Pushover Analysis of Asymmetric Steel Buildings

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Abstract

This research work includes the comparative study of building performances at its performance points with different eccentricity conditions. In steel Building with G+3 storeys, shear walls are used to generate different eccentricities like 0% to 10%, 10% to 20%, 20% to 30%, 30% to 40% and 40% to 50% of total length in that direction. Pushover Analysis is performed in SAP2000 to get performance of the building. Based on the results, it is observed that with the increase in percentage of eccentricity, base shear capacity decreases and displacement increases.

Keywords — *Pushover Analysis, Performance Point, Shear wall, Eccentricity.*

I. INTRODUCTION

As earthquake is unpredictable, it causes major damage to the structures as compared to other natural hazards. Structural engineering needs to get more advanced methodologies to sustain structural damages from earthquake forces. To obtain the performance point, an iterative method like pushover analysis is used. That performance point will give lateral load carrying capacity of building and also declares performance point by providing information of hinges in building.

To reach to the target displacement, an approximate analysis is used like pushover analysis method, by inducing constant height wise increasing lateral load. Pushover analysis generates capacity curve of building which includes a series of successive elastic analysis. Lateral load resisting element is first modeled and then initially gravity loads are applied. Along the full building height, lateral load pattern is distributed. The lateral forces are increased until some member yields. Again lateral forces will increase up to the yielding of another member, until the top of building reaches target displacement, these process continued. One by one member yielding of the building will be plotted in base shear to displacement graph and by joining all that points a curve is generated which is called as global capacity curve. Capacity spectrum is generated using capacity curve. By comparing the capacity spectrum and demand spectrum, an intersection point is obtained as performance point. By performance point, results will show the hinges of building in each performance levels. From those results, the performance objectives will be obtained and by changing the design it is possible to set performance objective of any building and that design is called a Performance Based Design (PBD).

In the past, many researchers concentrated on the application of the performance based design. Jose et al.,[A] evaluated the finite element models with various criteria in different types of analysis using linear-static, multi-mode pushover, and non-linear dynamic analysis. Dubal et al.,[B] studied the application of performance based seismic design method (PBSD) for soft storey RC building frames (10 storeys). Push over analysis results show significance of PBSD method in frames having soft story at lower floor levels as compared to higher ones. It was concluded that performance point of the frames with vertical irregularity of soft storey designed by PBSD method is enhanced than other frames designed by conventional method. Hirde and Mullani [C] carried out the performance based seismic design of multi-storey RCC building. Non-linear analysis was carried out to study seismic performance and it was compared with seismic performance of building designed with conventional code provisions. It was concluded that capacity design is necessary with column beam capacity ratio 1.3 and distribution of lateral strength is more rational in performance based design than IS code design method. Mistry et al.,[D] evaluated the capacity curve, demand curve, performance curve, base shear and displacement. It was concluded that the pushover analysis is an elegant tool to visualize the performance level of the building. Further, it was observed that with the increase in size of the column and beam, roof displacement decrease and base shear increase as vice versa.

Based on the brief literature review presented here, it is observed that comparison of performance of building with different eccentricities for steel structures is still an emerging area for research. The objectives of the present study have been identified as follows:

- To carry out the performance based analysis to obtain performance objectives of steel buildings for the future earthquake and also to understand its collapse mechanism in case of extensive damage.
- To obtain performance of multistorey asymmetric steel building.
- To evaluate the effect of eccentricity by varying the position of shear walls on performance of building.

II. NUMERICAL STUDY

In Software SAP2000, Nonlinear analysis is utilized to create 3D models and analyses have been done considering FEMA 356 and ATC 40. The software is able to predict the geometric nonlinear behaviour of space frames under static or dynamic loadings, taking into account both geometric nonlinearity and material inelasticity. Five models have been analysed by generating eccentricity using shear walls:

1) Eccentricity (0% to 10% of plan dimension)
2) Eccentricity (10% to 20% of plan dimension)
3) Eccentricity (20% to 30% of plan dimension)
4) Eccentricity (30% to 40% of plan dimension)
5) Eccentricity (40% to 50% of plan dimension)

Shear walls are placed in such a way that, building in X-axis remains symmetric and only stiffness along Y-axis may change and difference of centre of mass (*Cm*) and centre of stiffness (*Cs*) provides eccentricity with respect to total length of X-direction.

Following are the properties of the considered buildings:

- Plan dimension of structure: 15m x 15m
- No. of bays in X-direction: 3
- No. of bays in Y-direction: 3
- Floor height: 3.5m
- Size of beams: ISMB250
- Size of Columns: ISMB350
- Size of Steel shear walls: 0.02 m x 5 m
- Slab thickness (concrete) : 0.12 m
- Floor finish load: 1.5 kN/m^2
- Live load: 3 kN/m^2
- Seismic code: IS 1893 (Part 1) 2002
- Design code: IS 800-2007
- Zone: V
- Response reduction factor: 5
- Type of Soil: Medium

A. Steel Building With 0% - 10% Eccentricity

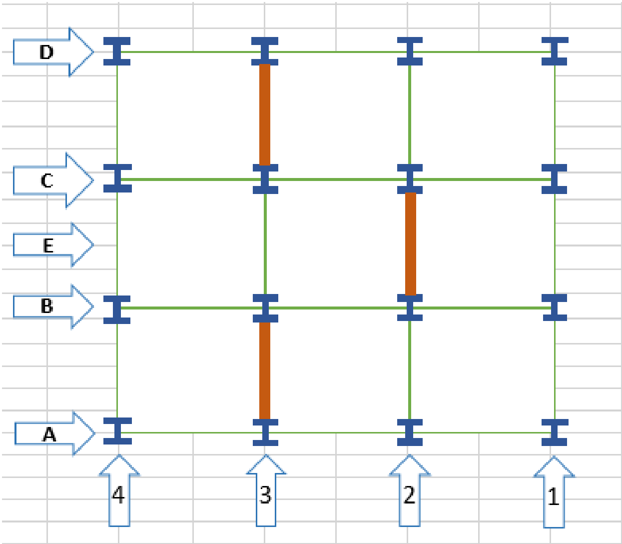

Fig. 1: Plan of Building (Eccentricity 5.32%)

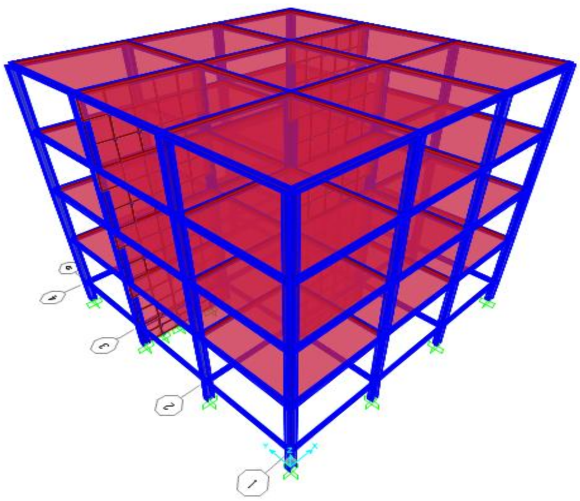

Fig. 2: 3D View of Steel Building with 5.32% Eccentricity

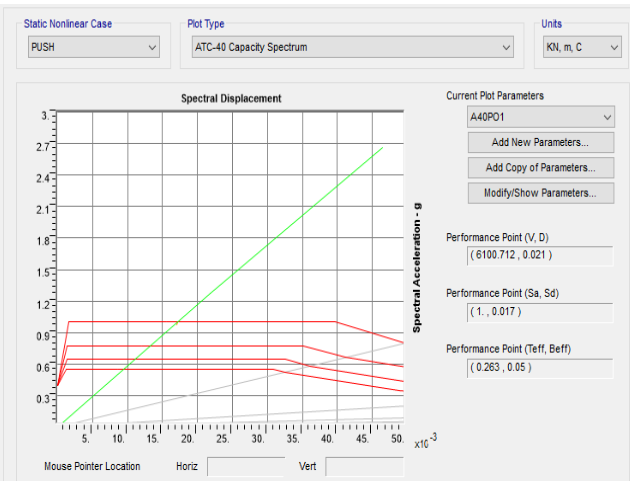

Fig. 3: Performance Point (Case-1)

LoadCase Text	Step Unitless	Displacement	BaseForce KN	AtoB Unitless	BtoIO Unitless
PUSH	0	-3.459E-18	0	400	0
PUSH	1	0.026691	7755.456	399	1

Table 1: Hinges in Building (Case-1)

Shear walls are placed such that the eccentricity due to *Cm* & *Cs* remains in range of 0% - 10% (5.32%). The capacity spectrum curve obtained from nonlinear static analysis is shown in Figure 3. The ultimate lateral load carrying capacity of building at performance point is around 6100.71kN and the corresponding roof displacement is 21 mm.

At performance point, out of 400 assigned hinges, 399 hinges are in linear range, 1 is in B – IO (Immediate occupancy) range. Thus the overall building performance is considered to be in Immediate Occupancy level.

B. Steel Building With 10% - 20% Eccentricity

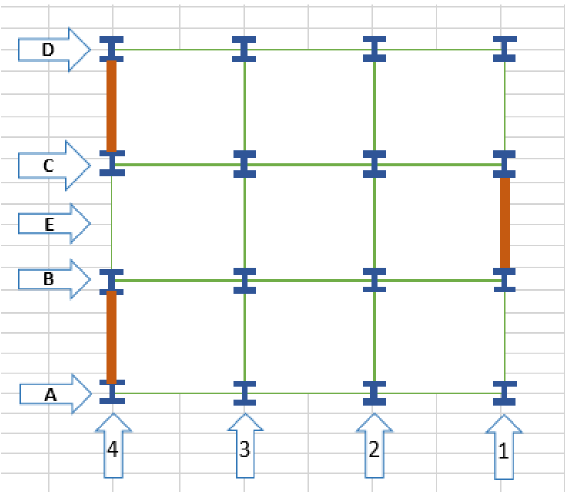

Fig. 4: Plan of Building (Eccentricity 15.96%)

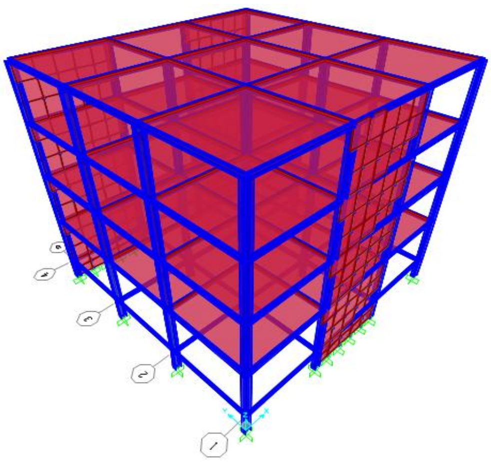

Fig. 5: 3D View of Steel Building with 15.96% Eccentricity

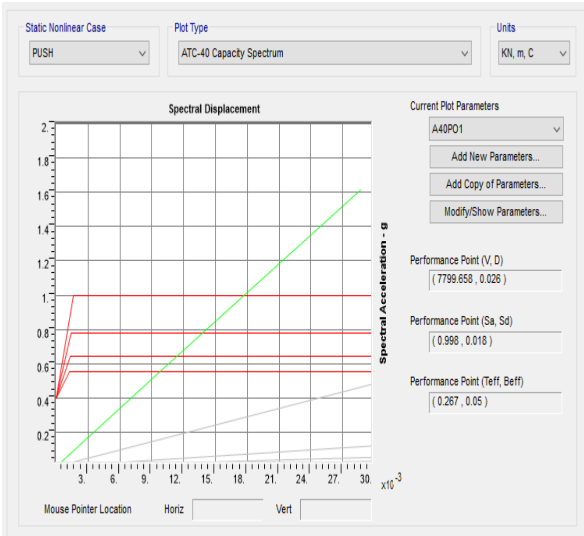

Fig. 6: Performance Point (Case-2)

LoadCase Text	Step Unitless	Displacement	BaseForce KN	AtoB Unitless	BtoIO Unitless	IOtoLS Unitless	LStoCP Unitless	CPtoC Unitless	CtoD Unitless
PUSH	0	-8.024E-17	0	400	0	0	0	0	0
PUSH	1	0.015576	4705.011	399	1	0	0	0	0
PUSH	2	0.0418	12609.04	387	5	5	1	1	1

Table 2: Hinges in building (Case-2)

At performance point, the ultimate load carrying capacity of building is 7799.65 kN and the corresponding roof displacement is 26 mm. It is observed that, out of 400 assigned hinges, 387 hinges are in linear range, 5 are in B – IO (Immediate occupancy) range, 5 are in IO – LS (Life safety) range, 1 is in LS – CP (Collapse Prevention), 1 is in CP – C (Collapse) and 1 is in C – D (Collapse). Thus the overall building performance is considered to be in Collapse level.

C. Steel Building With 20% - 30% Eccentricity

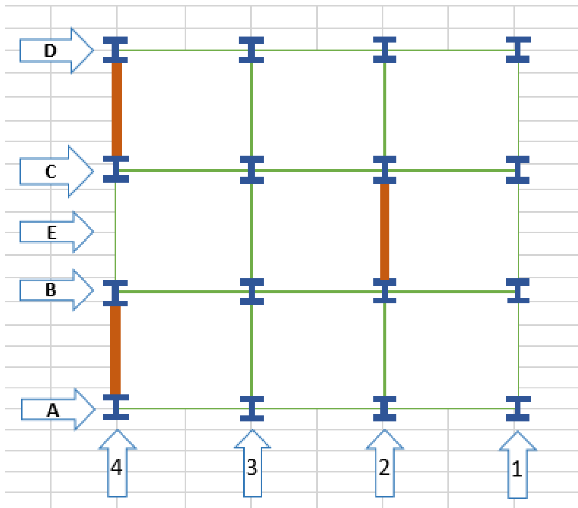

Fig. 7: Plan of Building (Eccentricity 23.69%)

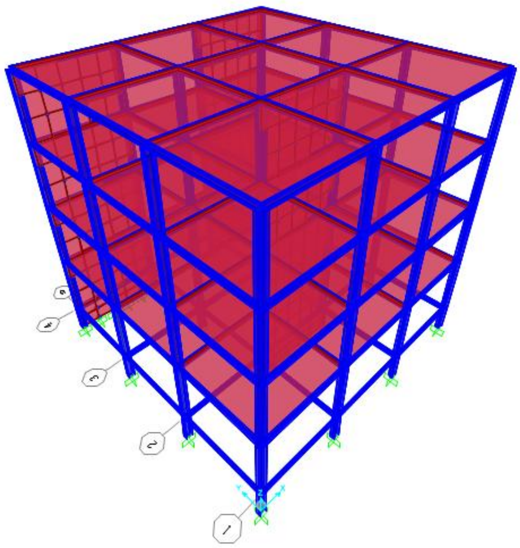

Fig. 8: 3D View of Steel Building with 23.69% Eccentricity

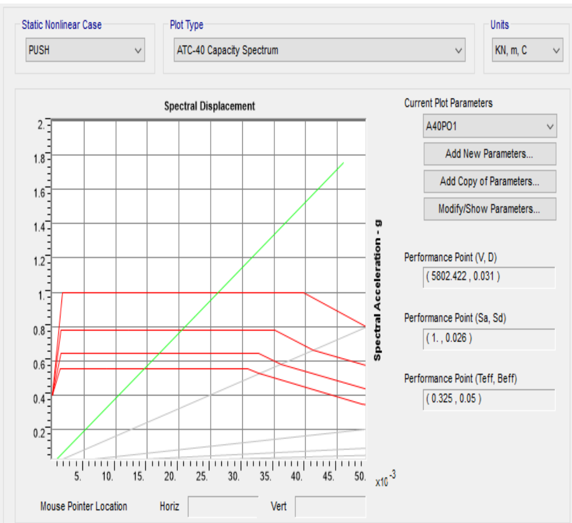

Fig. 9: Performance Point (Case-3)

LoadCase Text	Step Unitless	Displacement	BaseForce KN	AtoB Unitless	BtoIO Unitless	IOtoLS Unitless	LStoCP Unitless
PUSH	0	-3.072E-16	0	400	0	0	0
PUSH	1	0.026688	4961.408	399	1	0	0
PUSH	2	0.05464	10148.523	393	2	4	1

Table 3: Hinges in Building (Case-3)

At performance point, the ultimate load carrying capacity of building is 5802.42 kN and the corresponding roof displacement is 31 mm. And it is observed that, out of 400 assigned hinges, 393 hinges are in linear range, 2 are in B – IO (Immediate occupancy) range, 4 are in IO – LS (Life safety) range, 1 is in LS – CP (Collapse Prevention). Thus the overall building performance is considered to be in Collapse Prevention level.

D. Steel Building With 30% - 40% Eccentricity

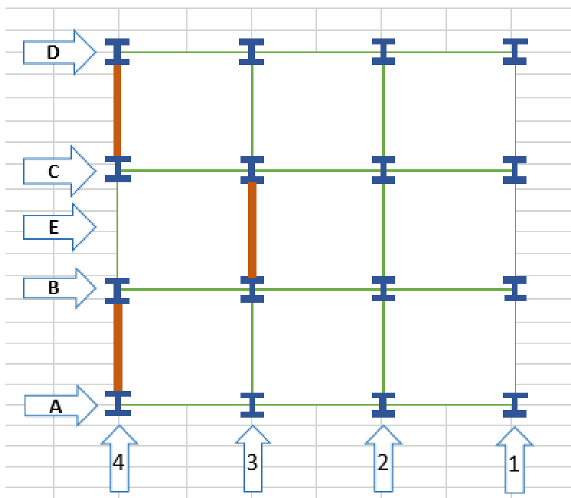

Fig. 10: Plan of Building (Eccentricity 37.25%)

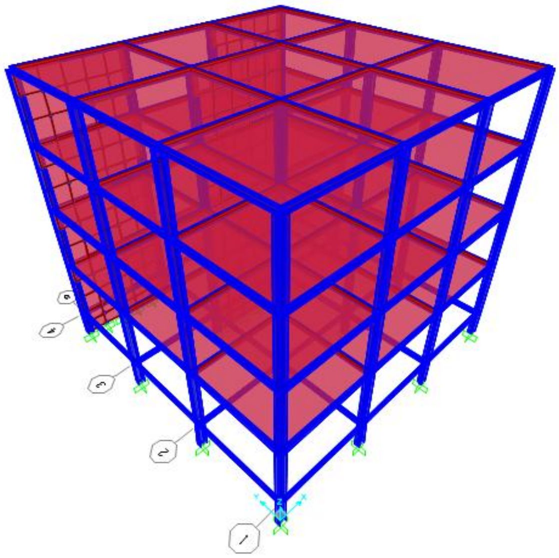

Fig. 11: 3D view of Steel Building with 37.25% Eccentricity

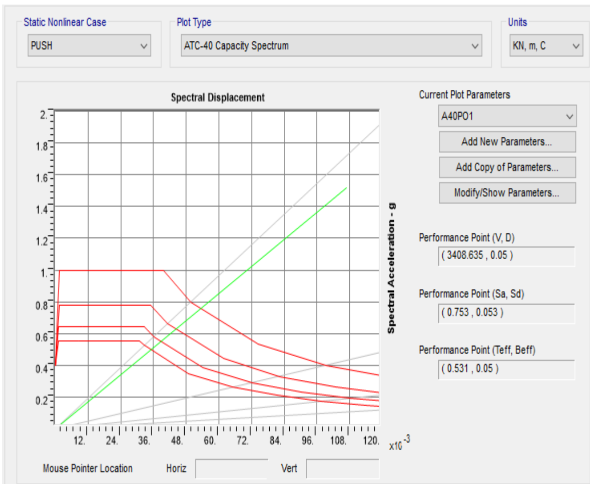

Fig. 12: Performance Point (Case-4)

LoadCase Text	Step Unitless	Displacement	BaseForce KN	AtoB Unitless	BtoIO Unitless	IOtoLS Unitless	LStoCP Unitless	CPtoC Unitless
PUSH	0	-4.941E-16	0	400	0	0	0	0
PUSH	1	0.049418	3360.082	399	1	0	0	0
PUSH	2	0.101417	6884.211	389	2	5	1	3

Table 4: Hinges in Building (Case-4)

At performance point, the ultimate load carrying capacity of building is 3408.63 kN and the corresponding roof displacement is 50 mm. And it is observed that, out of 400 assigned hinges, 389 hinges are in linear range, 2 are in B – IO (Immediate occupancy) range, 5 are in IO – LS (Life safety) range, 1 is in LS – CP (Collapse Prevention), 3 are in CP – C (Collapse). Thus the overall building performance is considered to be in Collapse level.

E. Steel Building With 40% - 50% Eccentricity

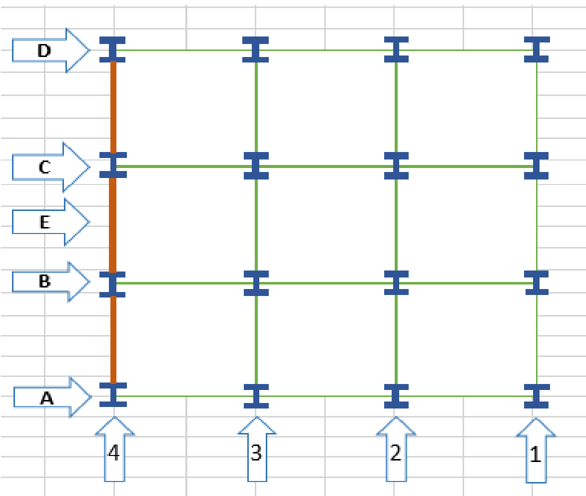

Fig. 13: Plan of Building (Eccentricity 47.90%)

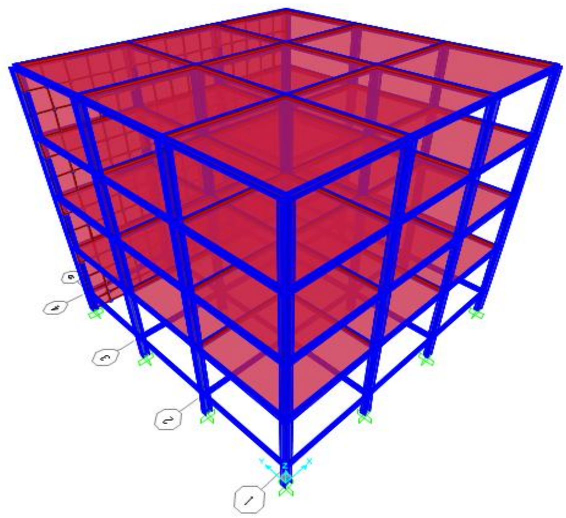

Fig. 14: 3D view of Steel Building with 47.90% Eccentricity

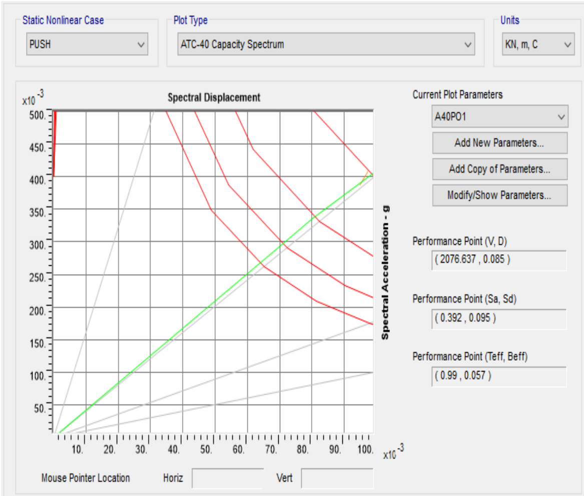

Fig. 15: Performance Point (Case-5)

LoadCase Text	Step Unitless	Displacement	BaseForce KN	AtoB Unitless	BtoIO Unitless	IOtoLS Unitless	LStoCP Unitless	CPtoC Unitless	CtoD Unitless
PUSH	0	-6.513E-17	0	400	0	0	0	0	0
PUSH	1	0.062	1529.131	400	0	0	0	0	0
PUSH	2	0.071149	1754.783	399	1	0	0	0	0
PUSH	3	0.089154	2169.729	390	3	3	0	3	1

Table 5: Hinges in Building (Case-5)

At performance point, the ultimate load carrying capacity of building is 2076.63 kN and the corresponding roof displacement is 85 mm. It is observed that, out of 400 assigned hinges, 390 hinges are in linear range, 3 are in B – IO (Immediate occupancy) range, 3 are in IO – LS (Life safety) range, 3 are in CP – C (Collapse) and 1 is in C – D (Collapse). Thus the overall building performance is considered to be in Collapse level.

Table 6 represents the comparison of base shear capacity and displacement of all five cases.

Eccentricity Range	Base Shear Capacity	Displacement	Performance Level
0% - 10% (5.32%)	6100.712 kN	0.021	Hinge -1 - Immidiate occupancy
10% - 20% (15.96%)	7799.658 kN	0.026	Hinge -1 - Collapse
20% - 30% (23.69%)	5802.422 kN	0.031	Hinge -1 - Collapse Prevention
30% - 40% (37.25%)	3408.635 kN	0.05	Hinge -3 - Collapse
40% - 50% (47.90%)	2076.637 kN	0.085	Hinge -1 - Collapse

Table 6: Combined Results

III. CONCLUSION

Based on the research work carried out herein, the following conclusions can be drawn:

- With the increase in the percentage of eccentricity, the bases hear capacity decreases and displacement increases.
- Base shear capacity significantly depends on the location of shear walls.
- With the increase in the eccentricity of building, the structure enters into collapse level.

IV.REFERENCES

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