stories have been seen in 1.5m and 1.0m wide shear wall compare with 0.5m wall.
E. Presented location of shear wall (i.e. DD*) working effectively at 31º ground slope.
F. The shear wall of size 0.25m*1.5m has been working effectively in all three ground slopes (22 º, 27 º and 31 º).
G. Hence model (4) with 1.5m wide shear wall (when ground slope is 31 º) is most favourable case for presented (i.e. DD* location) position of shear wall.

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