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Analysis of Seismic Behavior of Multistoried R.C.C Building Resting on Sloping Strata under Seismic Load

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Abstract: Construction of RC buildings in preferred locations in the north & eastern hilly regions have increased during the last few decades due to urbanization, population increase, and high influx of tourists. The buildings situated in hilly areas are much more prone to seismic environment in comparison to the buildings that are located in flat regions. Structures on slopes differ from other buildings since they are irregular both vertically and horizontally and therefore susceptible to severe damage when subjected to seismic action.

The columns of ground storey have varying height due to sloping ground. This paper presents the comparative analysis of various configurations of 15 storied building with to be found on varying slope with different plan and different structural arrangements situated on seismic zone IV. This study compares various reinforced concrete models framed and analysed their response against dynamic loading to identify and struggle the worst possible scenario. The study is carried out for a combination of three different slopes and different building configuration by response spectrum analysis method and various parameters are compared against various constraints.

Keywords: Multistorey building, hill slope angle, seismic response, sloping ground, response spectrum, optimum case, building configuration

I. INTRODUCTION

Indian seismic zones define the shaking properties of the ground, since it is highly recommend designing the structure seismic proof. All the structures should be analysed before the construction since there are many possibilities of failure. But what if the structure supposed to be constructed on hill like in northern and north eastern states of India. Since the slope varies there are many possibilities that during an earthquake, structure would collapse down from a hill. Typically, the structural stability of a structure depends upon various constraints, either it may be the typical topographical conditions or it may be the seismic proximity of the area which will be variable from place to place.

These glitches may be sorted by adopting proper and suitable building configuration as per need keeping in mind the economy of the project and the construction practices which will be the ultimate concluding factor that may leads to stability or proximity to the building.

II. SCOPE AND OBJECTIVE

To make the structure seismic proof it is essential to analyse the multistorey building on sloping ground under earthquake effects to determine its design parameters. Here the building is analysed for three different slopes 7.5˚, 15˚, 30˚ along with a regular building rested on flat terrain against various parameters.

The key objectives set for the analysis are:

A. To analyze and determine the maximum displacement in longitudinal and transverse directions
B. To find and compare base shear in both X and Z direction
C. To compare the maximum of axial forces in column at base
D. To compare and analyze the shear force and bending moment
E. To explore the optimum case among various structural arrangements to resist the seismic hazard and structural irregularities.

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III. MODELLING OF STRUCTURE

A 15 Storied multi-storeyed building is configured comprising of 5 numbers of equally spaced bays in both the direction of 4 m with a constant floor height of 3 m. Total of 3 cases in step back and 3 cases for step back set back cases including building rested on flat ground as well as sloping ground were considered. All the cases are analyzed and studied as per Indian Standard Code IS 1893 (Part1): 2016 against various seismic parameters and constraints for earthquake Zone IV by response spectrum analysis method by "STAAD Pro V8i" software to explore the possibilities to resist the deformation and withstand against seismic and structural hazards.

Table.1. Building description

Parameters	Assumed data
Length of building	20 m
Width of building	20 m
Height of building	48 m
Floor to floor height	3 m
Beam size	350 x 550 mm
Column size	550 x 600 mm
Slab thickness	165 mm
Shear wall	200 mm
Depth of foundation	3 m
Material properties	Concrete (M 25)
Support	Fixed

Table 2. Earthquake Parameters

Parameters	Assumed data
Soil type	Medium soil
Seismic zone	IV (Z = 0.24)
Response reduction factor	4
(Ordinary shear wall with SMRF)	
Importance factor	1.2 (For residential and commercial building)
Damping ratio	5 %
Fundamental natural period of vibration (Ta)	0.09*h/(d)0.5 Tax= 0.965 seconds Taz= 0.965 seconds

Following are the various cases taken for analysis against various parameters possessing following building and seismic data used for analysis of the two types of building configurations are tabulated below:

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Table 3. Different Cases with Respect to Building Configurations for Step Back Cases

Sl. no	Model configuration cases	Abbreviations	Degrees
1	15 storied regular building on flat ground	A0	0
2	15 storied regular building on 7.5° slope	A1	7.5°
3	15 storied regular building on 15° slope	B1	15°
4	15 storied regular building on 30° slope	C1	30°

Table 4.Different Cases with Respect to Building Configurations for Step Back Set Back Cases

Sl. No	Model configuration cases	Abbreviation	Degree
1	15 storied regular building on flat ground	A0	0°
2	15 storied regular building on 7.5° slope	A2	7.5°
3	15 storied regular building on 15° slope	B2	15°
4	15 storied regular building on 30° slope	C2	30°

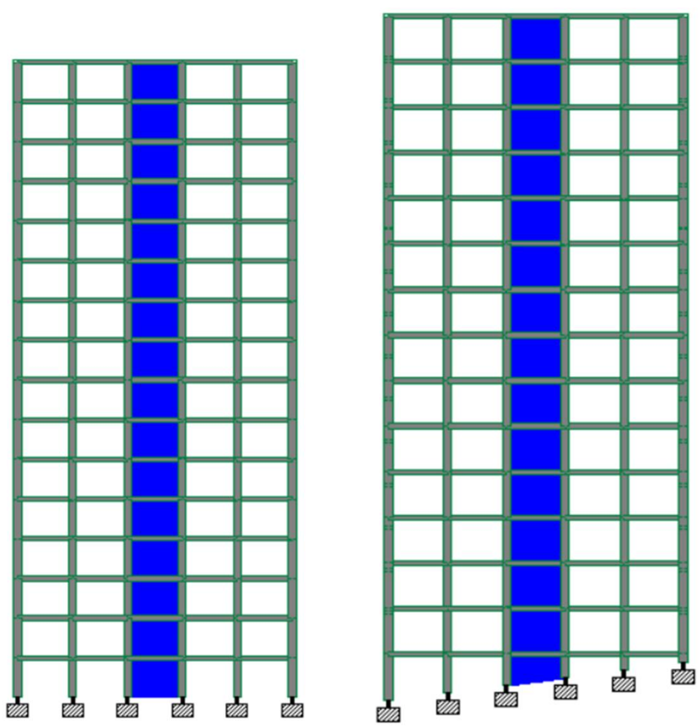

Fig.1. 2D view of A0 and A1 building configuration

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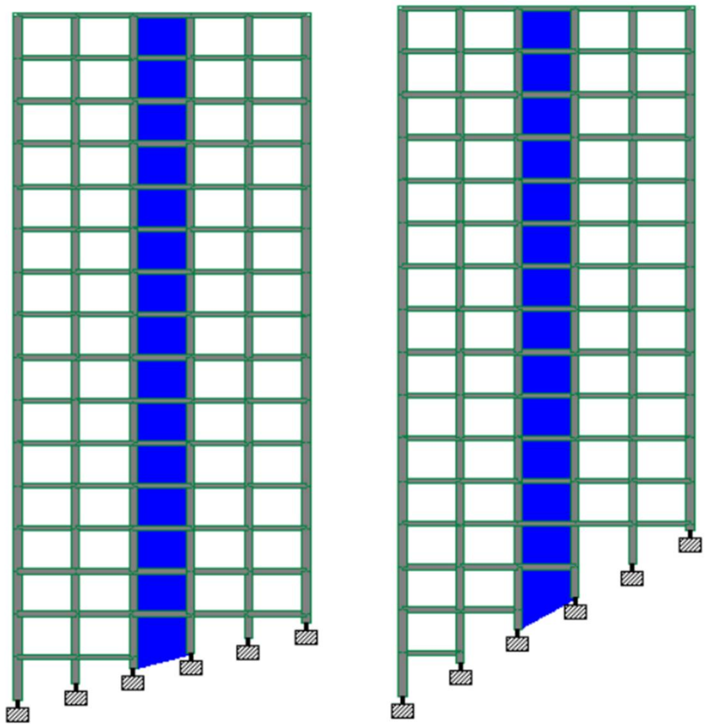

Fig.2. 2D view of B1 and C1 building configuration

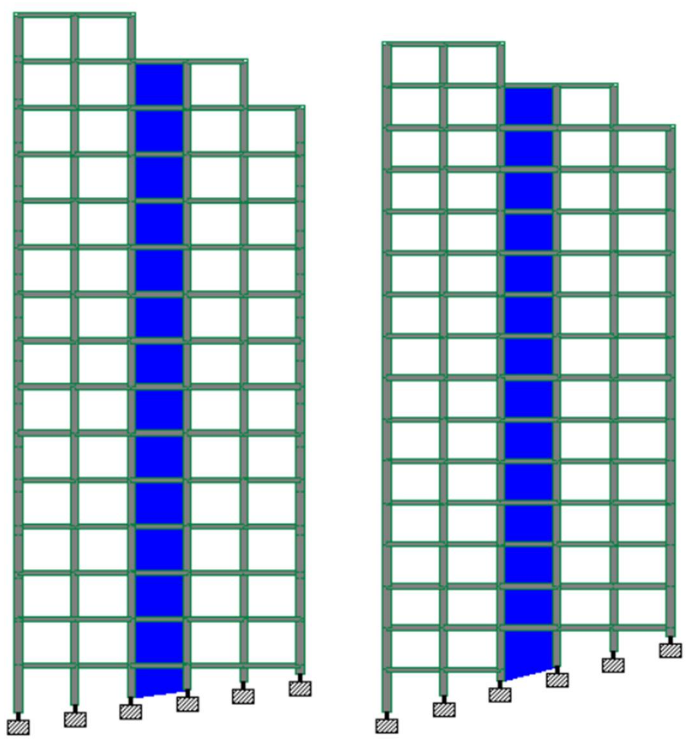

Fig.3. 2D view of A2 and B2 building configuration

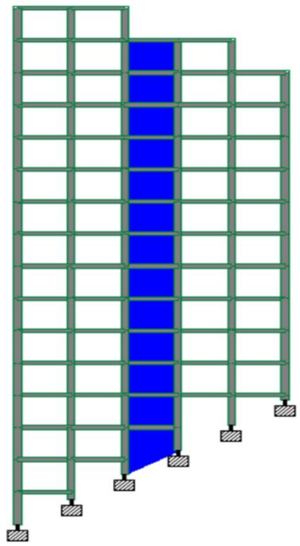

Fig.4. 2D view of C2 building configuration

Table 5. Loading Details

Parameters	Assumed data
Floor finish load	2.2 kN/ sq. m
Wall load (external)	14 kN/ m
Wall load (interior)	8.4 kN/m
Wall load (parapet)	2.4 kN/m
Water proofing	0.5 kN/sq. m
Imposed load (floors)	4 kN/sq.m
Imposed load (roof)	1.5 kN/sq. m

IV. RESULT AND DISCUSSION

In this study various cases are analysed as per IS 1893:2016 (part-1) by response spectrum method for seismic zone IV against all constraints as mentioned in the objectives. Dynamic analysis was performed against various seismic parameters for multiple load combination for all the models consist of structure on normal ground, step back configuration and step back & setback configuration. The parameters taken for comparative examinations for individual cases are maximum nodal displacement, maximum axial force, maximum shear force, maximum bending moment and base shear by tabular and graphical form.

Table 6. Maximum Nodal Displacement for Various Building Cases

Building	Displacement	Building	Displacement
A0	180.537	A0	180.537
A1	150.584	A2	132.762
B1	140.621	B2	128.952
C1	135.048	C2	116.765

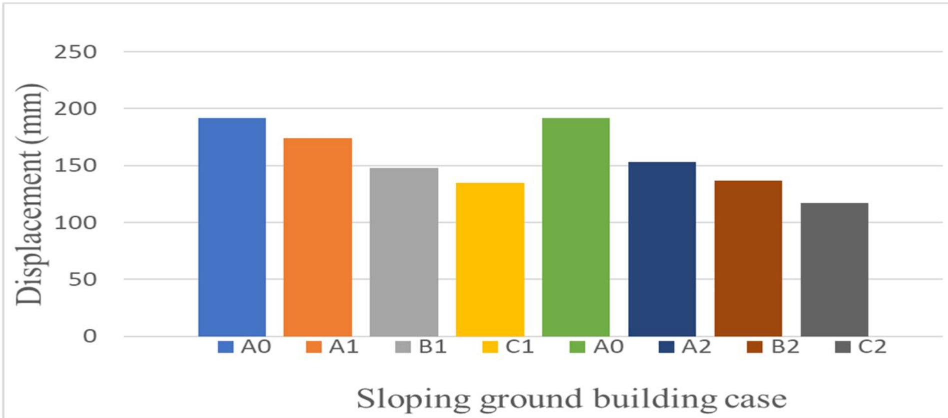

Fig 5. Graph showing maximum nodal displacement for various building cases

Table 7. Maximum Base Shear in X & Z Direction for A0 to D1 Building Cases

BUILDING	BASE SHEAR X	BASE SHEAR Z
A0	3320.36	3320.62
A1	3678.25	3678.90
B1	4471.31	4298.71
C1	3368.26	3485.38

Table 8. Maximum Base Shear in X & Z Direction for A0 to D2 Building Cases

BUILDING	BASE SHEAR X	BASE SHEAR Z
A0	3320.36	3320.62
A2	3612.65	3612.32
B2	4538.43	4308.23
C2	3427.66	3451.57

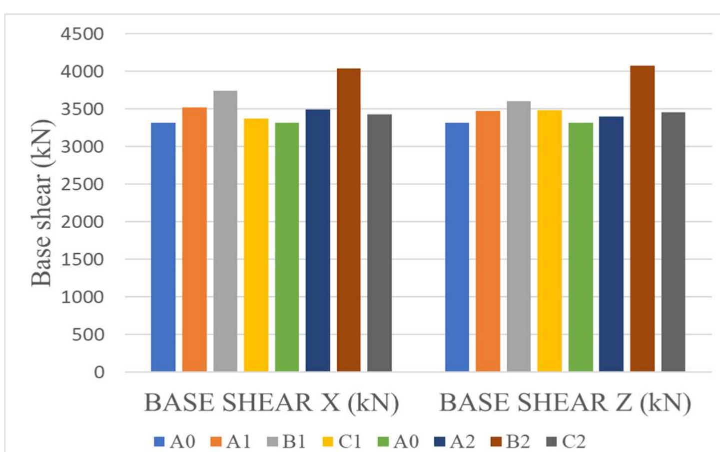

Fig 6. Graph showing Maximum Base Shear in X & Z direction for various building cases

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Table 9. Maximum Axial Forces for Various Building Cases

BUILDING	AXIAL FORCE	BUILDING	AXIAL FORCE
A0	7699.158	A0	7699.158
A1	9004.145	A2	8623.362
B1	7254.128	B2	6843.654
C1	5721.236	C2	5361.67

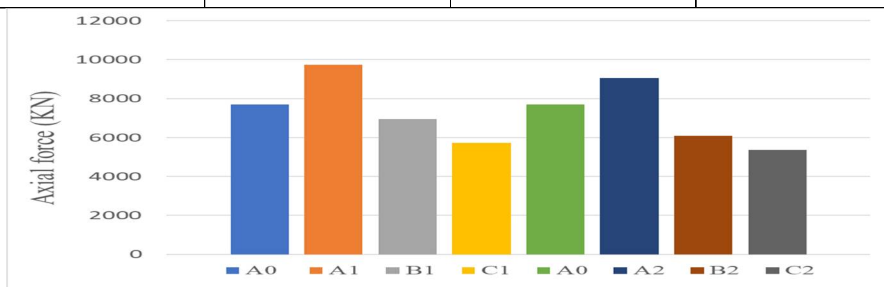

Fig 7. Graph showing axial force values for various building cases

Table 10. Maximum Shear Force in Beam for Various Building Cases

BUILDING	SHEAR FORCE	BUILDING	SHEAR FORCE
A0	191.613	A0	191.613
A1	194.235	A2	182.433
B1	185.258	B2	185.370
C1	172.548	C2	165.931

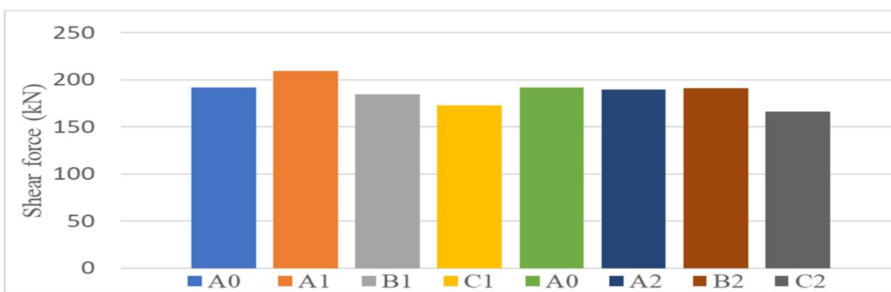

Fig 8. Graph showing shear force values for various building cases

Table 11. Maximum Bending Moment in Beam for Various Building Cases

BUILDING	BENDING MOMENT	BUILDING	BENDING MOMENT
A0	312.435	A0	312.435
A1	311.005	A2	287.121
B1	282.458	B2	277.873
C1	270.158	C2	252.659

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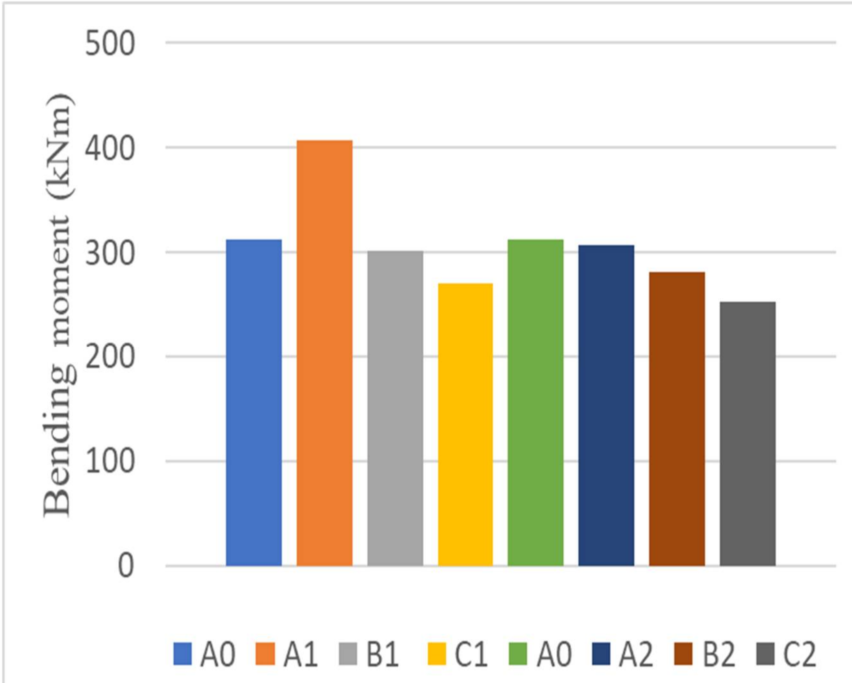

Fig 9. Graph showing Maximum Moment In Beam For Various Building Cases

V CONCLUSION

After analysing various parameters from above results following conclusions are drawn from this research work.

A. Nodal Displacement

After comparing various sloping cases with A0, it has been concluded that the nodal displacement is found minimum for building C1 and C2 with efficiency of 70.46 % for C1 and 60.93% for C2 respectively.

B. Base Shear

On analyzing base shear values the best case which has found out by comparing all buildings rested on sloping ground is building C1 1.44 % less efficient and C2 3.23 % less efficient.

C. Axial Force

On comparing axial force values for all the cases, it has concluded that the building C1 and C2 generate lesser axial forces with efficiency of 74.30 % and 69.63 % as compared to A0.

D. Shear Force

Subsequently analyzing shear force values in beam parallel to X and Z direction of A0 with other cases, again building C1 and C2 shows the least values with efficiency of 90% and 86% among all the sloping ground cases and for this parameter, building C1 and C2 is most efficient.

E. Bending Moment

Again, for bending moment parameters for beams, building C1 and C2 shows least values with efficiency of 86.46% and 80.86 % and shows itself as most efficient case.

From this study, out of all the cases with different configuration building C1 and C2 is found most efficient as per lowest parametric values. From observation of analysis, overall efficient building is C1 and C2 frame when compared to other frames which is then again analyzed by a suitable shear wall retrofitting method. So, C1 and C2 frame is again Re-Designed with Shear wall placed on corner side.

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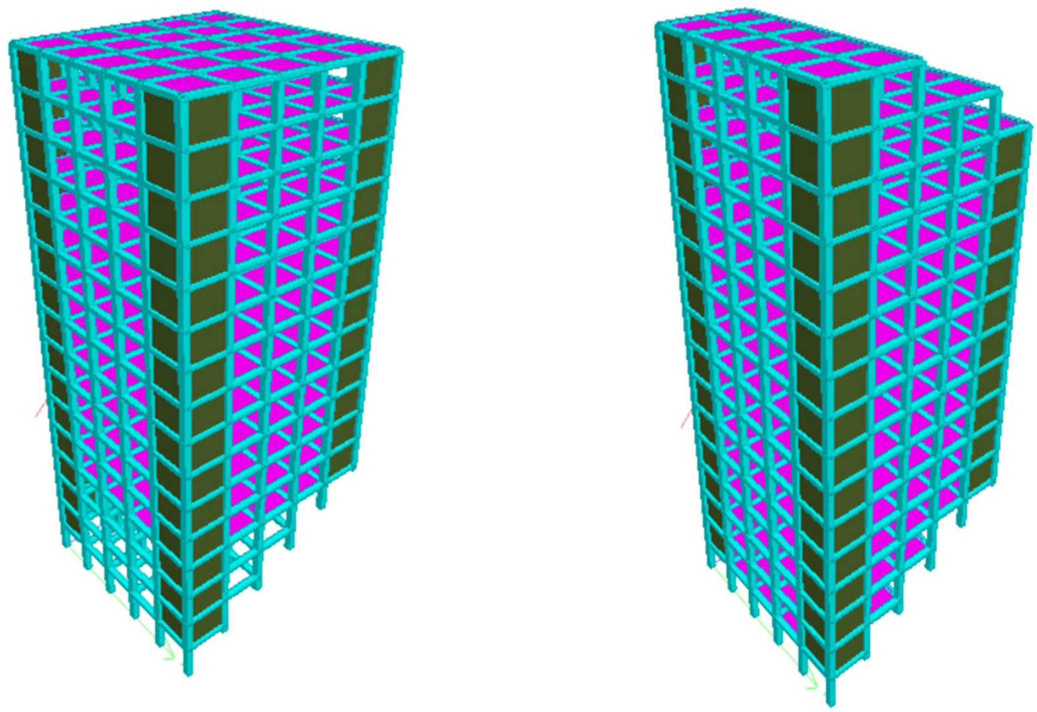

Fig 10. 3D View of C1 and C2 building with shear wall at corner

Table 12. Table Showing Maximum Nodal Displacement Values for Various Position of Shear Wall

Different cases	Maximum nodal displacement value (mm)	
	C1	C2
Shear wall at core	135.04	116.76
Shear wall at corner	127.78	113.59

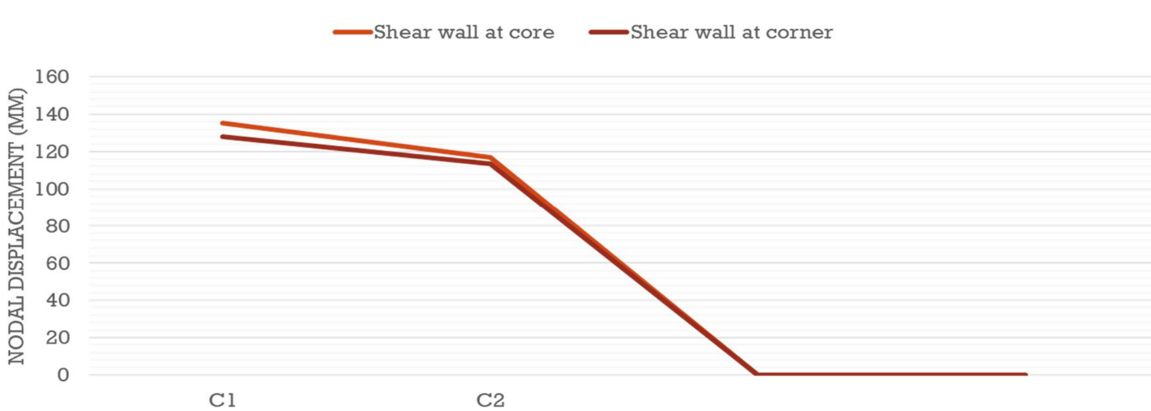

Fig 11. Graph showing maximum nodal displacement values for various position of shear wall

It has been clearly seen from after analysis, the maximum displacement of C1and C2 frame with shear wall at corner have been reduced to 94% of frame with core shear wall. Also, the values of maximum displacement will be more in step back configuration than step set back.

It has been clearly seen from after analysis, the maximum displacement of C1and C2 frame with shear wall at corner have been reduced to 94% of frame with core shear wall. Also, the values of maximum displacement will be more in step back configuration than step set back. Then the performance of step back building found more vulnerable during seismic excitation.

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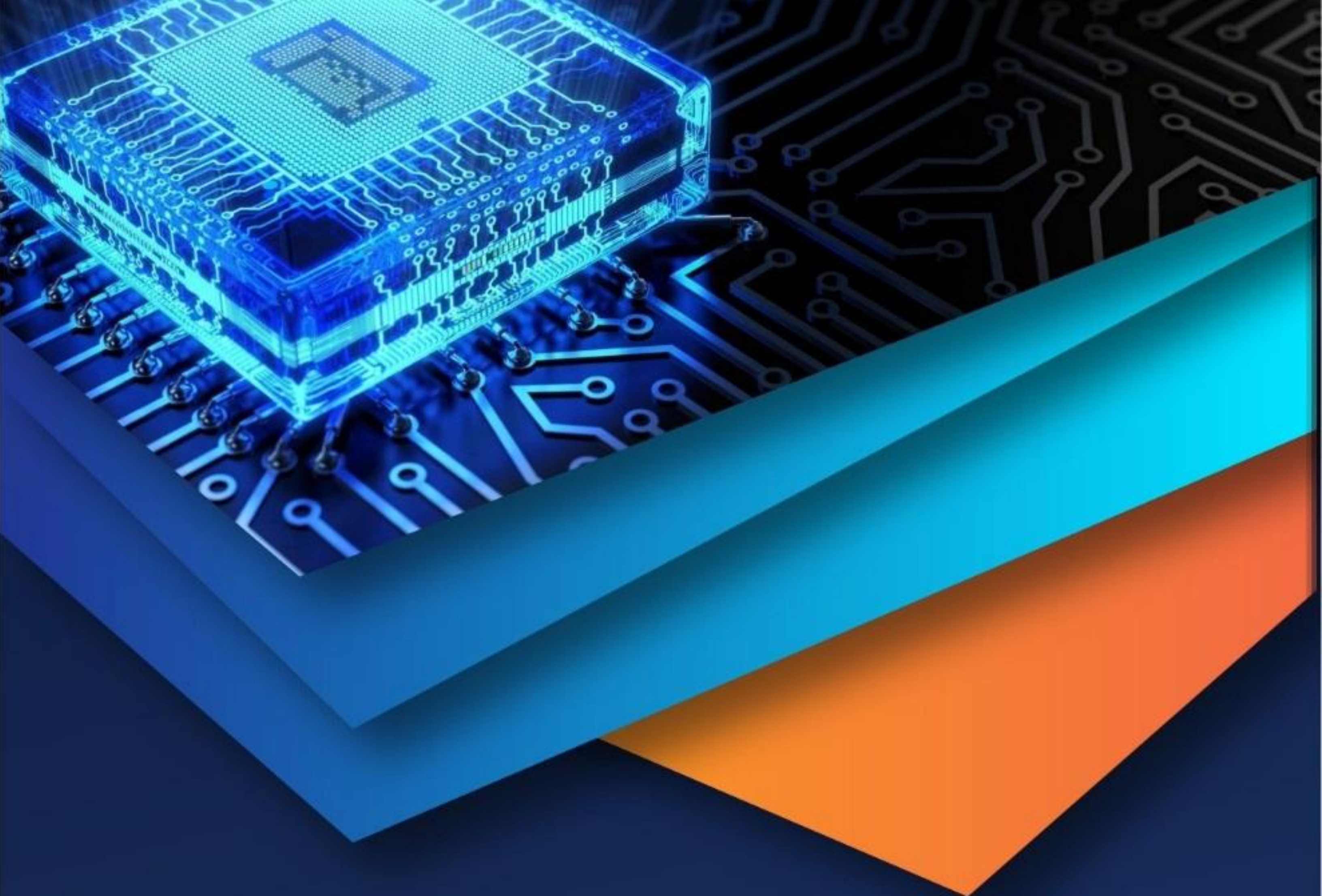

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