A Comparative Analysis of RCC Building Resting on Sloping and Normal Ground Under Lateral Forces

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Abstract- *The economic growth and rapid urbanization in hilly region has accelerated the real estate development. Due to this, population density in the hilly region has increased enormously. Therefore, there is popular and pressing demand for the construction of multistorey buildings on hill slope in and around the cities.*

Hill buildings are different from those in plains; they are very irregular and unsymmetrical in horizontal and vertical planes, and torsionally coupled. Hence, they are susceptible to severe damage when affected by earthquake ground motion. Past earthquakes [e.g. Kangra (1905), Bihar-Nepal (1934 & 1980), Assam (1950), Tokachi-Oki-Japan (1968), Uttarkashi-India (1991)][1], have proved that buildings located near the edge of stretch of hills or sloping ground suffered severe damages. Such buildings have mass and stiffness varying along the vertical and horizontal planes, resulting the center of mass and center of rigidity do not coincide on various floors. This requires torsional analysis; in addition to lateral forces under the action of earthquakes. Little information is available in the literature about the analysis of buildings on sloping ground. The investigation presented in this paper aimed at predicting the seismic response of RC buildings with different configuration on sloping and plain ground.

Keywords- R.C.C frame, Staad Pro, Time period.

I. INTRODUCTION

1.1 GENERAL

Due to scarcity of flat land in hilly areas, majority of the buildings is constructed on the hill slopes with regular structural configuration having foundations at different levels. Such buildings pose special structural and constructional problems. The variation of stiffness and mass in vertical as well as horizontal directions, results in center of mass and center of stiffness of a story not coinciding with each other and not being on a vertical line for different floors. A large portion of India is susceptible to damaging levels of seismic hazards. Hence, it is necessary to take in to account the seismic load for the design of structures. In buildings the lateral loads due to earthquake are a matter of concern. The structure should withstand moderate level of earthquake ground motion without structural damage, but possibly with some structural as well as non-structural damage. The annual losses due to earthquakes are very large in many parts of the world. They not only cause great destruction in terms of human casualties, but also have a tremendous economic impact on the affected area. India had witnessed several major disasters due to earthquakes over the past century. In fact more than 50 percent of the country is considered prone to severe earthquakes. The north - east region of the country as well as the entire Himalayan belt is susceptible to great earthquakes of magnitude more than 8.0.

The building is designed as two-dimensional vertical frames and analyzed for the maximum and minimum bending moments and shear forces by trial and error methods as per IS456-2000. The increase in the number of the story of a building and/or the increase in the seismic one factor of the site increases the total cost of RCC building. However, the relationship between these factors may not be linear. The difference in the cost of a regular 21-story building designed for a site defined as seismic zone III and an identical building designed for a site defined as seismic zone V is not necessary to match the difference in the cost of similar buildings but having a different number of stories. Such a comparison, though difficult to carry out due to various factors involved, can be possible through some assumptions. The shape and plinth area of the building is assumed to be constantly fixed throughout the analysis. The costs of all RCC columns for a particular building were determined by computing the amount of PCC (M20) and steel (HYSD) required for the construction and using their prevalent cost rates. The number of construction materials for columns was determined for 4, 6, 8 and 10 story buildings of identical nature for seismic zones III and V by using STAAD Pro analysis and design.

1.2 Safety

Concrete industry is sure that concrete is safer material than others. For example, vertical communications like staircases and elevator shafts is best to build from concrete because it best protects against fire or explosions. At high temperature concrete does not lose its strength or shape, it is fire resistant up to 2 hours, depending on thickness of the construction. Reinforced concrete is resistant to explosions. It fully complies with the provisions that the safest place in the building should be an evacuation route - staircase. Concrete does not require any additional cladding or painting to protect it from fire. Since the concrete is dense and heavy material, designed by the relevant rules, it can even withstand a large storm, or earthquakes. Best engineers and designers are able to design and calculate buildings so that the concrete construction becomes flexible.

1.3 Cost

Market prices for building materials are highly volatile. However, the production cost of concrete is the same. Even if steel price rapidly increases during the global crisis, the fact did not affect the price of concrete. Insurance companies recognize that cast-in-place concrete is more advantage because it is solid and secure. Therefore, it is possible to save up to 25% of the insurance per year, if building is built from reinforced concrete. No matter how bizarre it sounds, but metal construction prices depends on what kind of buildings at any given time are built in the world and how much of steel amount they took. It also depends on the dollar exchange rate fluctuations and other factors, which are limited in most of the world. The price fluctuations are as variable as the ranges for gold or oil.

1.4 Material availability

Concrete supply and availability may limit the availability of transport ships and shipping rates. In the event of a tight supply of any individual regions or countries, the smaller companies either pay abusive prices during concrete price or wait until the concrete is available.

1.5 Construction scheduling

Concrete building construction takes up to twice as long building period than steel buildings. Especially when we are talking about reinforced cast-in concrete. Each floor for reinforced concrete buildings can be built every 2nd to 4th day, depending on the thickness and type of concrete. In one day it can be build up to 4,000 m^2. Such a cyclical construction also gives its advantages in biggest cities, where buildings are tightly next to each other and have limited traffic, where it is difficult to access with cranes and other construction equipment.

1.6 Design possibilities

It is possible to make any desired shape out of concrete. That gives a good scope for design. By using reinforced cast-in concrete floors, it is also possible to reach a wider space in the room, because the thickness of floor is relatively small. In particular, it is typical for offices and multistory buildings. Steel has the highest weight and strength ratio compared to any other building material. With metal construction it is possible to construct a building where between the load-bearing elements there is a relatively large span. With help of steel structures it is possible to build a large overhang - up to 20 meters, what gives building a unique look.

II. LITERATURE REVIEW

Hill buildings are different from those in plains; they are very irregular and unsymmetrical in horizontal and vertical planes, and torsionally coupled. Hence, they are susceptible to severe damage when affected by earthquake ground motion. Past earthquakes [e.g. Kangra (1905), Bihar- Nepal (1934 & 1980), Assam (1950), Tokachi-Oki-Japan (1968), Uttarkashi-India (1991)][1], have proved that buildings located near the edge of stretch of hills or sloping ground suffered severe damages. Such buildings have mass and stiffness varying along the vertical and horizontal planes, resulting the center of mass and center of rigidity do not coincide on various floors. This requires torsional analysis; in addition to lateral forces under the action of earthquakes.

Little information is available in the literature about the analysis of buildings on sloping ground. The investigation presented in this paper aimed at predicting the comparison of RC buildings with different configuration on sloping and plain ground.

1) Sujit Kumar et.al (2014) In this journal, they studied the effect of sloping ground on structural performance of RCC building under Seismic load. They considered G+4 storey RCC building on varying slopes for the analysis. In this study, the slope angles considered for the analysis are 0o, 7.5o and 15o. STAAD Pro v8i is the structural analysis software used to study the effect of sloping ground by considering the seismic forces as per IS: 1893-2002. The parameters taken for the analysis are horizontal reactions, axial force and bending moment column and footing bending moment. They observed that because of increase in stiffness the shorter columns attract more

forces, which in turn increases the bending moment and horizontal forces significantly.

2) Sandip Doijad and SurekhaBhalchandra (2015) In this journal, they studied the seismic behaviour of RC buildings with different configuration of Shear walls on plain and sloping ground. They considered G+8 storey RCC building for analysis. The angle of the sloping ground considered for the analysis along with the levelled ground are 9o, 18o and 27o. The analysis was carried out using SAP2000 software for Zone II and for medium soil. Straight and Symmetrical angle shaped configuration of the shear wall are considered and finally the results are compared. And they observed the increase in Base shear of the building in Y and X direction due to the presence of Shear wall on both sloping and plain ground. They concluded that among the twoconfiguration considered Straight shaped shear wall shows the higher resistance to the lateral forces.
3) P. Manjunath and Yogeendra R. Holebsgilu (2016) They analysed the multi storey building on sloping and plain ground with flat slab. In this study 10 storied 3D model with 4 bays in Y direction and 6 bays in X direction. The slope of the ground is taken between 0o to 30o. ETABS 2015 software is used to analyse and design the model for different soil type and for the seismic zone V. They concluded that decrease in seismic weight is seen when the slope at the base is increased and the performance of the building is increased when the stiffness of the soil is more. They also said that decrease in acceleration, displacement and drift is seen for stiffer soil compared to loose soil.
4) RAHUL PANDEY In research paper "Comparative study of analysis and design of R.C. and steel structures "a 3-D model was prepared for the frame analysis of building in ETABS for the earthquake zone 5 and the results were indicating the same thing that the storey drifts of steel structures are comparatively more than RC structures within the permissible limit. And RCC frame has the lowest value of storey drift because of its high stiffness, which indicates that as the value of stiffness increases, storey drift values decreases with it.
5) NITIN M. WARADE &P.J. SALUNKEsubmitted a research paper "Comparative Study of Analysis and Design of R.C. and Steel Structures" it is concluded that base shear in steel structure is less than the R.C. structure because of the less seismic weight which gives better seismic response during earthquake. In this paper for the frame analysis a 3-D model was prepared in ETABS for the earthquake zone 5.
6) BIMALA PILLAI, PRIYABRATA GUHA The principle objective of this project is to comparison between RCC and Steel Structure and designs a multi-storeyed building using STAAD Pro. The design involves load calculations and analyzing the whole structure by STAAD Pro. The design methods used in STAAD Pro analysis are Limit State Design conforming to Indian Standard Code of Practice. The Thesis involves Staad Modeling, Analysis the members due to the effect of Wind & Seismic load & Compare them for a 35 meter height Building with Concrete & Steel construction. The proposal structure is a 10 storied building with 3.50 m as the height of each floor. The overall plan dimension of the building is 30.0 m x 20.0m.

Dead Weight of the Steel framed structure is much lesser than RCC framed structure.Bending moment due to Wind force is increased in Steel structure for high rise building.

III. METHODOLOGY

I. WORKING WITH STAAD.Pro:

3.1 Input Generation
3.2 Types of Structures
3.3 Generation of the structure
3.4 Material Constants
3.5 Supports
3.6 Loads
- 3.6.1 Joint loads
- 3.6.2 Member load
- 3.6.3 Area/floor load
- 3.6.4 Fixed end member load
- 3.6.5 Load Generator – Moving load, Wind & Seismic
- 3.6.6 Moving Load Generator
- 3.6.7 Seismic Load Generator
- 3.6.8 Wind Load Generator

3.7 General Comments
- 3.7.1 Allowable Stresses
- 3.7.2 Multiple Analyses

3.8 Post Processing Facilities
- 3.8.1 Stability Requirements
- 3.8.2 Deflection Check
- 3.8.3 Code Checking

II. LOADS CONSIDERED

3.9 Dead Loads
3.10 Imposed Loads:
3.11 Wind Load:
- 3.11.1 Design Wind Speed (V,)
- 3.11.2 Risk Coefficient
- 3.11.3 Terrain, Height and Structure Size Factor

3.11.4 Topography
3.12 Wind Pressures and Forces on Buildings/Structures
3.13 SEISMIC LOAD:
3.13.1 Design Lateral Force
3.13.2 Design Seismic Base Shear
3.13.3 Fundamental Natural Period
3.13.4 Distribution of Design Force
3.13.5 Dynamic Analysis
3.13.6 Time History Method-
3.13.7 Response Spectrum Method-

IV. BUILDING DETAILS

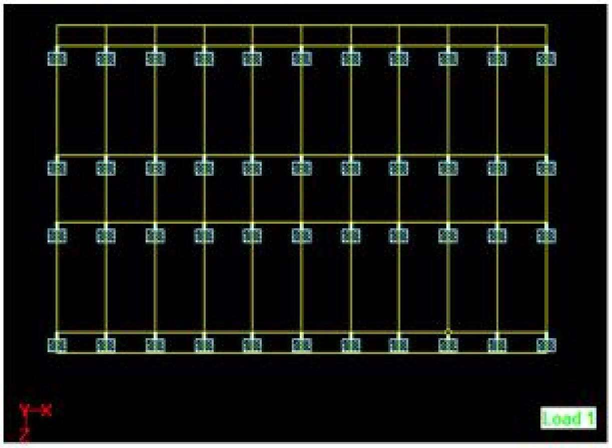


Fig.1 Plan showing typical floor

The building considered here is a residential building. The plan dimension is 40m x 24m. The study is carried out on the same building plan for both R.C.C construction on plain and sloping terrain. The basic loading on both types of structures are kept same.

Table no:1 Data analysis for R.C.C structure

DESCRIPTION	R.C.C
Plan dimension	24mx40m
Total height of the building	52.85m
Height of each storey	3.3m
Size of beams 8.0m spans	300x450mm
Size of beams 5.0m spans	300x375mm
Size of beams 4.0m spans	300x375mm
Size of beams 1.5m spans	300x450mm
Size of columns up to 8th floor	450x750mm
Size of columns up to 15th floor	450x450mm
Thickness of slab	150mm
Thickness of external walls	230mm
Thickness of internal walls	115mm
Seismic zone	III
Wind speed	50m/s
Soil condition	Hard soil
Importance factor	1.0
Zone factor	0.16
Floor finish	1.5kN/m2
Live load at all floors	3.0kn/m2
Grade of concrete	M30
Grade of steel	Fe415
Density of concrete	25kN/m3
Density of brick	18kN/m3
Damping ratio	5%
Design software	STAAD Pro V8I
Analysis type	Static analysis

4.1 Physical parameters of building:

Length = 10 bays @ 4.0m = 40.0m
Width = 3 bays @ (1.5 Projection8+5+8+1.5 Projection8) =24.0m
Height = 15 storeys @ 3.3m = 52.8m
(1.0m parapet being non- structural for seismic purposes, is not considered of building frame height)
Live load on the floors is 3kN/m2
Live load on the roof is 1.5kN/m2

Grade of concrete and steel used:

Used M30 concrete and Fe 415 steel

4.2 Generation of member property for RCC structure on plain ground:

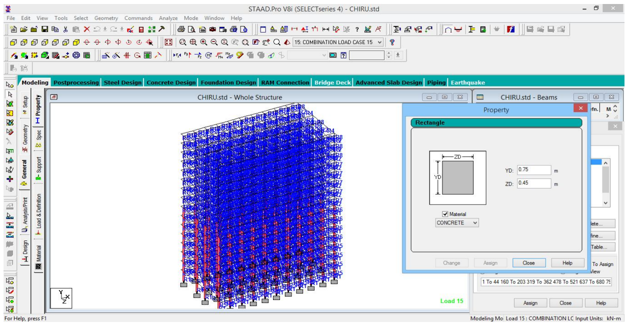


Fig 4

Generation of member property can be done in **STAAD.Pro**by using the window as shown above. The member section is selected and the dimensions have been specified. The beams are having a dimension of following:

Size of beams 8.0m spans 300x450mm
Size of beams 5.0m spans 300x375mm
Size of beams 4.0m spans 300x375mm
Size of beams 1.5m spans 300x450mm
Size of columns up to 8th floor 450x750mm
Size of columns up to 15th floor 450x450mm

4.3 Generation of member property for RCC structure on Hilly Terrain:

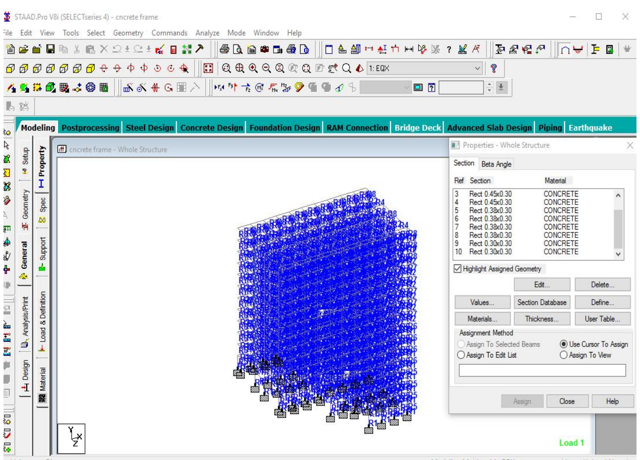


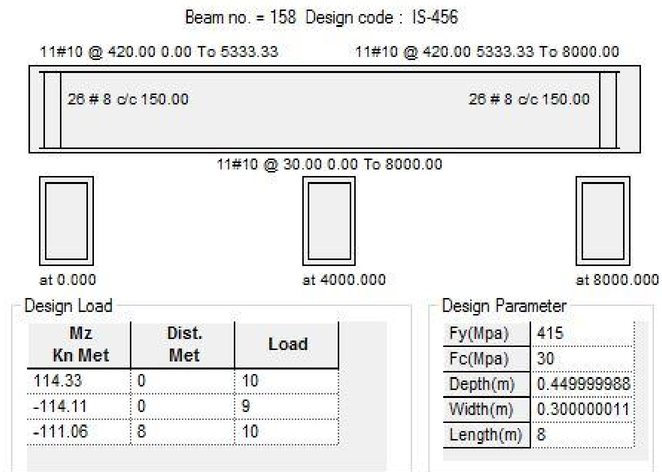
Fig 5

Generation of member property can be done in **STAAD.Pro** by using the window as shown above. The member section is selected and the dimensions have been specified. The beams are having a dimension of following:

Size of beams 8.0m spans ISMB550
Size of beams 5.0m spans ISMB400
Size of beams 4.0m spans ISMB300
Size of beams 1.5m spans ISMB250
Size of columns up to 8th floor ISWB600H
Size of columns up to 15th floor ISWB400

4.4 Design Output

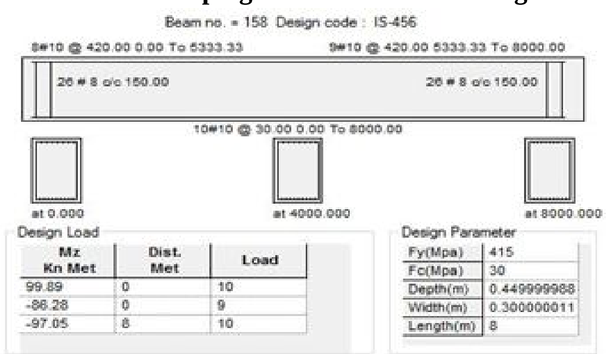
RCC Structure Plain Ground Concrete Design Results



S.NO	FACTOR	R.C.C BUILDING PLAIN TERRAIN
1	Time period	1.45 sec
2	Maximum nodal displacement	181mm
3	**Maximum support reaction**	
	FY (D.L)	1810kN
	FY(L.L)	1240kN
4	**Storey drift**	
	x-direction	0.57 cm
	z-direction	1.705 cm
5	Base shear	672kN
OUTER COLUMN(COLUMN NO.495)		
7	Deflection	8.9mm
8	**Maximum bending moment**	
	My	284.2 KN.m
	Mz	193.8 KN.m
9	**Maximum shear force**	
	Fy	46.8kN
	Fz	87.1kN
10	Axial force	1384kN
INNER COLUMN(COLUMN NO.22)		
11	Deflection	8.9mm
12		
	My	325.2kN.m
	Mz	204.8kN.m
13	**Maximum shear force**	
	My	52.3kN
	Mz	114.9kN
14	Axial force	1384kN
END BEAM(BEAM NO.46)		
15	Deflection	7.0 mm

16	**Maximum bending moment**	
	My	0.45 kN.m
	Mz	141.5kN.m
17	**Maximum shear force**	
	Fy	0.15 kN0
	Fz	39.6kN
INTERMEDIATE BEAM(BEAM NO.101)		
18	Deflection	8.8 mm
19	**Maximum bending moment**	
	My	0.28 kN.m
	Mz	254.0kN.m

RCC Structure Sloping Terrain Concrete Design Results



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4.5 Cost Comparison

COST ANALYSIS				
STRUCTURE TYPE	MATERIALS	QUANTITY USED	RATE OF MATERIAL	AMOUNT
R.C.C on Plain Ground	CONCRETE	1570 CUM	8500/CUM	1,33,45,000
	STEEL	157 MT	52000/MT	81,64,000
			TOTAL AMOUNT	2,15,09,000
R.C.C on Hilly Terrain	CONCRETE	1345 CUM	8500/CUM	1,14,32,500
	STEEL	150 MT	52000/MT	78,00,000
			TOTAL AMOUNT	1,92,32,500

V.CONCLUSION

Analysis and design results of R.C.C Structure on Plain Ground and Sloping Terrain are given in chapter. The comparison of results of building shows that:-

- Although, the buildings on plain ground attract less action forces as compared to buildings on sloping ground, overall economic cost involved in levelling the sloping ground
- In buildings on sloping ground, it is observed that extreme left column at ground level, which are short, are the worst affected. Special attention should be given to these columns in design and detailing.
- The graph shows that there is significant reduction in bending moments of columns in Z Direction from R.C.C Structure on Plain Ground and Sloping Terrain
- Base shear of R.C.C Structure on sloping terrain is very less compared to R.C.C structure plain ground.

- The storey drift in R.C.C Structure on Plain Ground and Sloping Terrain is nearly equal. This is because; steel structure is more flexible as compared to RCC structure.
- Bending moment is seem to be reduced due to step up columns in R.C.C Structure on sloping terrain
- The bending moment in column is increase at base of frame due to the long column and short column effect in R.C.C Structure on sloping ground.
- From the study, it is observed that the building which are resting on sloping are subjected to short column effect , attract more forces and are worst affected during seismic excitation. Hence form design point of view, special attention should be given to the size, orientation, and ductility demand of short column.
- It is also found that the hill slope building are subjected to significant torsional effects due to uneven distribution of Axial force in the various frames of building suggest development of torsional movement which is found to be higher on a sloping ground building. This values further reinforce the concept of short column effect as well as torsion and twisting develop in structure due to uneven heighted column.

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