whereas it decreases this value for footing located at higher depth.

SLOPE15^{o} provides significant variation of 0.10 to 2.12 times in the footing reaction (Mz) compared to SLOPE 0^{o}. The maximum increase in ratio 2.12 times is found in footings located at lesser depth (i.e. footing F1, F6, F11, F16 and F21) whereas the maximum decrease in ratio of nearly 0.10 times is found in footings located at higher depth (i.e. footing F5, F10, F15, F20 and F25). The maximum footing reaction (Mz) for SLOPE 0^{0} is 92.82 kN-m is found in footing F12 and F14 whereas the maximum footing reaction for SLOPE 15^{0} is 182.88 kN-m is found in footing F11.

The sloping ground causes increase of bending moment reaction (Mz) for footings located at lesser depth whereas it decreases this value for footing located at higher depth. Seismic in Z-direction significant change in bending moment of footing in sloping ground structures.

5.1 CRITICAL FORCES IN FOOTING OF BUILDING FRAME

Comparison of critical horizontal forces, vertical reaction and bending moment in footing for different ground slopes for various analyses

Table-9 Comparison of critical forces in footing for different ground slopes for various analyses

Forces/ Component	Plane Ground		Sloping Ground (7.5^{0})		Sloping Ground (15^{0})		Comparison of various analysis	
	1		2		3		2/1	3/1
	Footing No.	Value	Footing No.	Value	Footing No.	Value		
Horizontal Reaction Fx (kN)	12	68.47	11	145.68	11	195.29	2.13	2.85
Vertical Reaction Fy (kN)	13	863.25	14	868.05	14	873.72	1.01	1.01
Bending Moment Mz (kN-m)	14	139.77	11	226.38	11	275.97	1.61	1.97

Table-9 depicts that critical horizontal reaction Fx (kN) and critical bending moment Mz (kN-m) reaction in the footing varies significantly with change in ratio of 2.85 and 1.97 times respectively for sloping ground (15^{o}) compared to plane ground. However critical value of vertical reaction in footing remain almost same for different ground slopes.

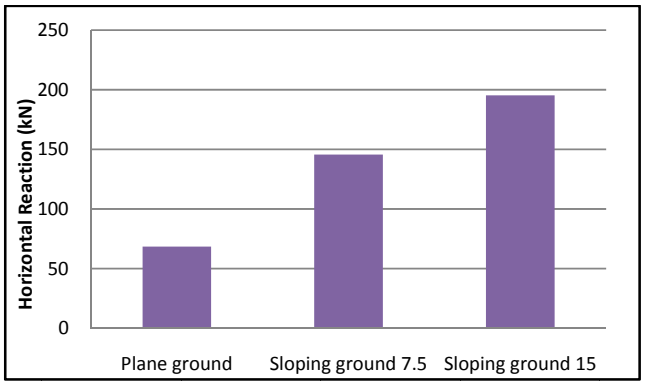

Figure 13: Comparison of critical horizontal reaction in footing between plane and sloping grounds (7.5^{o}, 15^{o}) buildings

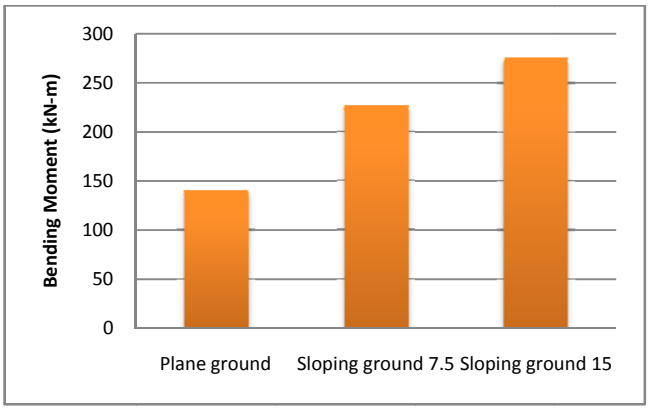

Figure 14: Comparison of critical bending moment in footing between plane and sloping grounds (7.5^{o}, 15^{o}) buildings

5.2 BENDING MOMENT IN THE COLUMNS

The bending moment in the columns of sloping ground due to various analyses is depicted in Table-10

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Comparison of bending moment Mz (kN-m) in columns below plinth level for various ground slopes under seismic loads in X-direction.

Table-10 Comparison of bending moment Mz (kN-m) in footing columns for various analyses (EQX)

Column No	Load case	Nodes	Ground slope (in degree)			Comparison of various analyses	
			0	7.5	15		
			1	2	3	2/1	3/1
1	EQX	51	-39.49	-10.58	7.81	0.27	-0.20
		1	83.31	145.44	176.64	1.75	2.12
2	EQX	52	-24.27	-2.82	1.14	0.11	-0.05
		2	89.76	99.49	82.40	1.11	0.92
3	EQX	53	-24.43	-10.92	-11.94	0.45	0.49
		3	89.66	68.76	43.02	0.77	0.48
4	EQX	54	-24.27	-15.85	-17.38	0.65	0.72
		4	89.76	48.90	23.92	0.54	0.27
5	EQX	55	-39.49	-32.12	-29.52	0.81	0.75
		5	83.31	28.46	8.29	0.34	0.10
6	EQX	56	-40.41	-10.75	8.17	0.27	-0.20
		6	85.30	148.95	181.12	1.75	2.12
7	EQX	57	-24.83	-2.83	1.28	0.11	-0.05
		7	91.90	101.89	84.51	1.11	0.92
8	EQX	58	-24.99	-11.13	-12.14	0.45	0.49
		8	91.80	70.42	44.14	0.77	0.48
9	EQX	59	-24.83	-16.18	-17.72	0.65	0.71
		9	91.90	50.09	24.57	0.55	0.27
10	EQX	60	-40.41	-32.83	-30.16	0.81	0.75
		10	85.30	29.17	8.55	0.34	0.10
11	EQX	61	-40.79	-10.84	8.28	0.27	-0.20
		11	86.16	150.39	182.88	1.75	2.12
12	EQX	62	-25.06	-2.85	1.31	0.11	-0.05
		12	92.82	102.87	85.33	1.11	0.92
13	EQX	63	-25.23	-11.22	-12.24	0.44	0.49
		13	92.71	71.10	44.58	0.77	0.48
14	EQX	64	-25.06	-16.33	-17.88	0.65	0.71
		14	92.82	50.58	24.81	0.54	0.27
15	EQX	65	-40.79	-33.13	-30.44	0.81	0.75
		15	86.16	29.46	8.64	0.34	0.10

Table-10 depicts that bending moment in columns varies significantly for various ground slopes under seismic load in X direction. SLOPE 7.5^0 provides significant variation of 0.11 to 1.75 times in the bending moment in column (Mz) compared to SLOPE 0^o. The maximum increase in ratio 1.75 times is found in columns located at lesser depth (i.e. column C11) below plinth level. Whereas the maximum decrease in ratio 0.11 times is found in columns located at intermediate depth (i.e. column C2, C7 and C12) below plinth level. The maximum bending moment in column (Mz) for SLOPE 0^0 is 92.82kN-m is found in column (i.e. C12) whereas the maximum bending moment in column for SLOPE 7.5^0 is 150.39kN-m is found in column C11. The sloping ground causes increase in bending moment for columns located at lesser depth whereas it decreases this value for column located at higher depth below plinth level.

SLOPE 15^0 provides significant variation of -0.05 to 2.12 times in the bending moment in column (Mz) compared to SLOPE 0^o. The maximum increase in ratio 2.12 times is found in columns located at lesser depth (i.e. column C11) below plinth level Whereas the maximum decrease in ratio -0.05times is found in columns located at intermediate depth (i.e. column C2, C7 and C12) below plinth level.

The maximum bending moment in column (Mz) for SLOPE 0^0 is 92.82kN-m is found in column (i.e. C12) whereas the maximum bending moment in column for SLOPE 15^0 is 182.88kN-m is found in column C11. The sloping ground causes increase of bending moment in column (Mz) for columns located at lesser depth whereas it decreases this value for column located at higher depth in below plinth

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level. Bending moment Mz (kN-m) in columns below and above plinth level for various ground slopes under seismic loads in Z-direction is minutely affected.

Comparison of critical axial forces Fx (kN) and bending moment Mz (kN-m) in columns for various ground slopes are discussed for various analyses.

5.2 CRITICAL FORCES IN COLUMN OF BUILDING FRAME

Table 11- Comparison of critical forces in column for different ground slopes for various analyses

Forces/ Component	Plane Ground		Sloping Ground (7.5°)		Sloping Ground (15°)		Comparison of various analysis	
	1		2		3			
	Column No.	Value	Column No.	Value	Column No.	Value	2/1	3/1
Axial Force Fx (kN)	13	863.25	14	868.10	14	873.72	1.01	1.01
Bending Moment Mz (kN-m)	14	139.78	11	226.40	11	276.00	1.62	1.97

Table-11 depicts that critical bending moment Mz (kN-m) in the column increases significantly with change in ratio of 1.97 times for sloping ground (15°) compared to plane ground. However critical value of vertical reaction in column remains almost same for different ground slopes.

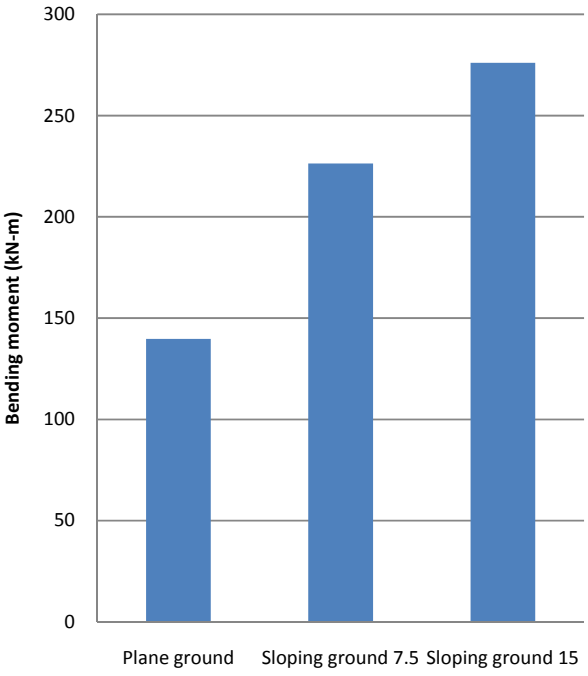

Figure 15: Comparison of critical bending moment in column between plane and sloping grounds (7.5°, 15°) buildings

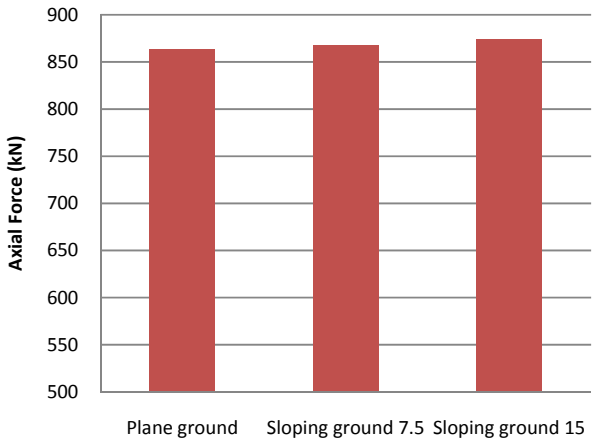

Figure 16: Comparison of critical axial force in column between plane and sloping grounds (7.5°, 15°) buildings

Figure 17 and figure18 shows the bending moment in plane ground and sloping ground (15°) building changes accordingly varying depth. Graphs shows clear that higher bending moment in smaller depth side and decreases with increase in depth.

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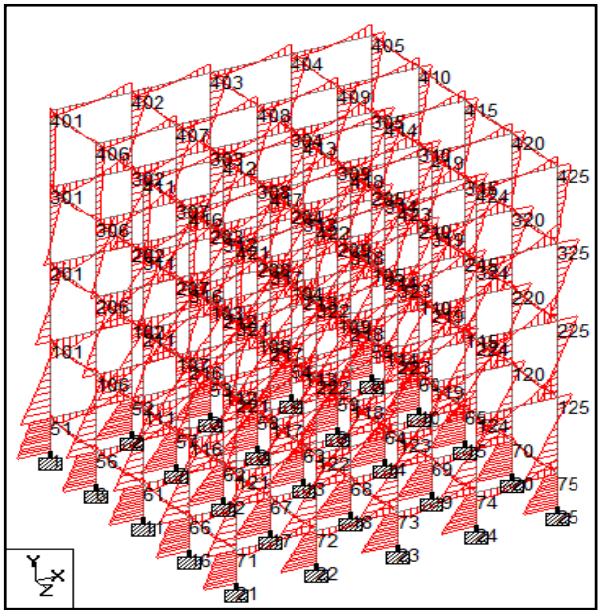

Figure17: Bending moment diagram of plane ground building frame

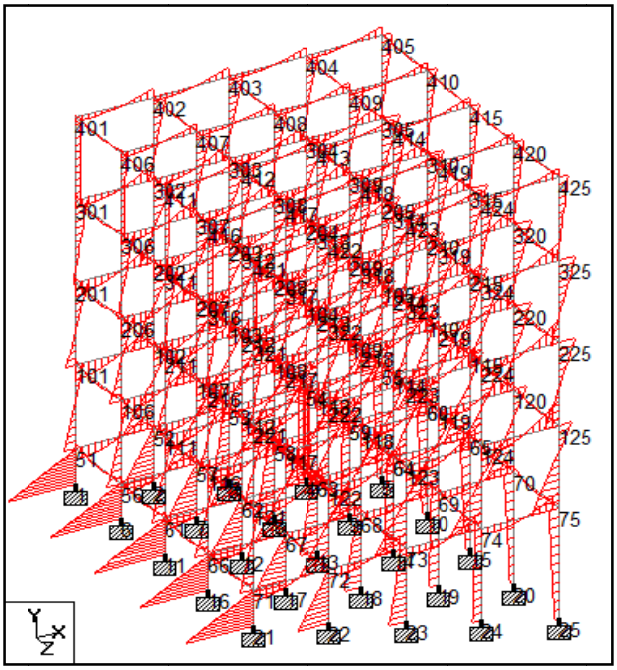

Figure18: Bending moment diagram of sloping ground (15^{o}) building frame

6. CONCLUSIONS

The following conclusions may be drawn from the study:

a) The critical horizontal forces and bending moment in footing increases significantly with increase in ground slope. However critical values of vertical reaction in footing remain almost same for different ground slopes.

b) The critical bending moment in the column increases significantly for sloping ground (15^{o}) compared to plane ground. However critical value of axial force in column remains almost same for different ground slopes. Thus, the section of these columns is required to contain more steel to provide a greater resistance.

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