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RESEARCH ARTICLE -ENGINEERNG TECHNOLOGY

Free Vibration and Seismic Analysis on Sloping Ground Considering Different Structural System

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Abstract: Due to scarcity of the plain ground in city areas buildings are being constructed on sloping ground. Buildings constructed on sloping grounds are characterized by plan and elevational irregularity and their center of mass and center of stiffness are not coinciding. The columns of building are resting at different level in vertical planes on sloping ground and they are loaded with varying loads depending on their locations. In order to analyze and design buildings on sloping ground it is required to find effect of slopes on the structural members of building. The bending moments in columns under lateral loadings are higher due to short column effect in sloping building. The stiffness of column sis higher on sloping ground due to reduction in length of columns. In order to study this effects building is modelled in FE software SAP 2000 with 39-degree slope. To reduce the short column effect, it is modelled using V and X bracing at ground floor level and at corner bay of building. It is subjected to seismic forces and nonlinear analysis is performed. After investigation it is concluded that bracing system provides effective solution to reduce severe seismic forces for building constructed on sloping regions

Keywords: Sloping ground, Seismic response,X bracing, Diagonal bracing and inverted V bracing

1. Introduction

Any area having an altitude of more than 600 m from the mean sea level or an average slope of 30 may be classified as hilly in India, which includes the Himalayas, the Central Highlands, the Deccan Plateau and the north eastern hill ranges. Depending upon the altitude and prevailing climatic conditions, hill regions have been classified into three categories as Foot-hill regions (below 1200 m), Mid-Hill regions (1200–3500 m) and High-hill regions (above 3500) Analysis of buildings in hill region is somewhat different than the buildings on levelled ground, since the column of the hill building rests at different levels on the slope. 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, hence they demand tensional analysis, in addition to lateral forces under the action of earthquakes. The unsymmetrical buildings require great attention in the analysis and design under the action of seismic excitation. Past earthquakes in which, buildings located near the edge of a stretch of hills or on sloping ground suffered serious damages. The shorter column attracts more forces and undergoes damage, when subjected to earthquakes. The other problems associated with hill buildings are, additional lateral earth pressure at various levels, slope instability, different soil profile yielding unequal settlement of foundation

In this study, the main objective is to understand the behaviour of the building on sloping ground for various types of frame and improve short column effect by applying different types of bracing at different patent to study the effect of building on sloping ground. The performance of building has been studied with the help of Structural Analysis Program (SAP) models. For this purpose a building on sloping ground is modelled and appropriate size of beam ad columns are assigned to the building, different Earthquake (EQ) analysis such as static, dynamic are carried out In this study, some observations about seismic behaviour of hill building during the worst earthquake of Bhuj and other earthquakes are studied. An analytical study is also performed to investigate seismic behaviour of hill buildings. Dynamic response of hill buildings is compared with that of static response of the same buildings in terms of base shear for static and dynamic cases and deflection for static and dynamic cases

The seismic behavior of typical configuration of hill buildings is investigated using linear time history analysis. It is observed that hill buildings have significantly different dynamic characteristics so dynamic analysis must be performed for this type of buildings the stores immediately above the road level, in case of down-hill building, are particularly vulnerable to earthquake action. The analytical finding is corroborated by the damage pattern observed during earthquake.

2. Numerical Data

The finite element analysis software SAP2000 Nonlinear is utilized to create 3D model and run all analyses. The software is able to calculate the geometric nonlinear behavior of space frames under static or dynamic loadings, taking into account both geometric nonlinearity and material inelasticity. The software accepts static loads (either forces or displacements) as well as dynamic (accelerations) actions and has the ability to perform Eigen values, nonlinear static pushover and nonlinear dynamic analyses. To reduce short column effect provide different types of bracing like diagonal, inverted V and X bracing at its different patent. There are three different configuration take in this paper shown as below

TYPE-1 first type of configuration takes a bracing on it every ground floor

TYPE-2 another type building have providing bracing at corner of the building and

TYPE-3 last one of the building is providing bracing at slope of building

[1] Space Frame: G + 10storey
[2] Angle of slope in ground: 39 degree
[3] Height of Ground floor - 3.5 m
[4] Height of typical floor - 3.5 m
[5] In X direction 4 bays of 7 m x 5m
[6] In Y direction 3 bays of 5 m x 7m
[7] Floor thickness: 0.125
[8] Size of beam: 230mm x 500mm
[9] Size of column: 300mm x 850mm
[10] Bracing size:400mmx400mm
[11] Density of concrete: 25kN/m^2

Volume 8, Issue 1, Jan. 2019, PP.70-83

Loads:

[1] Wall load On typical floor level: 16kN/m
[2] Live load : $3kN/m^2$
[3] Dead load : $4.125kN/m^2$ (including Floor finish.)

For Static analysis:

[1] Zone - 5
[2] Importance factor: 1
[3] Response Reduction Factor: 5
[4] Soil Type: Medium soil.

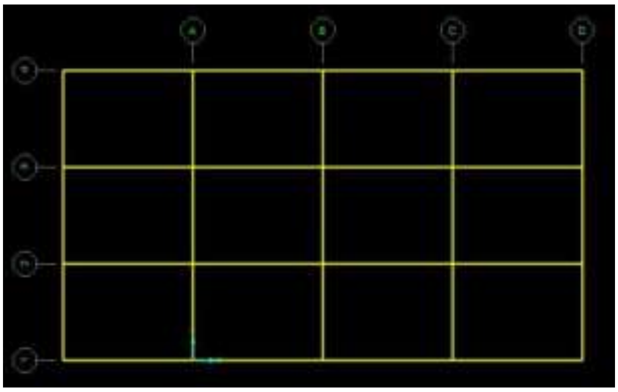

Figure 1 Plan of Building

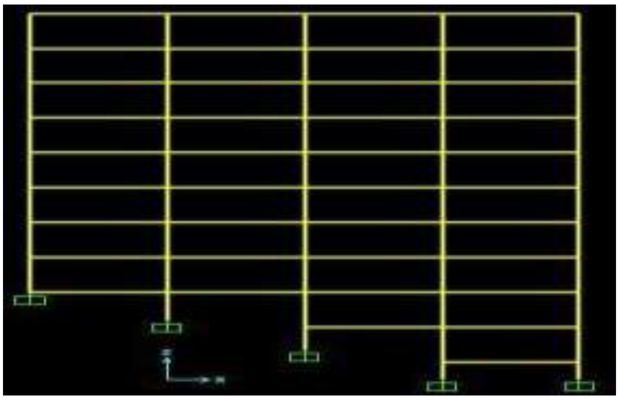

Figure 2 Elevation of Building

Journal of Engineering Technology
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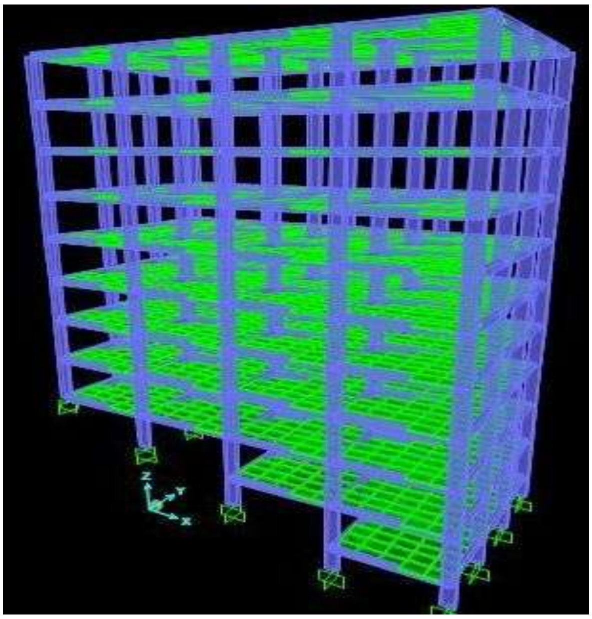

Figure 3 3D View of Building

3. RESULTS AND DISCUSSIONS

The analysis results in terms of Time period, Displacement and maximum moment and maximum shear force data is shown. The time period of structure is shown in Fig 4, Fig-5 & Fig-6.Mode-1 time period value is shown in table-1. Response and Earthquake base shear load is shown in table-2 and displacement of different frame structural system shown in figure-7 to figure-15. The summary of lateral loads due to earthquake and Response is shown in Table 1 It is observed that storey displacement in x-direction and y-direction due to earthquake load is higher compared. In sloping ground building main problem is short column effect due to It short size it has large moment and shear force are coming so to improve various structural system provide bracing and compare at table-3 which system have high moment and shear and which system or patent is best for to reduce short column effect.

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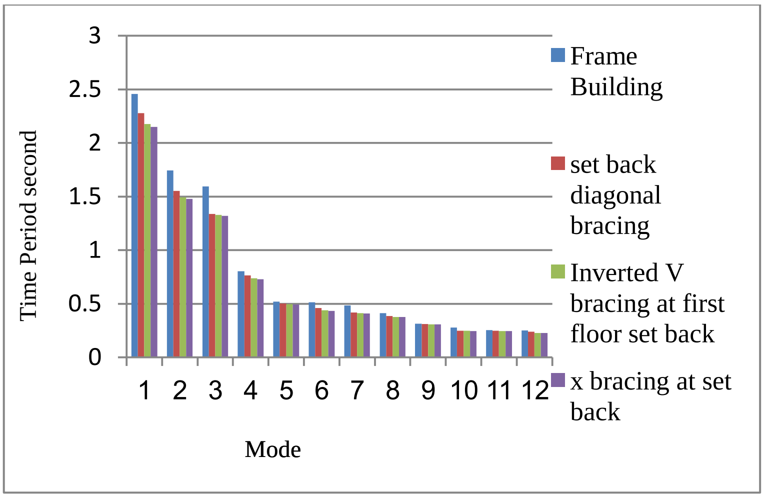

Figure 4 Time Period of Type-1 and frame Structural system for Different Mode

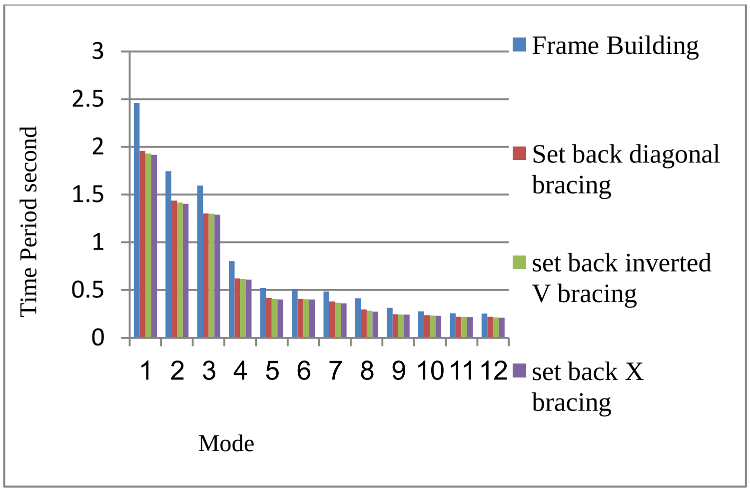

Figure 5 Time Period of Type-2 and Frame Structural system for Different Mode

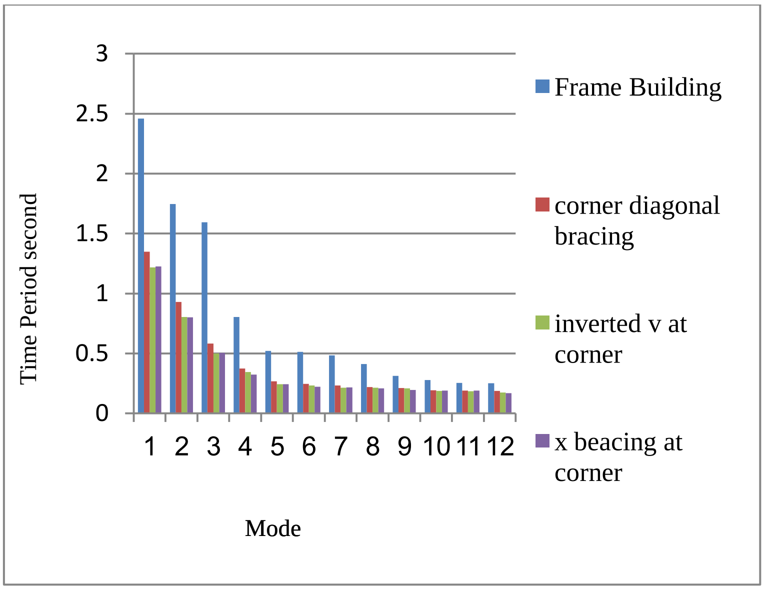

Figure 6 Time Period of Type-3 and Frame Structural System for Different Mode

Table 1 First Mode Time Period of Different Type of Building

Type of building	Structural System	Time period mode-1[second]
Frame	Frame	2.45
Type-1	Diagonal Bracing	2.27
	Inverted V Bracing	2.17
	X Bracing	2.15
Type-2	Diagonal Bracing	1.95
	Inverted V Bracing	1.93
	X Bracing	1.91
Type-3	Diagonal Bracing	1.35
	Inverted V Bracing	1.21
	X Bracing	1.22

Journal of Engineering Technology
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Table 2 Base shear of Different Seismic Loading

Type of building	Structural System	EQx KN	EQy KN	RES X KN	RES Y KN
Frame	Frame	2058.5	1461	2098	1489
Type-1	Diagonal Bracing	2326	1585	2372	1616
	Inverted V Bracing	2423	1661	2470	1693
	X Bracing	2454	1688	2502	1720
Type-2	Diagonal Bracing	3960	2725	4028	2741
	Inverted V Bracing	4606	3046	4697	3105
	X Bracing	4696	3070	4887	3130
Type-3	Diagonal Bracing	2538	1865	2887	1901
	Inverted V Bracing	2593	1900	2643	1937
	X Bracing	2624	1937	2694	1975

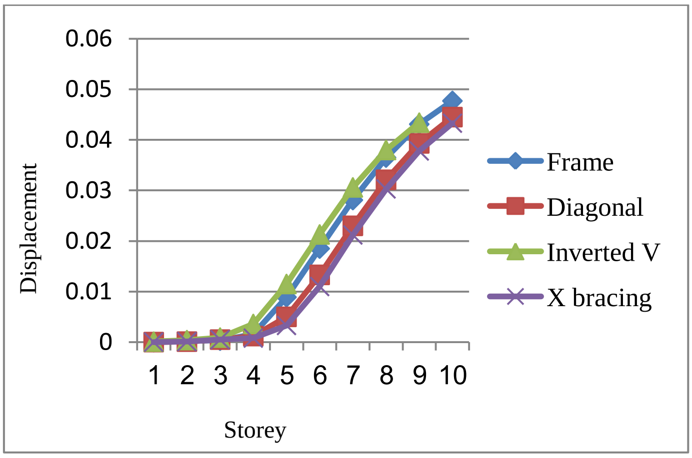

Figure 7 Displacement due to Earthquake at X direction of Frame &Type-1 Structural systems.

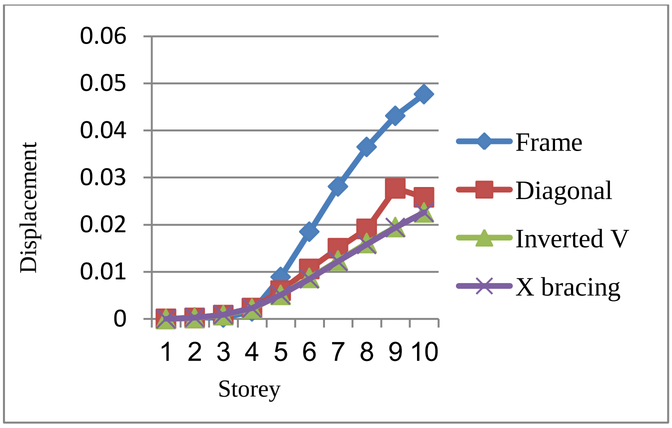

Figure 8 Displacement due to Earthquake at X direction of Frame &Type-2 Structural systems.

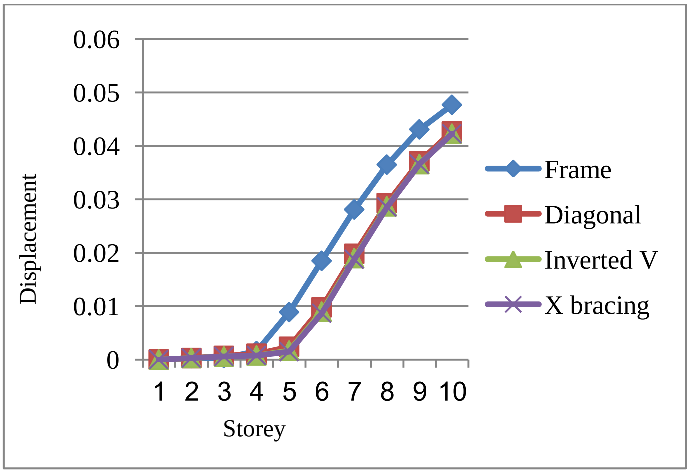

Figure 9 Displacement due to Earthquake at X direction of Frame &Type-3 Structural systems.

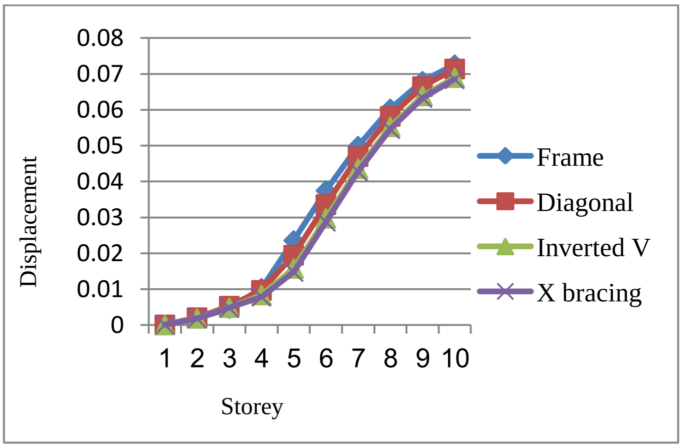

Figure 10 Displacement due to Earthquake at Y direction of Frame &Type-1 Structural systems.

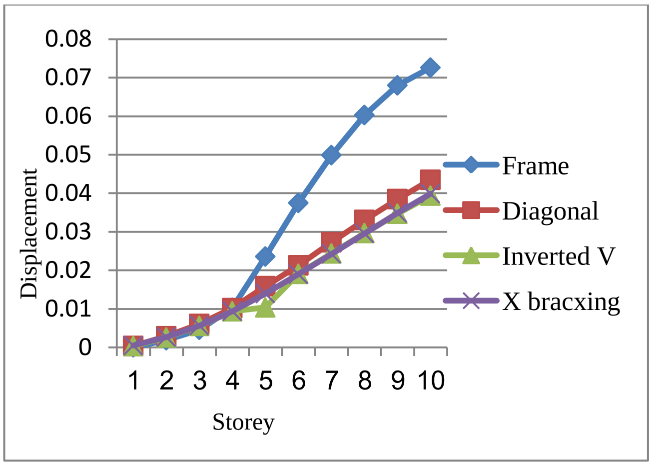

Figure 11 Displacement due to Earthquake at Y direction of Frame &Type-2 Structural systems.

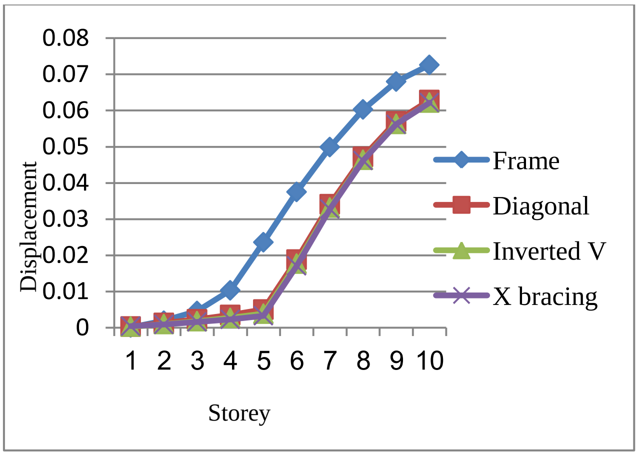

Figure 12 Displacement due to Earthquake at Y direction of Frame &Type-3 Structural systems.

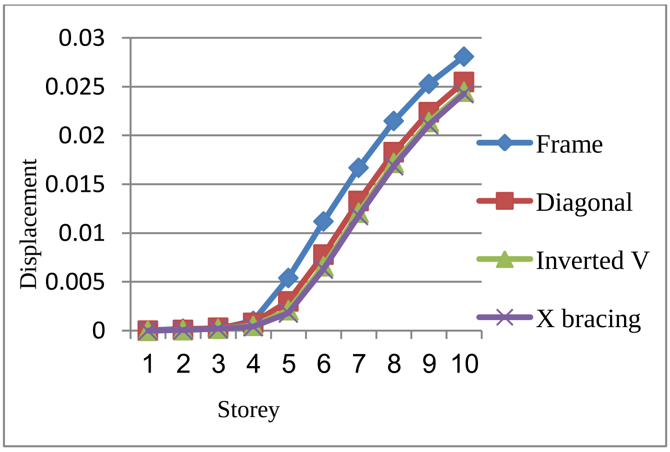

Figure 13 Displacement due to Response at X direction of Frame &Type-1 Structural systems.

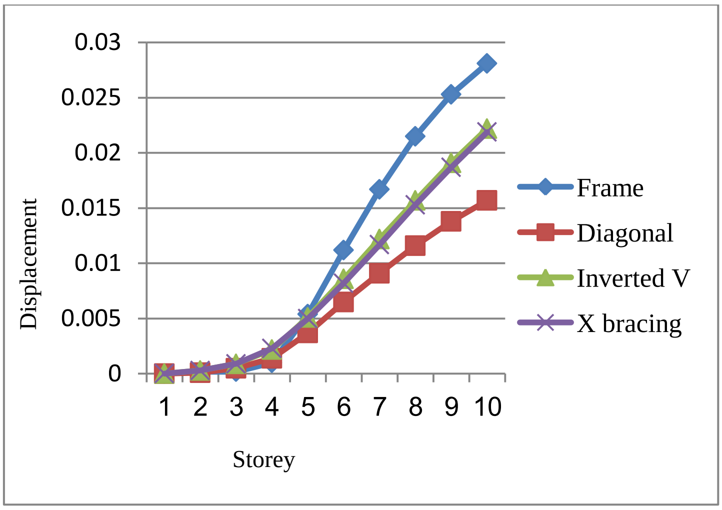

Figure 14 Displacement due to Response at X direction of Frame &Type-2 Structural systems.

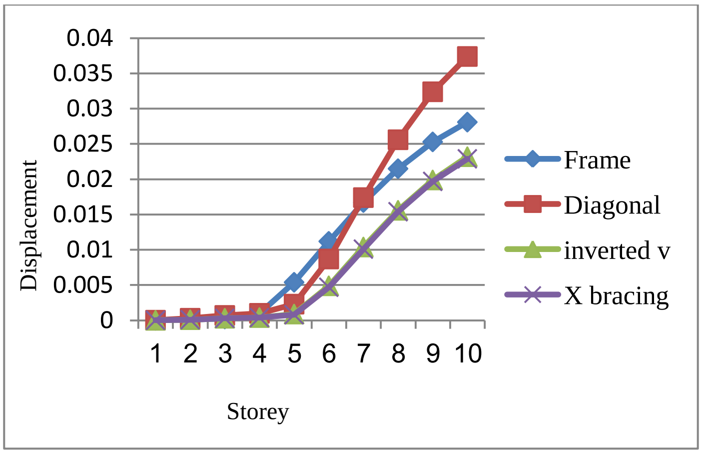

Figure 15 Displacement due to Response at X direction of Frame &Type-3 Structural systems.

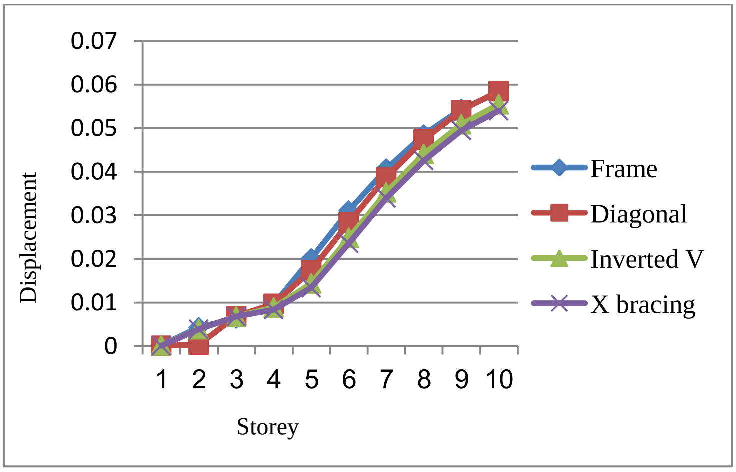

Figure 16 Displacement due to Response at Y direction of Frame &Type-1 Structural systems.

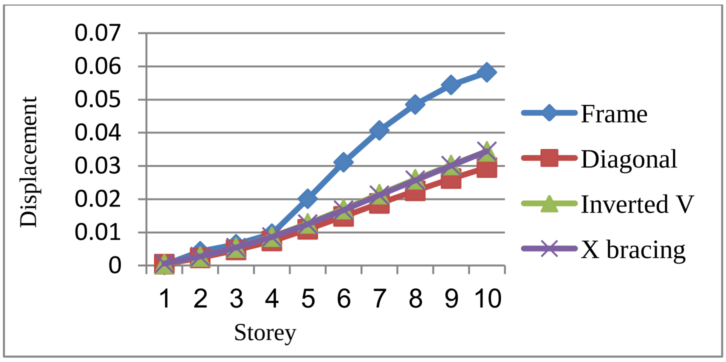

Figure 17 Displacement due to Response at Y direction of Frame &Type-2 Structural systems.

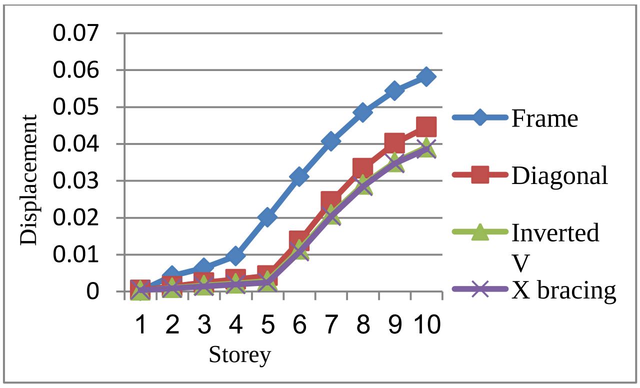

Figure 18 Displacement due to Response at Y direction of Frame &Type-3 Structural systems

Table 3 Shortest Column X Direction Moment and Shear

Types of Building	Structural System	Moment (KN.m)	Shear (KN)
Frame Building	Frame Structure	**795.3**	**564.1**
Type-1	Diagonal Bracing	904	988
	Inverted V bracing	563	636.91
	X Bracing	945	1121.7
Type-2	Diagonal Bracing	920.1	931.2
	Inverted V bracing	871.08	1045.3
	X Bracing	**1182.06**	**1311.56**
Type-3	Diagonal Bracing	367.6	433.13
	Inverted V bracing	311.3	280
	X Bracing	**169.9**	**215**

Table 4 Displacement of Top Storey at different Earthquake Loading

Type of building	Structural System	EQx mm	EQy mm	RES X mm	RES Y mm
Frame	Frame	0.0477	0.0726	0.0281	0.0582
Type-1	Diagonal Bracing	0.0445	0.0714	0.0255	0.0585
	Inverted V Bracing	0.0434	0.069	0.0245	0.0555
	X Bracing	0.0433	0.0685	0.0243	0.054
Type-2	Diagonal Bracing	0.0258	0.0435	0.0157	0.0295
	Inverted V Bracing	0.0226	0.0394	0.0222	0.0344
	X Bracing	0.0226	0.0399	0.0219	0.0344
Type-3	Diagonal Bracing	0.0427	0.0629	0.0281	0.0446
	Inverted V Bracing	0.0423	0.0622	0.0374	0.0391
	X Bracing	0.0423	0.0622	0.0229	0.0386

4. Summary and conclusions

The economic growth & 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 & pressing demand for the construction of multi -storey buildings on hill slope in and around the cities.

The buildings situated on hill slopes in earthquake prone areas are generally irregular, torsional coupled & hence, susceptible to serve damage when affected by earthquake ground motion. Such buildings have mass & stiffness varying along the vertical & horizontal planes, resulting the center of mass & center of rigidity do not coincide on various floors, hence they demand torsional analysis, in addition to lateral forces under the action of earthquakes. These unsymmetrical buildings require great attention in the analysis & design. Analysis of hill buildings is somewhat different than the buildings on levelled ground, since the column of hill building rests at different levels on the slope. The shorter column attracts more forces & undergoes damage, when subjected to earthquakes.Due to this various problem occurs on sloping ground building the structural safety of building is requiring necessary. so providing various bracing system to improve stability.

- The displacement response of building on the sloping ground is more as compared with the level ground.
- Time period of building is decrease in type -1 , type-2 and type-3 type building as compare to frame building.

- Minimum time period in type-3 inverted bracing building and maximum time period in frame structural system.
- Displacement of different type building has increase height increase.
- Displacement of building has more improvement in type-2 structural system as compare to another type of building.
- The bending moment and shear force increases in type-1 & type -2 structural system building.
- Building have minimum moment and shear force in type -3 X- bracing building and maximum at type-2 X bracing system.

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