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Research Paper on Effect of Earthquake on RCC Building over Hilly Terrain Area

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***Abstract:** This research paper consists on effects of earthquake on RCC building over hilly terrain area. The Indian standard code of practice IS- 1893 (Part I: 2002), IS-13920, IS-456-2000 guidelines and methodology are used to analyze and designed building. Buildings on hilly terrain require more attention than those on plane ground. On the slopes, buildings are always irregular and unsymmetrical in shape and have foundations at different levels. Such buildings pose special structural and constructional problems. In this work, seismic analysis of RCC buildings of (i.e. G+14) on hilly terrain with different slopes of 11^0, 18^0 and 27^0 has been carried out. Etab2015 structural analysis software is used to analyze buildings on hilly sloping ground under the effect of earthquake forces in zone III and V. Building having plan dimension 21m x 15m, resting on level ground has been analyzed & compared with similar buildings resting on sloping terrain. Seismic Analysis is done by Response spectrum method. The behaviour of building components was examined and compared in this work. Seismic characteristics in terms of displacement, story drift, time period and base shear have been compared with various models. In addition to these, twisting, torsion, short column effect, variation in moments of beams and columns.*
***Keywords:** Etab2015, hilly terrain, irregular, Response spectrum method, seismic analysis, unsymmetrical, zone III and V.*

I. INTRODUCTION

Earthquakes have raised concern regarding the issue of safety of existing buildings. Constructing a structure on plain ground itself requires proper care to make it seismic resistant as per IS: 1893. Needless to say, hilly terrain structures are even more tricky. The safety from hazards is possible by means of seismic evaluation and performance & retrofitting of existing structures. Disaster due to Earthquake has always been one of the greatest natural calamities thrust upon mankind since time immemorial, bringing in its wake untold miseries and hardships to the people affected.

There is general saying that it's not the earthquake which kills people but it's the bad engineering which kills people. With industrialization came the demand of high rise building and came dangers with that. During past earthquakes, reinforced concrete (RC) frame buildings that have columns of different heights within one storey, suffered more damage in the shorter columns as compared to taller columns in the same storey. of buildings on hill slope in active seismic belts is of great concern, due to the loss of lives in the past earthquakes. It is necessary to study the seismic behaviour of reinforced concrete framed buildings located on hilly terrain, under earth quake excitations. the building regulations are very important in India. Stairs cannot be built too steep, they can't be over a certain number of steps before a landing, the headroom must be considered, the handrails to have a minimum height with a minimum space between the balusters, a stair has to have a landing at a doorway and so on. Be sure to check your local regulations. All the treads should be the same width, and all the risers should be the same height. Watch the head height clearance. Our minimum is 2.1m, (just about door height). This is measured vertical from the nosing line of the tread. In effect you should not have to duck your head going up a stair.

A. The objective of the paper is to be

1) To study Hilly slope buildings, considering earthquake forces for zone III and V of India & their Influence on buildings.
2) To study effect of center stair case on plain ground and sloping ground by using response spectrum method. Analysis of buildings on sloping ground with different angles of slope 11^0,18^0 and 27^0 in longitudinal and transverse direction using software E-Tab 2015.
3) To analyze and study un-symmetry with same high of building.
4) To study the variation of base shear, storey displacement, storey drift, column forces with respect to variation in number of bays, hill slope angle, storey height of building frames.
5) Carry out 3-D analysis using Response Spectrum Method on sloping grounds.

II. MATERIALS AND METHODS

A. *Structural Configure ration*

1) Plan Dimension: 21 x 15m
2) Height of Floor: 3m
3) Slab Thickness: 150mm
4) Inclined Slab Thickness: 150mm
5) Full Brick Wall: 230 mm thick
6) Internal Brick Wall: 230 mm thick
7) Grade of concrete: M30 & M35
8) Grade of steel: Fe500 & Fe550
9) Parapet wall height 1 m.
10) Density of concrete 25 KN/m^3
11) Density of masonry wall 20KN/m^3

B. *Seismic data (As per IS: 1893)*

1) Zone factor: 0.16 & 0.36 (Zone III & V rasp.)
2) Response reduction factor: 5 (SMRF)
3) Important factor: 1.5
4) Type of Soil: II,(Medium Soil)
5) Damping: 0.05

C. *Loading data* (as per IS 875-Part I & II)

1) DL due to Slab 3.75 Kn/m^2
2) DL due to Full Brick Wall 11.04 Kn/m
3) LL 3.0 Kn/m^2
4) RLL 1.5 Kn/m^2
5) FF 1 Kn/m^2
6) RFF 2 Kn/m^2

D. *Combinations*

In the limit state design of reinforced, the following load combinations are considered:

1) 1.5 DL + 1.5 LL
2) 1.5 DL + 1.5 RSAX
3) 1.5 DL - 1.5 RSAX
4) 1.5 DL + 1.5 RSAY
5) 1.5 DL - 1.5RSAY
6) 1.2 DL + 1.2 LL + 1.2 RSAX
7) 1.2 DL + 1.2 LL - 1.2 RSAX
8) 1.2 DL + 1.2 LL + 1.2 RSAY
9) 1.2 DL + 1.2 LL - 1.2 RSAY
10) 0.9 DL + 1.5 RSAX
11) 0.9 DL - 1.5 RSAX
12) 0.9 DL + 1.5 RSAY
13) 0.9 DL - 1.5 RSAY

Table No. 1: Properties of Table for Building Configure rations

Stories	Size of Column	Size of Beam
G+14	600mmX 600mm	300mmX600mm

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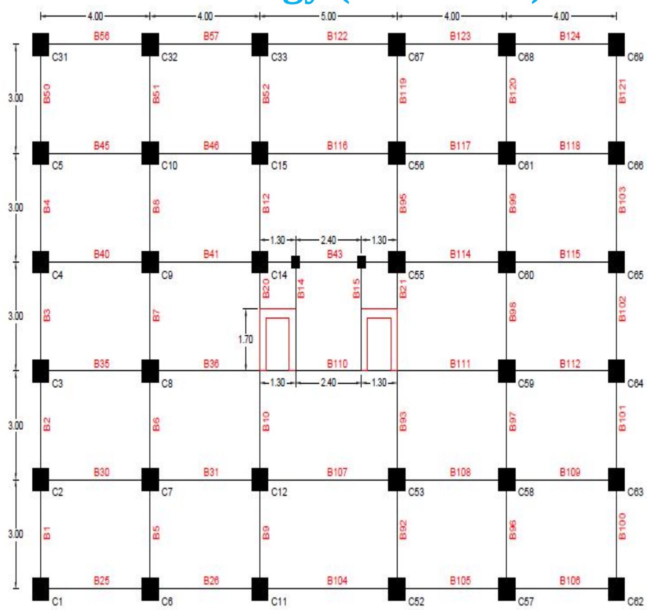

Figure 1:Plan of Building

E. Method of Analysis

Analysis is done by using ETAB 2015 with response spectrum method.

Basic four types of models are considered:

1) Rectangular building of G+14 stories on plain ground.

2) Rectangular building of G+14 stories on 11^0 sloping ground.

3) Rectangular building of G+14 stories on 18^0 sloping ground.

4) Rectangular building of G+14 stories on 27^0 sloping ground.

5) Analysis is done in three different case studies as follows

a) In Case Study, I: All the structural models i.e. (Buildings resting on Plain Ground, on 11^0 sloping ground, on 18^0 sloping ground, on 27^0 sloping ground) are compared in Zone III and Zone V respectively considering parameters such as base shear, drift, displacement, time period, column axial load, column bending moment, column shear force.

b) In Case Study II: In this study, Case-1 Building resting on Plain Ground is compared with Building resting on 11^0 sloping ground, Case-2 Building resting on Plain Ground is compared with Building resting on 18^0 sloping ground, Case-3 Building resting on Plain Ground is compared with Building resting on 27^0 sloping ground are compared in Zone III and Zone V respectively considering parameters such as drift, displacement, time period.

c) In Case Study III: In final case study, Buildings resting on Plain Ground, on 11^0 sloping ground, on 18^0 sloping ground and on 27^0 sloping ground are compared in Zone III and Zone V respectively considering parameters such as drift, displacement, Time Period. As plan of structure is irregular type as per IS code 1893-2002 provision for irregular shape dynamic analysis is necessary. Method adopted for dynamic analysis by response spectrum method IS 1893-2002 is used.

d) Design Spectrum: The design horizontal seismic coefficient (αh)

$\alpha h = (Z/2*I/R*Sa/g)$

Where, Z= Zone factor given in Table 2 (as per IS 1893 Part1)

Table No.2: Zone factor

Seismic Zone	II	III	IV	V
Seismic Intensity	Low	Moderate	Severe	Very Severe
Z	0.10	0.16	0.24	0.36

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= Importance factor, (as per Table 6, IS 1893 Part1)

R=Response reduction factor, (as per Table 7, IS 1893 Part1)

Sa/g= Average response acceleration coefficient for rock or soil sites as given by Figure. 2 and Table 3 based on appropriate natural periods and damping of the structure. These curves represent free field ground motion.

For Sa/g:

Time Period (Ta) = $(0.09h/\sqrt{d})$

Where, h= Height of building,

d=Base dimension of the building at the plinth level, in m, along the considered direction of the lateral force.

Table No. 3: Percentage of Imposed Load (Live load) to be considered in Seismic Weight Calculation

Imposed Uniformity Distributed Floor Loads(Kn/m2)	Percentage of Imposed Load
Upto and including 3.0	25
Above 3.0	50

Design Seismic Base Shear (V_B)

The total design lateral force or design seismic base shear (V_B) shall be determined by the following expression:

$V_B = \alpha h * W$

Where, αh = design horizontal seismic coefficient

W=Seismic weight of the building as per IS 1893 (part1)

IV. RESULTS AND DISCUSSION

A. Case Study I

1) Results for Building Resting on Plain Ground.

Table No. 4: Comparison of Storey Drift on plain ground in (X & Y Direction)

Sr. No.	Direction	Drift X direction (RSAX)		Drift Y direction (RSAY)	
	(Degree)	0^0		0^0	
	Story's	Zone III	Zone V	Zone III	Zone V
15	Story 15	0.001	0.001	0.000	0.000
14	Story 14	0.001	0.001	0.000	0.000
13	Story 13	0.001	0.001	0.000	0.000
12	Story 12	0.001	0.001	0.000	0.000
11	Story 11	0.001	0.001	0.000	0.000
10	Story 10	0.001	0.001	0.001	0.001
9	Story 9	0.001	0.001	0.001	0.001
8	Story 8	0.001	0.002	0.001	0.001
7	Story 7	0.001	0.002	0.001	0.001
6	Story 6	0.001	0.002	0.001	0.001
5	Story 5	0.001	0.002	0.001	0.001
4	Story 4	0.001	0.002	0.001	0.001
3	Story 3	0.001	0.002	0.001	0.001
2	Story 2	0.001	0.002	0.001	0.001
1	Story 1	0.001	0.001	0.000	0.000
0	Story 0	0.000	0.000	0.000	0.000

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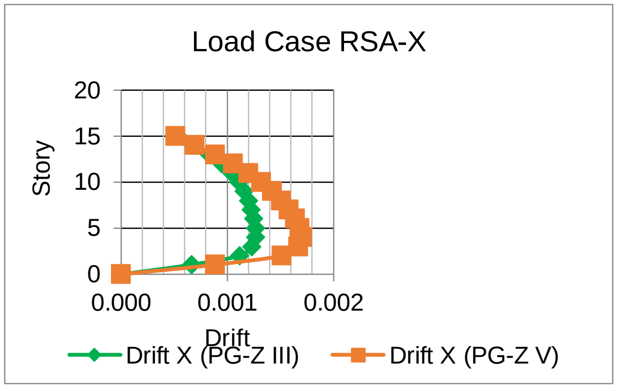

Figure 1: Comparison of Storey Drift (X-Direction)

From Figure 1 it is observed that the Storey Drift in X-direction is observed that the Storey Drift in Zone V is approximately 50% greater than the Storey Drift in Zone III.

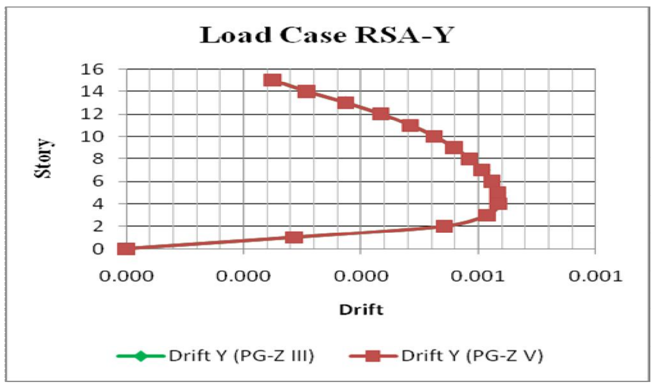

Figure 2: Comparison of Storey Drift (Y-Direction) From Figure 2 it is observed that the Storey Drift in Zone V is almost same with Storey Drift in Zone III.

Table No 5: Comparison of Storey Displacement on plain ground in (X & Y Direction)

Displacement					
Sr. No.	Direction (Degree)	X (RSAX) (0^0)		Y (RSAY) (0^0)	
	Story's	Zone	Zone V	Zone	Zone V
15	Story 15	41.90	53.60	21.40	21.40
14	Story 14	40.40	52.20	20.70	20.70
13	Story 13	38.70	50.30	19.90	19.90
12	Story 12	36.60	48.00	18.90	18.90
11	Story 11	34.30	45.20	17.70	17.70
10	Story 10	31.60	42.00	16.40	16.40
9	Story 9	28.80	38.50	14.90	14.90
8	Story 8	25.80	34.60	13.30	13.30
7	Story 7	22.60	30.50	11.70	11.70
6	Story 6	19.20	26.00	9.90	9.90
5	Story 5	15.70	21.40	8.10	8.10
4	Story 4	12.10	16.60	6.20	6.20
3	Story 3	8.50	11.70	4.30	4.30
2	Story 2	5.00	6.90	2.50	2.50
1	Story 1	1.80	2.60	0.90	0.90
0	Story 0	0.00	0.00	0.00	0.00

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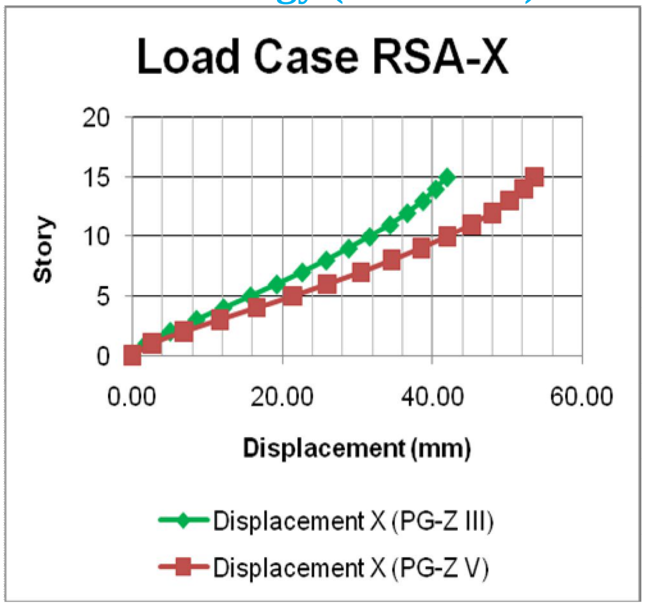

Figure 3: Comparison of Storey Displacement (X- Direction)

From Figure 3 it is observed that the storey displacement in Zone V is approximately 22% greater than the storey displacement in Zone III

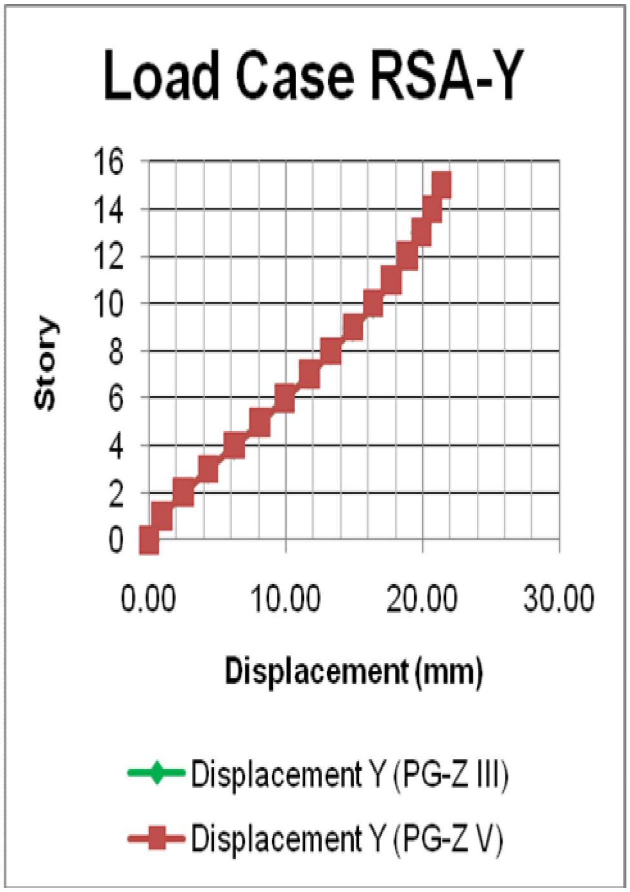

Figure 4: Comparison of Storey Displacement (Y-Direction)

From Figure 4 iit is observed that the storey displacement in Zone V is almost same of the storey displacement in Zone III.

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Table No 6: Comparison of Time Period on plain ground in (X & Y Direction)

Base Shear					
Sr. No.	*Direction*	*X (RSAX)*		*Y (RSAY)*	
	(Degree)	*(0^0)*		*(0^0)*	
	Story's	Z III	Z V	Z III	Z V
15	Story 15	326.6	682.4	268.6	268.6
14	Story 14	799.4	1715.4	666.8	666.8
13	Story 13	1162.6	2576.9	993.6	993.6
12	Story 12	1429.7	3281.9	1257.2	1257.2
11	Story 11	1628.9	3871.7	1474.9	1474.9
10	Story 10	1781.5	4376.2	1658.6	1658.6
9	Story 9	1902.7	4813.3	1816.4	1816.4
8	Story 8	2012.6	5206.6	1958.9	1958.9
7	Story 7	2132.1	5581.4	2097.0	2097.0
6	Story 6	2268.4	5945.8	2233.5	2233.5
5	Story 5	2416.9	6293.2	2365.6	2365.6
4	Story 4	2571.4	6616.9	2489.9	2489.9
3	Story 3	2719.7	6902.3	2599.2	2599.2
2	Story 2	2833.6	7111.1	2676.9	2676.9
1	Story 1	2884.0	7200.8	2708.1	2708.1
0	Story 0	0.0	0.0	0.0	0.0

Time Period					
Sr. No.	*Direction*	*X (RSAX)*		*Y (RSAY)*	
	(Degree)	*(0^0)*		*(0^0)*	
	Story's	Zone III	Zone V	Zone III	Zone V
1	Mode 1	1.8	1.3	1.3	1.3
2	Mode 2	1.8	1.3	1.3	1.3
3	Mode 3	1.7	1.2	1.2	1.2
4	Mode 4	0.6	0.4	0.4	0.4
5	Mode 5	0.6	0.4	0.4	0.4
6	Mode 6	0.5	0.4	0.4	0.4
7	Mode 7	0.3	0.2	0.2	0.2
8	Mode 8	0.3	0.2	0.2	0.2
9	Mode 9	0.3	0.2	0.2	0.2
10	Mode 10	0.2	0.2	0.2	0.2
11	Mode 11	0.2	0.2	0.2	0.2
12	Mode 12	0.2	0.1	0.1	0.1

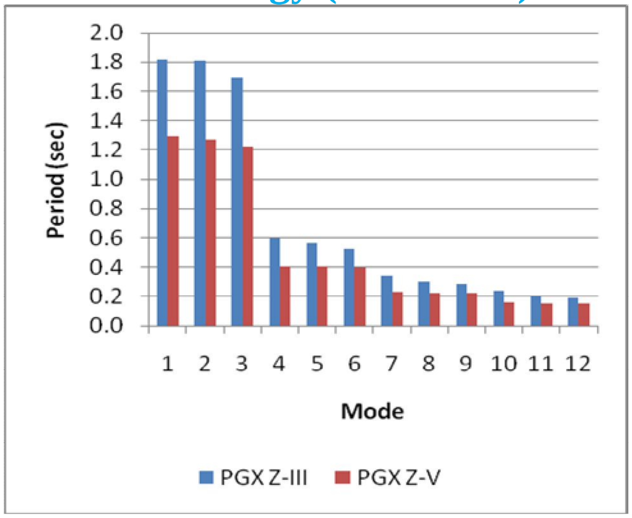

Figure 5: Comparison of Time Period (X-Direction)

From Figure 5 it is observed that the Time Period for in Zone III is approximately 28% greater than in Zone V.

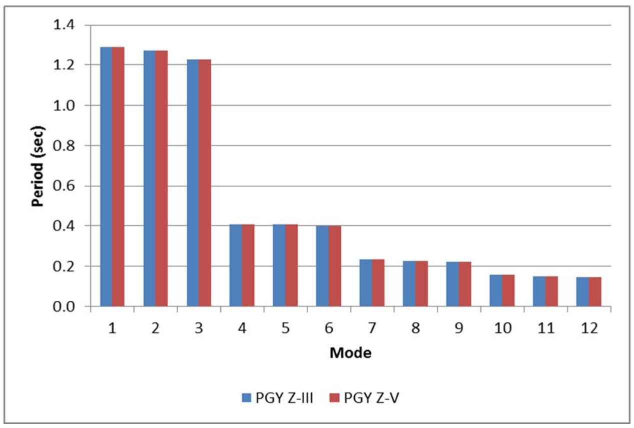

Figure 6: Comparison of Time Period (Y-Direction)

From Figure 6.6 it is observed that the time period for in Zone III is almost same than the in-Zone V.

Table No.7: Comparison of Base Shear on plain ground in (X & Y Direction

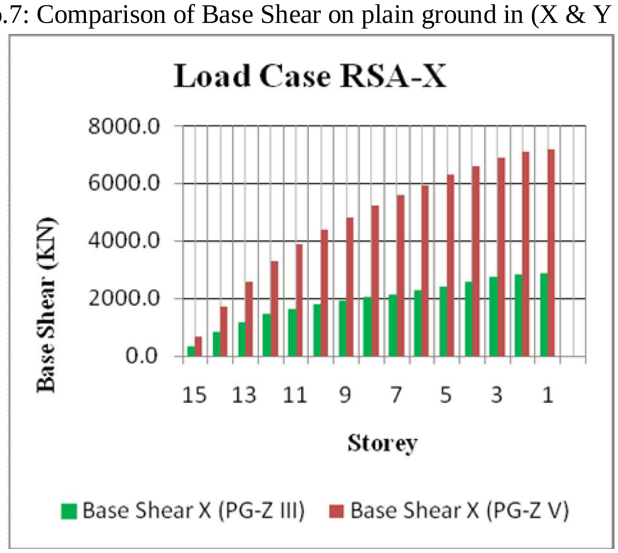

Figure 7: Comparison of Base Shear (X-Direction)

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From Figure 7 it is observed that the base shear for in Zone V is approximately 60% greater than in Zone III.

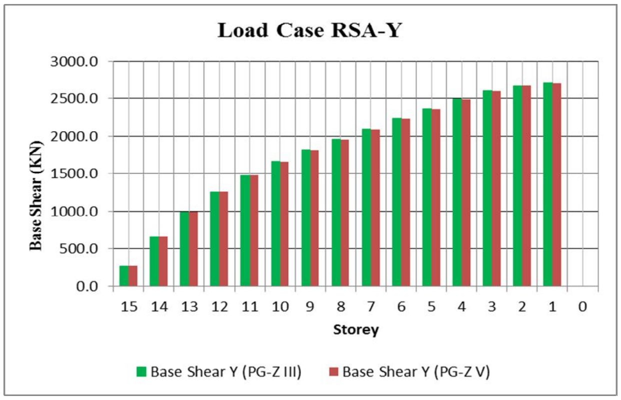

Figure 8: Comparison of Base Shear (Y-Direction)

From Figure 8 it is observed that the base shear for in Zone V is almost same in Zone III.

Table No. 8: Comparison of Axial Load in Column on plain ground in (X & Y Direction)

Axial Load (Pu)					
X-Direction			*Y-Direction*		
Column No.	Z-III (0^0)	Z-V (0^0)	Colum n No.	Z-III (0^0)	Z-V (0^0)
	Story 1	Story 1		Story 1	Story 1
C5	360.8	1300.2	C1	585.0	585.0
C10	240.0	257.5	C2	158.3	160.0
C15	156.5	145.6	C3	41.0	42.0
C20	-	-	C4	37.5	42.0
C25	-	-	C5	154.7	170.0
C30	-	-	C6	600.8	650.0
C4	367.8	1124.6	C7	191.8	200.0
C9	150.3	401.6	C8	103.5	110.0
C14	728.5	1555.0	C9	68.3	70.2
C19	132.0	144.5	C10	174.9	180.2
C24	-	-	C11	631.2	650.2
C29	-	-	C12	376.0	400.2
C3	371.9	1120.3	C13	-	-
C8	188.7	478.7	C14	643.5	700.2
C13	-	-	C15	257.3	300.2

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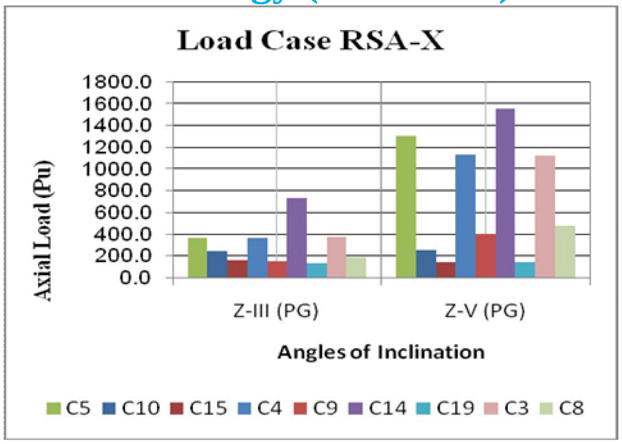

Figure 9: Comparison of Axial Load in Columns (X-Direction)

From Figure 9 it is observed that the Max Axial Force in Zone V is approximately 55% greater than in Zone III.

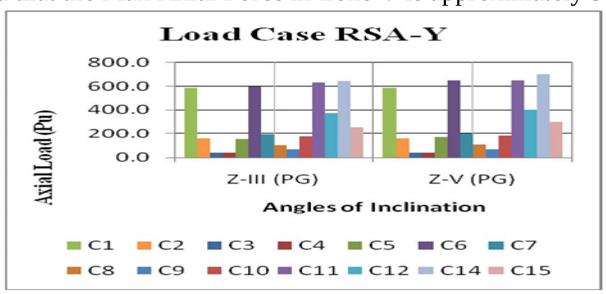

Figure 10: Comparison of Axial Load in Columns. (Y-Direction**)**

From Figure 10 it is observed that the Max Axial Force in Zone V is approximately 95% greater than in Zone III

Table No. 9: Comparison of Bending Moment for Columns on plain ground in (X & Y Direction)

Moment (M3)					
X-Direction			*Y-Direction*		
Column No.	Z-III Story 1	Z-V Story 1	Column No.	Z-III Story 1	Z-V Story 1
C5	61.1	277.8	C1	56.0	89.0
C10	69.9	310.7	C2	45.0	63.0
C15	68.3	305.3	C3	45.6	20.5
C20	-	-	C4	86.0	89.0
C25	-	-	C5	56.0	78.0
C30	-	-	C6	56.0	59.0
C4	63.3	275.2	C7	46.0	78.0
C9	72.9	309.9	C8	56.0	47.0
C14	74.1	311.9	C9	85.0	86.3
C19	56.0	75.0	C10	56.9	56.6
C24	-	-	C11	47.0	89.3
C29	-	-	C12	85.3	46.3
C3	65.6	273.0	C13	-	-
C8	77.1	310.8	C14	23.5	45.3
C13	-	-	C15	53.5	43.3

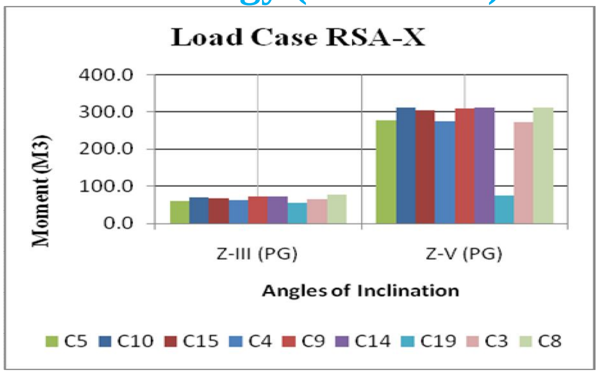

Figure 11: Comparison of Bending Moment (X-Direction)

From Figure 11 it is observed that the Max Bending Moment in Zone V is approximately 83% greater than in ZoneIII

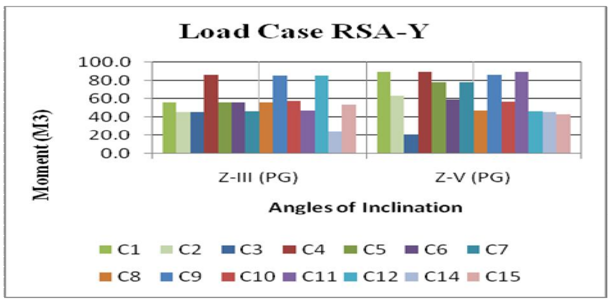

Figure 12: Comparison of Bending Moment (Y-Direction**)**

From Figure 12 it is observed that the Max Bending Moment in Zone V is approximately 74% greater than in Zone III.

Table No. 10: Comparison of Shear Force for Column on plain ground in (X & Y Direction)

Shear Force (V3)					
X-Direction			*Y-Direction*		
Column No.	Z-III Stor1	Z-V Story 1	Column No.	Z-III Story 1	Z-V Story 1
C5	45.0	58.0	C1	35.0	39.0
C10	42.3	45.0	C2	48.2	52.0
C15	46.9	56.0	C3	48.5	56.2
C20	-	-	C4	48.5	69.0
C25	-	-	C5	48.2	72.0
C30	-	-	C6	35.1	65.2
C4	56.3	89.0	C7	48.5	68.0
C9	52.3	68.0	C8	48.2	67.0
C14	45.6	56.0	C9	48.4	42.2
C19	46.3	45.0	C10	48.3	43.2
C24	-	-	C11	35.1	35.9
C29	-	-	C12	55.5	50.3
C3	49.3	35.0	C13	-	-
C8	68.0	56.0	C14	57.5	52.3
C13	-	-	C15	49.6	49.8

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Figure 13: Comparison of Shear Force in Columns (X-Direction)

From Figure 13 it is observed that the Max Shear Force in Zone V is approximately 53% greater than in Zone III.

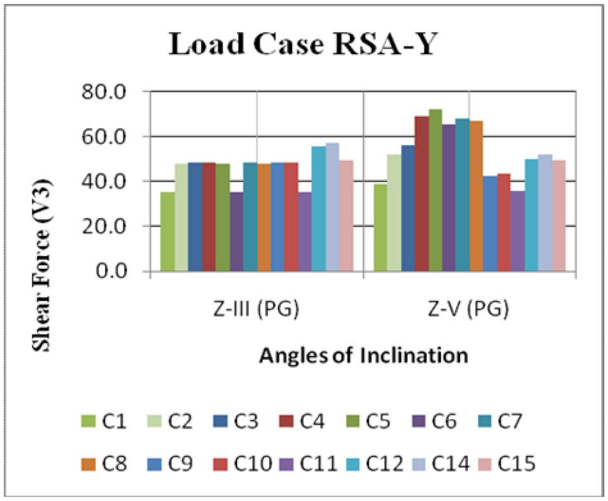

Figure 14: Comparison of Shear Force in Columns (Y-Direction)

From Figure 14 it is observed that the Max Shear Force in Zone V is approximately 52% greater than in Zone III.

B. Case Study II

1) Comparison Results For Building Resting On Plain Ground And 11^0 Sloping Ground. Case 1

Table No. 11: Comparison of Storey Drift on plain ground and 11^0 sloping ground in (X & Y Direction)

Drift									
	Direction	*X direction (RSAX)*		*Y direction (RSAY)*		*X direction (RSAX)*		*Y direction (RSAY)*	
	Degree	*PG(0^0)*		*PG(0^0)*		*11^0*		*11^0*	
Sr. No.	Story	Z-III	Z-V	ZIII	Z-V	Z-III	Z-V	Z-III	Z-V
15	Story 15	0.001	0.001	0	0	0	0.001	0	0
14	Story 14	0.001	0.001	0	0	0	0.001	0	0
13	Story 13	0.001	0.001	0	0	0	0.001	0	0
12	Story 12	0.001	0.001	0	0	0	0.001	0	0
11	Story 11	0.001	0.001	0	0	0.001	0.001	0.001	0.001
10	Story 10	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
9	Story 9	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
8	Story 8	0.001	0.002	0.001	0.001	0.001	0.002	0.001	0.001
7	Story 7	0.001	0.002	0.001	0.001	0.001	0.002	0.001	0.001
6	Story 6	0.001	0.002	0.001	0.001	0.001	0.002	0.001	0.001
5	Story 5	0.001	0.002	0.001	0.001	0.001	0.002	0.001	0.001
4	Story 4	0.001	0.002	0.001	0.001	0.001	0.002	0.001	0.001
3	Story 3	0.001	0.002	0.001	0.001	0.001	0.002	0.001	0.001
2	Story 2	0.001	0.002	0.001	0.001	0	0.001	0.001	0.001
1	Story 1	0.001	0.001	0	0	0	0	0	0
0	Story 0	0	0	0	0	0	0	0	0

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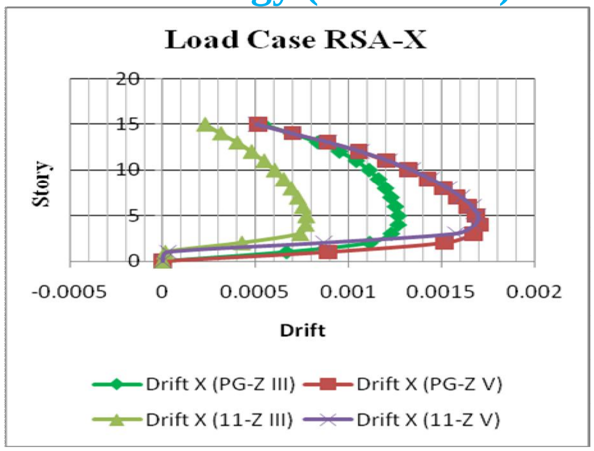

Figure 15: Comparison of Storey Drift (X-Direction)

From Figure 54 it is observed that the Storey Drift in PG (0^0) is approximately 15% greater than the Storey Drift in 11^0.

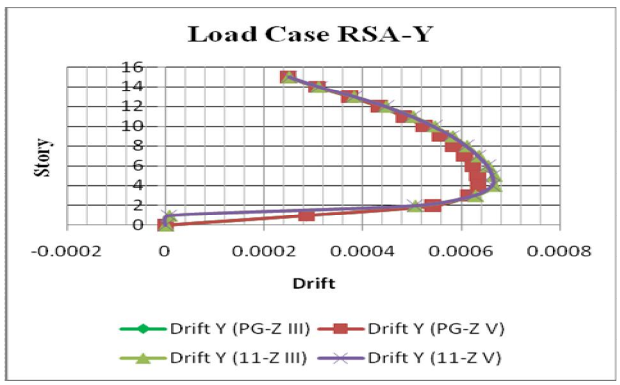

Figure 16: Comparison of Storey Drift (Y-Direction)

From Figure 55 it is observed that the Storey Drift in 11^0 is approximately 0.7% greater than the Storey Drift in 0^0

Table No. 12: Comparison of Storey Displacement on plain ground and 11^0 sloping ground in (X & Y Direction

Sr. No.	Direction	X (RSAX)		Y (RSAY)		X d (RSAX)		Y (RSAY)	
	Degree	(0^0)		(0^0)		11^0		11^0	
	Story's	Z- III	Z-V	Z-	Z -	Z-	Z-V	Z-III	Z- V
15	Story	41.9	53.6	21.4	21.4	22.4	49.5	21.4	21.3
14	Story	40.4	52.2	20.7	20.7	21.8	48.1	20.7	20.6
13	Story	38.7	50.3	19.9	19.9	21.0	46.2	19.8	19.7
12	Story	36.6	48.0	18.9	18.9	19.9	43.9	18.8	18.7
11	Story	34.3	45.2	17.7	17.7	18.6	41.0	17.5	17.4
10	Story	31.6	42.0	16.4	16.4	17.2	37.8	16.1	16.1
9	Story 9	28.8	38.5	14.9	14.9	15.5	34.1	14.6	14.5
8	Story 8	25.8	34.6	13.3	13.3	13.7	30.2	12.9	12.9
7	Story 7	22.6	30.5	11.7	11.7	11.8	25.9	11.2	11.1
6	Story 6	19.2	26.0	9.90	9.90	9.80	21.4	9.30	9.30
5	Story 5	15.7	21.4	8.10	8.1	7.60	16.6	7.40	7.30
4	Story 4	12.1	16.6	6.20	6.20	5.40	11.8	5.40	5.30
3	Story 3	8.50	11.7	4.30	4.30	3.30	7.00	3.40	3.40
2	Story 2	5.00	6.90	2.50	2.50	1.20	2.60	1.50	1.50
1	Story 1	1.80	2.60	0.90	0.90	0.00	0.00	0.00	0.00
0	Story 0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

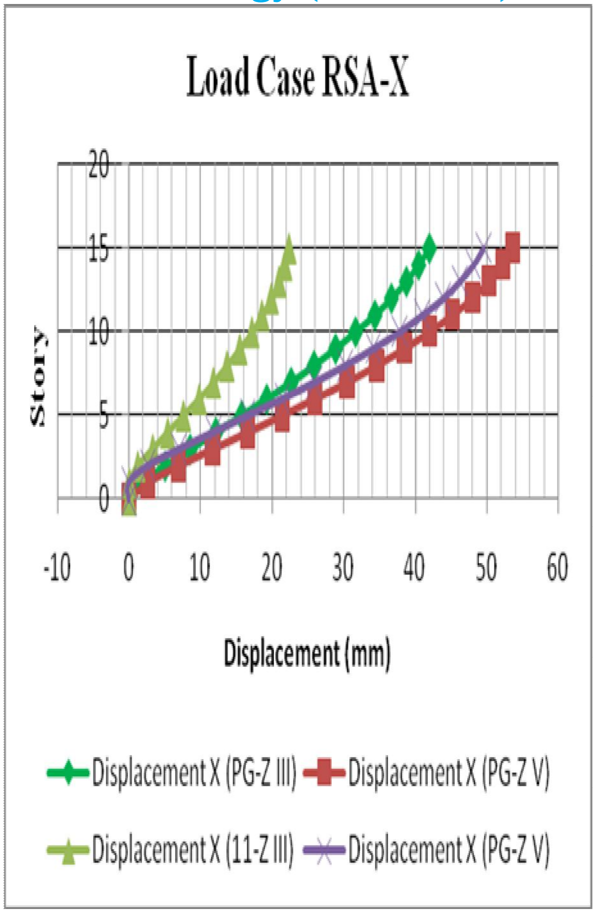

Figure 17: Comparison of Storey Displacement (X-Direction)

From Figure 56 it is observed that the storey displacement in 0^0 is approximately 5% greater than the storey displacement in 11^0.

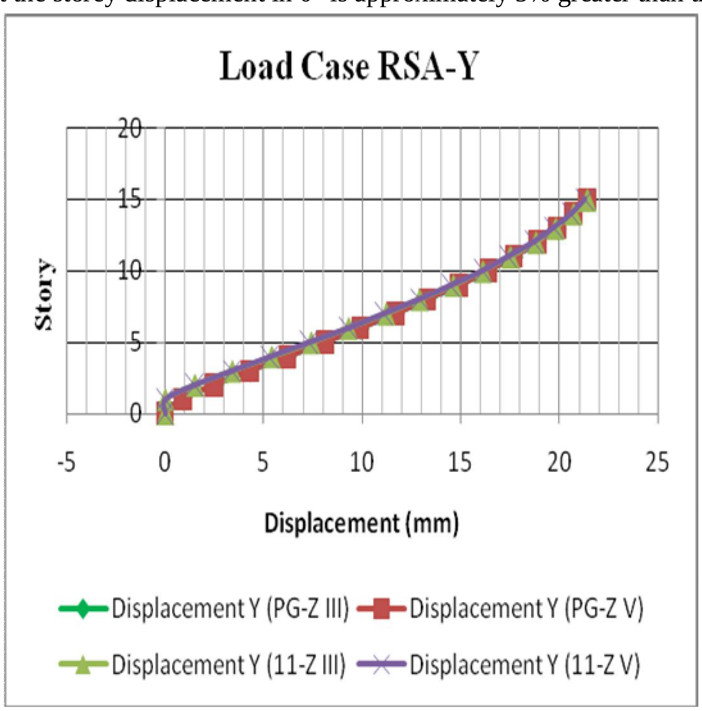

Figure 18: Comparison of Storey Displacement (Y-Direction)

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From Figure 57 it is observed that the storey displacement is almost same

Table No. 13: Comparison of Time Period on plain ground and 11^0 sloping ground in (X & Y Direction)

Sr. No	Direction	X (RSAX)		Y (RSAY)		X (RSAX)		Y (RSAY)	
	(Degree	PG(0^0)		PG(0^0)		11^0		11^0	
	Story	Z-III	Z-V	Z-III	Z-V	Z-III	Z- V	Z-III	Z-V
1	Mode 1	1.8	1.3	1.3	1.3	1.2	1.2	1.3	1.3
2	Mode 2	1.8	1.3	1.3	1.3	1.2	1.2	1.3	1.3
3	Mode 3	1.7	1.2	1.2	1.2	1.1	1.1	1.2	1.2
4	Mode 4	0.6	0.4	0.4	0.4	0.4	0.4	1.2	1.2
5	Mode 5	0.6	0.4	0.4	0.4	0.4	0.4	1.2	1.2
6	Mode 6	0.5	0.4	0.4	0.4	0.4	0.4	1.2	0.4
7	Mode 7	0.3	0.2	0.2	0.2	0.2	0.2	1.2	0.4
8	Mode 8	0.3	0.2	0.2	0.2	0.2	0.2	1.2	0.4
9	Mode 9	0.3	0.2	0.2	0.2	0.2	0.2	1.2	0.2
10	Mode 10	0.2	0.2	0.2	0.2	0.1	0.1	0.4	0.2
11	Mode 11	0.2	0.2	0.2	0.2	0.1	0.1	0.4	0.2
12	Mode 12	0.2	0.1	0.1	0.1	0.1	0.1	0.4	0.2

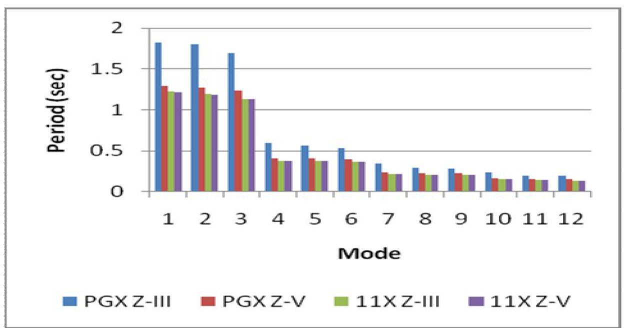

Figure 19: Comparison of Time Period (X-Direction)

From Figure 58 it is observed that the Time Period for 0^0 is approximately 35% greater than in 11^0 in mode 1.

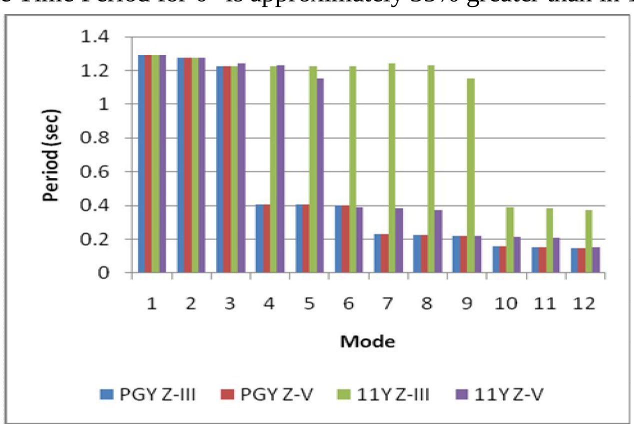

Figure 20: Comparison of Time Period (Y-Direction)

From Figure 59 it is observed that the time period is almost same in mode 1.

C. Case Study III

1) Comparison Results For Building Resting On Plain Ground, On 11^0 Sloping Ground, On 18^0 Sloping Ground, On 27^0 Sloping

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Ground.

Table No.14: Comparison of Storey Drift on plain ground, on 11^0 sloping ground, on 18^0 sloping ground, on 27^0 sloping ground in (X & Y Direction)

DRIFT									
Sr. No.	Directio	Y direction (RSAY)							
	Degree	0^0		11^0		18^0		27^0	
	Story	Z III	Z V	Z III	Z V	Z III	Z V	Z III	Z V
15	Story 15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	Story 14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	Story 13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	Story 12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	Story 11	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.000
10	Story 10	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
9	Story 9	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
8	Story 8	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
7	Story 7	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
6	Story 6	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
5	Story 5	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
4	Story 4	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
3	Story 3	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
2	Story 2	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
1	Story 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	Story 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

DRIFT									
Sr. No.	Direction	X direction (RSAX)							
	Degree	0^0		11^0		18^0		27^0	
	Story	ZIII	ZV	ZIII	ZV	ZIII	ZV	ZIII	Z V
15	Story 15	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000
14	Story 14	0.001	0.001	0.000	0.001	0.000	0.001	0.000	0.001
13	Story 13	0.001	0.001	0.000	0.001	0.000	0.001	0.000	0.001
12	Story 12	0.001	0.001	0.000	0.001	0.000	0.001	0.000	0.001
11	Story 11	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
10	Story 10	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
9	Story 9	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
8	Story 8	0.001	0.002	0.001	0.002	0.001	0.002	0.001	0.001
7	Story 7	0.001	0.002	0.001	0.002	0.001	0.002	0.001	0.002
6	Story 6	0.001	0.002	0.001	0.002	0.001	0.002	0.001	0.001
5	Story 5	0.001	0.002	0.001	0.002	0.001	0.002	0.001	0.001
4	Story 4	0.001	0.002	0.001	0.002	0.001	0.002	0.000	0.001
3	Story 3	0.001	0.002	0.001	0.002	0.000	0.001	0.000	0.000
2	Story 2	0.001	0.002	0.000	0.001	0.000	0.001	0.000	0.000
1	Story 1	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
0	Story 0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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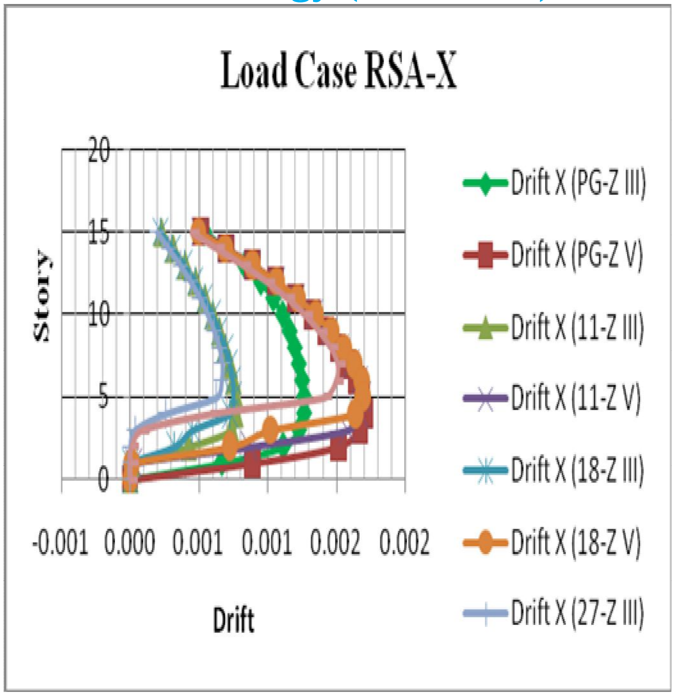

Figure 21: Comparison of Storey Drift (X-Direction) From Fig. 72 it is observed that the Storey Drift in Zone III for 0^0 is approximately 87% greater than the Storey Drift in Zone III for 27^0 & Storey Drift in Zone V for 0^0 is approximately 15% greater than the Storey Drift in Zone V for 27^0

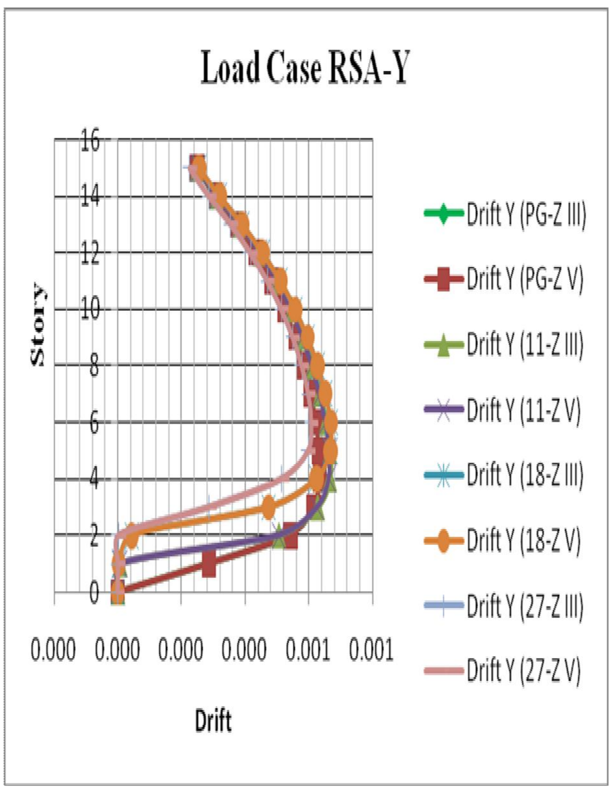

Figure 22: Comparison of Storey Drift. (Y-Direction)

From Figure 73 it is observed that the Storey Drift in Zone III for 0^0 is approximately 5% greater than the Storey Drift in Zone III for 27^0 and Storey Drift in Zone V for 0^0 is approximately 5% greater than the Storey Drift in Zone V for 27^0.

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Table No.15: Comparison of Storey Displacement on plain ground, on 11^0 sloping ground, on 18^0 sloping ground, on 27^0 sloping ground in (X & Y Direction)

Sr. No.	Displacement								
	Directio	*X direction (RSAX)*							
	Degree	*0^0*		*11^0*		*18^0*		*27^0*	
	Story	Z III	Z V	Z III	Z V	Z III	Z V	Z III	Z V
15	Story 15	41.9	53.6	22.4	49.5	20.2	45.5	16.4	37.0
14	Story 14	40.4	52.2	21.8	48.1	19.6	44.1	15.9	35.7
13	Story 13	38.7	50.3	21.0	46.2	18.8	42.3	15.1	34.0
12	Story 12	36.6	48.0	19.9	43.9	17.7	39.9	14.1	31.7
11	Story 11	34.3	45.2	18.6	41.0	16.5	37.0	12.9	29.0
10	Story 10	31.6	42.0	17.2	37.8	15.0	33.7	11.5	25.8
9	Story 9	28.8	38.5	15.5	34.1	13.3	30.0	9.90	22.2
8	Story 8	25.8	34.6	13.7	30.2	11.6	26.0	8.10	18.3
7	Story 7	22.6	30.5	11.8	25.9	9.60	21.6	6.30	14.1
6	Story 6	19.2	26.0	9.80	21.4	7.60	17.1	4.40	9.80
5	Story 5	15.7	21.4	7.60	16.6	5.50	12.3	2.40	5.50
4	Story 4	12.1	16.6	5.40	11.8	3.30	7.50	0.70	1.70
3	Story 3	8.50	11.7	3.30	7.00	1.30	3.00	0.00	0.00
2	Story 2	5.00	6.90	1.20	2.60	0.00	0.00	0.00	0.00
1	Story 1	1.80	2.60	0.00	0.00	0.00	0.00	0.00	0.01
0	Story 0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Sr. No.	Displacement								
	Direction	*Y direction (RSAY)*							
	Degree	*0^0*		*11^0*		*18^0*		*27^0*	
	Story	Z III	Z V	Z III	Z V	Z III	Z V	Z III	Z V
15	Story 15	21.4	21.4	21.4	21.3	18.5	18.5	17.4	17.4
14	Story 14	20.7	20.7	20.7	20.6	17.8	17.8	16.8	16.8
13	Story 13	19.9	19.9	19.8	19.7	17.0	17.0	16.0	16.0
12	Story 12	18.9	18.9	18.8	18.7	15.9	15.9	15.0	15.0
11	Story 11	17.7	17.7	17.5	17.4	14.7	14.7	13.8	13.8
10	Story 10	16.4	16.4	16.1	16.1	13.4	13.4	12.5	12.5
9	Story 9	14.9	14.9	14.6	14.5	11.9	11.9	11.0	11.0
8	Story 8	13.3	13.3	12.9	12.9	10.3	10.3	9.40	9.40
7	Story 7	11.7	11.7	11.2	11.1	8.50	8.50	7.70	7.70
6	Story 6	9.90	9.90	9.30	9.30	6.70	6.70	5.90	5.90
5	Story 5	8.10	8.10	7.40	7.30	4.90	4.90	4.10	4.10
4	Story 4	6.20	6.20	5.40	5.30	3.00	3.00	2.40	2.40
3	Story 3	4.30	4.30	3.40	3.40	1.30	1.30	0.80	0.80
2	Story 2	2.50	2.50	1.50	1.50	0.00	0.00	0.00	0.00
1	Story 1	0.90	0.90	0.00	0.00	0.00	0.00	0.00	0.00
0	Story 0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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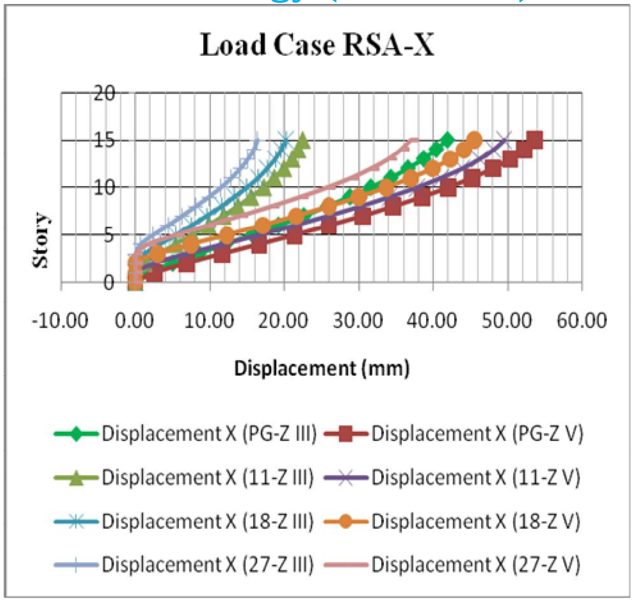

Figure 23: Comparison of Storey Displacement (X-Direction)

From Figure 74 for X-direction x-axis represents storey displacement and y-axis represents storey level for zone III and zone V for plain ground building, 11^0 sloping ground, 18^0 sloping ground, 27^0 sloping ground both zones are started at the same storey displacement and ended at different displacement point it is observed that the storey displacement in Zone III for 0^0 is approximately 61% greater than the storey displacement in Zone III for 27^0 and storey displacement in Zone V for 0^0 is approximately 31% greater than the storey displacement in Zone V for 27^0

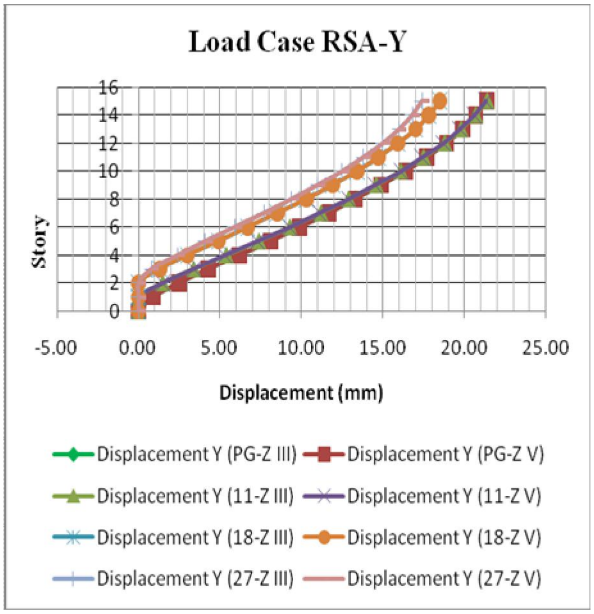

Figure 24: Comparison of Storey Displacement (Y-Direction)

From Figure 75 for Y-direction x-axis represents storey displacement and y-axis represents storey level for zone III and zone V for plain ground building, 11^0 sloping ground, 18^0 sloping ground, 27^0 sloping ground both zones are started at the same storey displacement and ended at almost same displacement point it is observed that the storey displacement in Zone III for 0^0 is approximately 19% greater than the storey displacement in Zone III for 27^0 and storey displacement in Zone V for 0^0 is approximately 20% greater than the storey displacement in Zone V for 27^0

Table No16: Comparson of Time Period on plain ground, on 11^0 sloping ground, on 18^0 sloping ground, on 27^0 sloping ground in

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(X & Y Direction)

Time Period									
Sr. No	*Direction*	*X direction (RSAX)*							
	Degree	*(0^0)*		*11^0*		*18^0*		*27^0*	
	Story	Z III	Z V	Z III	Z V	Z III	Z V	Z III	Z V
1	Mode 1	1.8	1.3	1.2	1.2	1.2	1.2	1.0	1.0
2	Mode 2	1.8	1.3	1.2	1.2	1.1	1.1	1.0	1.0
3	Mode 3	1.7	1.2	1.1	1.1	1.1	1.1	0.9	0.9
4	Mode 4	0.6	0.4	0.4	0.4	1.0	1.0	0.3	0.3
5	Mode 5	0.6	0.4	0.4	0.4	0.4	0.4	0.3	0.3
6	Mode 6	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3
7	Mode 7	0.3	0.2	0.2	0.2	0.3	0.3	0.2	0.2
8	Mode 8	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
9	Mode 9	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
10	Mode 10	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.1
11	Mode 11	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
12	Mode 12	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Sr. No	*Direction*	*Y direction (RSAY)*							
	(Degree	*(0^0)*		*11^0*		*18^0*		*27^0*	
	Story	Z	Z V	Z III	Z V	Z III	Z V	Z III	Z V
1	Mode 1	1.3	1.3	1.3	1.3	1.3	1.3	1.1	1.1
2	Mode 2	1.3	1.3	1.3	1.3	1.1	1.1	1.1	1.1
3	Mode 3	1.2	1.2	1.2	1.2	1.1	1.1	1.0	1.0
4	Mode 4	0.4	0.4	1.2	1.2	0.4	0.4	0.3	0.3
5	Mode 5	0.4	0.4	1.2	1.2	0.4	0.4	0.3	0.3
6	Mode 6	0.4	0.4	1.2	0.4	0.3	0.3	0.3	0.3
7	Mode 7	0.2	0.2	1.2	0.4	0.2	0.2	0.2	0.2
8	Mode 8	0.2	0.2	1.2	0.4	0.2	0.2	0.2	0.2
9	Mode 9	0.2	0.2	1.2	0.2	0.2	0.2	0.2	0.2
10	Mode 10	0.2	0.2	0.4	0.2	0.1	0.1	0.1	0.1
11	Mode 11	0.2	0.2	0.4	0.2	0.1	0.1	0.1	0.1
12	Mode 12	0.1	0.1	0.4	0.2	0.1	0.1	0.1	0.1

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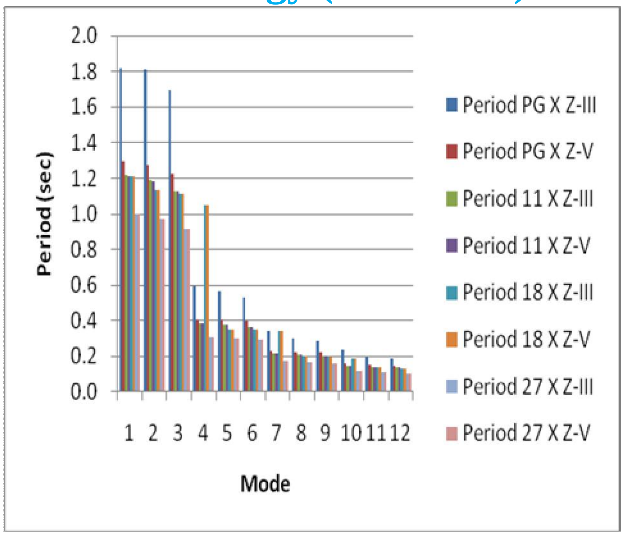

Figure 25: Comparison of Time Period (X-Direction)

From Figure 76 for X-direction x-axis represents period in sec and y-axis represents storey level for zone III and zone V for plain ground building, 11^0 sloping ground, 18^0 sloping ground, 27^0 sloping ground both zones are started at the same period and ended at different periods it is observed that the Time Period for in Zone III for 0^0 is approximately 45% greater than in Zone III for 27^0 and Time Period for in Zone V for 0^0 is approximately 23% greater than in Zone V for 27^0.

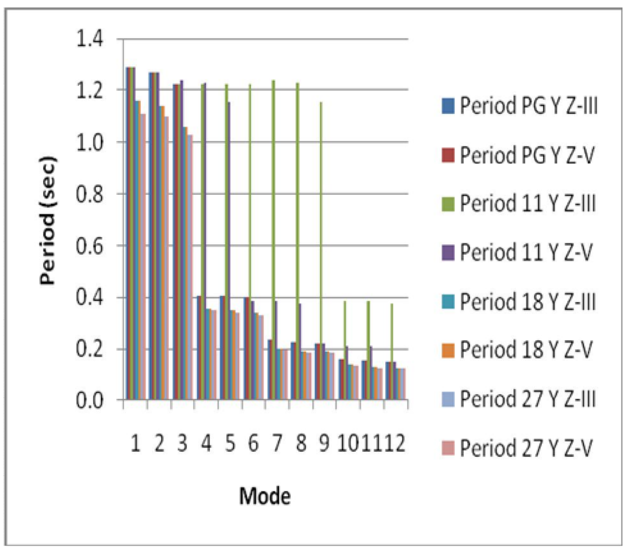

Figure 26: Comparison of Time Period (Y-Direction)

From Figure 7 for Y-direction x-axis represents period in sec and y-axis represents storey level for zone III and zone V for plain ground building, 11^0 sloping ground, 18^0 sloping ground, 27^0 sloping ground both zones are started at the same period and ended at different periods it is observed that the Time Period for in Zone III for 0^0 is approximately 15% greater than in Zone III for 27^0 and Time Period for in Zone V for 0^0 is approximately 16% greater than in Zone V for 27^0.

V. CONCLUSION

On the basis of the results of dynamic analysis of Plain building and other three configurations of buildings, the following conclusions can be drawn,

A. Due to the sloping ground condition in building, forces in columns are subjected to much higher shear and bending as compared to Plain ground building.

B. Drift and Displacement is least during seismic excitation in transverse direction. Such buildings are more suitable for stability of the structure on hilly terrain than other configurations of buildings.
C. Plain buildings attract less force as compared to Sloping buildings. But, overall economic cost involved in levelling the sloping ground building and other related issues needs to be studied in detail.
D. Torsion in sloping ground is much higher than buildings resting over plain ground.
E. Columns on sloping ground attract more forces and due to sloping ground short column produces more effect during earthquake.
F. Considering all parameters, 27^0 sloping ground building is more suitable on hilly terrain as compared to other building types.

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VII. LIST OF SYMBOLS

RCC reinforced cement concrete
RC reinforced concrete
ESA Equivalent static analysis
RSA Response spectrum analysisIS Indian Standards

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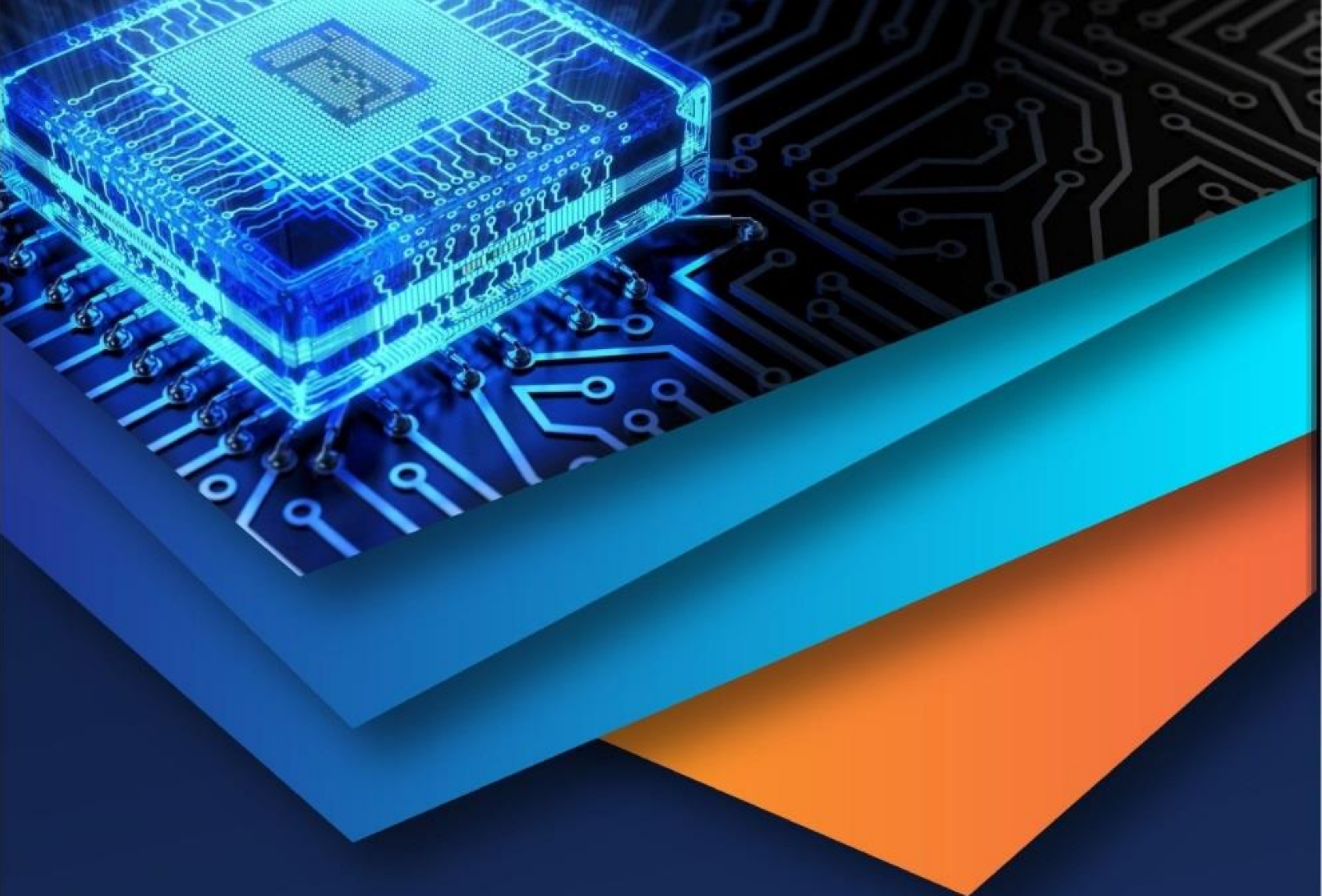

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