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ASSESSMENT OF PROGRESSIVE COLLAPSE IN ASYMMETRIC HIGH RISE BUILDING

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Abstract: Progressive collapse is a critical safety concern in modern high-rise buildings, especially when asymmetry is present in the structural design. Asymmetric buildings, due to irregular geometry, load distribution, and structural variations, pose unique challenges in terms of their vulnerability to progressive collapse. An asymmetric model of a 12storey structure is made on ETABS Software and analysis of reinforced concrete framed structure under critical column removal has been carried using the linear static analysis methods as per the guidelines provided in GSA (2003) and FEMA: 356 guidelines respectively taking into consideration the provisions of IS1893:2016 codes to simulate dynamic collapse problems.

Keywords: *Progressive Collapse, High Rise Building ETABS, GSA, FEMA*

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I.INTRODUCTION:

The term "progressive collapse" refers to the spread of localized structural failure throughout a building, often starting from a single point of failure and extending to larger sections, potentially leading to the collapse of the entire structure. This phenomenon is especially hazardous in high-rise buildings, where failure in one component can trigger catastrophic events due to interconnected load-bearing systems. Asymmetry in building design introduces additional complexities by creating uneven load paths and differing structural responses to applied forces.High-rise buildings, which are typically designed to withstand seismic forces, wind loads, and other dynamic stresses, must also account for potential progressive collapse scenarios. Asymmetric buildings, often designed for aesthetic, functional, or site-specific reasons, deviate from uniformity in terms of mass distribution, stiffness, and geometric layout. These deviations complicate the collapse dynamics, as certain load-bearing elements may become overstrained under abnormal conditions.

This paper aims to evaluate the causes and mechanisms of progressive collapse in asymmetric high-rise buildings, focusing on the need for specialized assessment techniques and mitigation strategies.

II. OBJECTIVE OF THE STUDY

Following are the objectives of this work-

1. To explore how failures in structural elements of asymmetric high-rise buildings trigger a cascade of failures throughout the building, leading to progressive collapse.
2. By calculating the DCR for each of these critical components, the paper aims to determine which parts of the building are most likely to fail first under extreme loading conditions, such as localized impacts or internal structural failures.
3. Using PMM, the paper will assess the probability of failure for different structural components based on various collapse scenarios, such as localized damage due to explosions or fire, and establish how likely it is for the collapse to propagate throughout the building.

III. MODELLING

3.1 Structure Modelling

The building consider in the study is to be located in seismic Zone II, and intended for Commercial use (Hotel). Building is founded medium strength soil. The columns at base are assumed to be provided with Mat footing. Response reduction factor for the special moment resting frame without shear wall and frame with shear wall has taken as 4 (Ductile detailing is assumed). The finish load on the floor is taken as 1.5 KN/m^2. Live load on the floor is taken as 3.0 KN/m^2. In seismic weight calculation, 25% of the floor live loads are considered in the analysis. Details of the structure are given in table 3.6.

Table 1 Details of building Model in ETABS

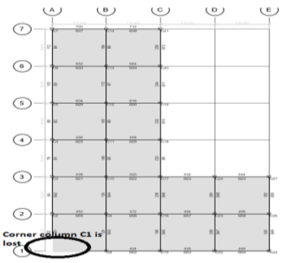
Type of structure	Commercial building
Plan dimension	30 m x 40 m
Total height of building	36 m
Height of typical storey	3 m
Height of bottom storey	3 m
Bay width in longitudinal direction	7.5 m
Bay width in transverse direction	8 m
Size of beam (Ground to 12th storey)	250 mm x 550 mm
Size of Perimeter (Outer)column (Ground to 12th storey)	600 mm x 600 mm
Thickness of slab	150 mm
Size of Interior column (Ground to 12st storey)	600 mm x 600 mm
Seismic zone	II
Soil condition	Medium
Response reduction factor	4
Damping coefficient	5%
Importance factor	1
Density of Brick Masonry	20 kN/m3
Grade of concrete	M30
Grade of steel	HYSD Fe415

The following cases has been considered for the analysis of work. Modeling has been carried out using ETAB 16.2.1.

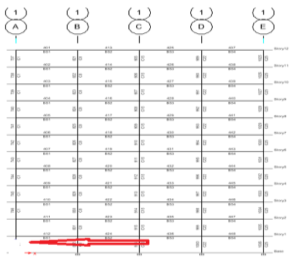
Case (1) Column is lost due to accident load – In this exterior column will be lost.

3.2.1 Corner column of ground floor is lost–

In this case we consider that corner column C 1 of ground floor is suddenly removed.



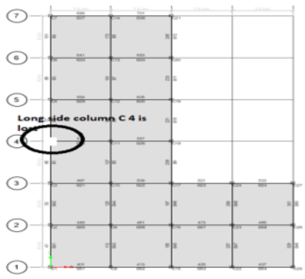
PLAN



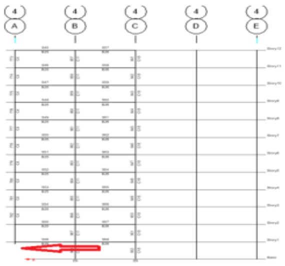
ELEVATION

3.2.2 Long side column of ground floor is lost –

In this case we consider that long side column C 4 of ground floor is suddenly removed



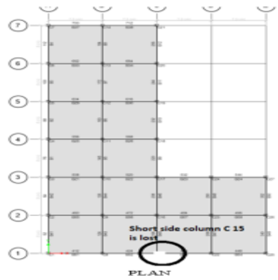
PLAN



ELEVATION

3.2.3 Short side column of ground floor is lost –

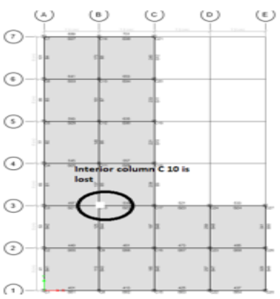
In this case we consider that Short side column C 15 of ground floor is suddenly removed.

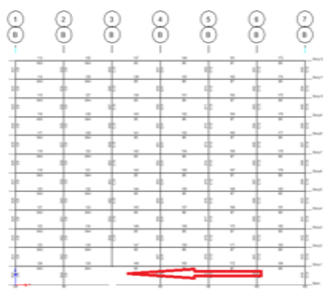


Case (2) Column is lost due to Blast load – In this interior column will be lost.

3.2.4 Interior column of ground floor is lost –

In this case we consider that interior column C 10 of ground floor is suddenly removed.





floor is suddenly removed.

IV.RESULT AND DISCUSSION

STOREY RESPONSE (MAXIMUM STOREY DISPLACEMENT) CURVES FOR ALL THE STRUCTURES

4.1.1 Storey Response (maximum storey displacement)

TABLE: Story Response In Global X direction				
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**
	m		mm	mm
Story12	36	Top	39.835	1.007
Story11	33	Top	38.167	0.952
Story10	30	Top	35.691	0.883
Story9	27	Top	32.397	0.795
Story8	24	Top	28.394	0.687
Story7	21	Top	23.823	0.562
Story6	18	Top	18.829	0.424
Story5	15	Top	13.573	0.283
Story4	12	Top	8.277	0.149
Story3	9	Top	3.38	0.045
Story2	6	Top	0	0
Story1	3	Top	0.399	0.005
Base	0	Top	0	0

Graphs for Corner column C 1 of GF removal -

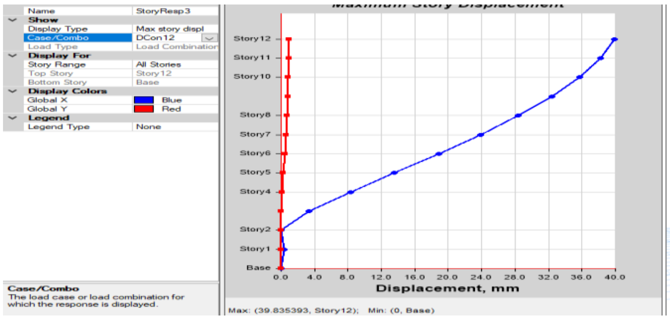
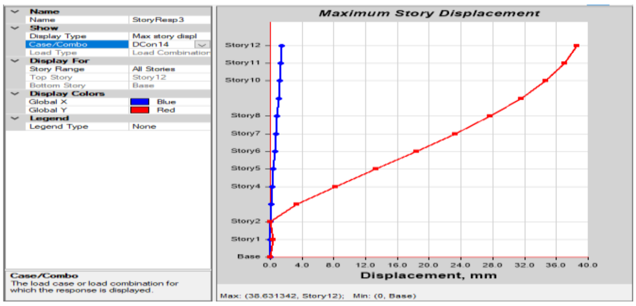


Figure 1 maximum storey displacement curves for X direction

TABLE: Story Response in Global Y direction				
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**
	m		mm	mm
Story12	36	Top	1.375	38.631
Story11	33	Top	1.266	37.062
Story10	30	Top	1.149	34.696
Story9	27	Top	1.02	31.53
Story8	24	Top	0.877	27.674
Story7	21	Top	0.723	23.262
Story6	18	Top	0.561	18.433
Story5	15	Top	0.398	13.338
Story4	12	Top	0.242	8.182
Story3	9	Top	0.107	3.378
Story2	6	Top	0	0
Story1	3	Top	0.03	0.414
Base	0	Top	0	0



4.1.2 Storey Response (maximum storey displacement) Graphs for Long Side column C 4 of GF removal.

TABLE: Story Response in Global X direction				
Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	mm
Story12	36	Top	43.046	1.2
Story11	33	Top	41.562	1.143
Story10	30	Top	39.389	1.076
Story9	27	Top	36.52	0.992
Story8	24	Top	33.048	0.89
Story7	21	Top	29.09	0.773
Story6	18	Top	24.76	0.643
Story5	15	Top	20.167	0.504
Story4	12	Top	15.416	0.362
Story3	9	Top	10.628	0.223
Story2	6	Top	6.009	0.1
Story1	3	Top	2.029	0.017
Base	0	Top	0	0

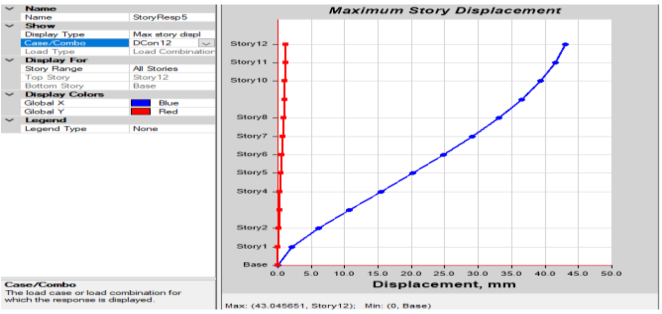


Figure 3 maximum storey displacement curves for X direction

TABLE: Story Response in Global Y direction				
Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	mm
Story12	36	Top	1.023	41.069
Story11	33	Top	0.928	39.737
Story10	30	Top	0.821	37.727
Story9	27	Top	0.708	35.037
Story8	24	Top	0.636	31.759
Story7	21	Top	0.551	28.005
Story6	18	Top	0.456	23.886
Story5	15	Top	0.354	19.503
Story4	12	Top	0.248	14.954
Story3	9	Top	0.144	10.354
Story2	6	Top	0.054	5.889
Story1	3	Top	0.014	2.016
Base	0	Top	0	0

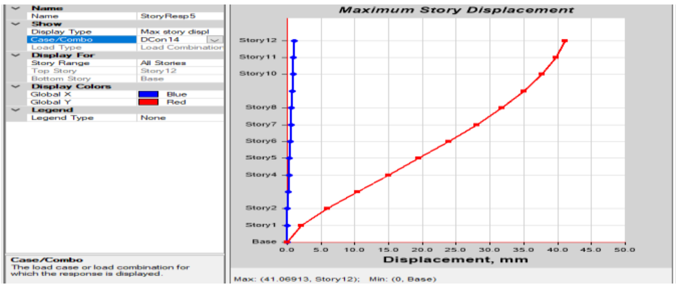


Figure 4 maximum storey displacement curves for Y direction

4.1.3 Storey Response (maximum storey displacement) Graphs for Short Side column C 15 of GF removal-

TABLE: Story Response in Global X direction				
Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	mm
Story12	36	Top	40.97	5.923
Story11	33	Top	39.644	5.389
Story10	30	Top	37.661	4.867
Story9	27	Top	34.983	4.337
Story8	24	Top	31.702	3.797
Story7	21	Top	27.931	3.25
Story6	18	Top	23.788	2.698
Story5	15	Top	19.405	2.162
Story4	12	Top	14.922	1.666
Story3	9	Top	10.385	1.173
Story2	6	Top	5.963	0.685
Story1	3	Top	2.072	0.226
Base	0	Top	0	0

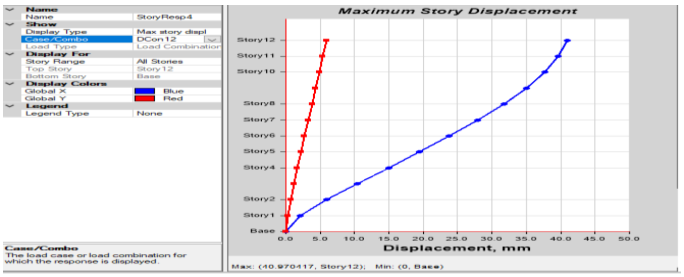


TABLE: Story Response in Global Y direction				
Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	mm
Story12	36	Top	3.125	48.625
Story11	33	Top	2.872	46.597
Story10	30	Top	2.613	43.899
Story9	27	Top	2.344	40.526
Story8	24	Top	2.063	36.567
Story7	21	Top	1.771	32.134
Story6	18	Top	1.471	27.337
Story5	15	Top	1.167	22.277
Story4	12	Top	0.863	17.054
Story3	9	Top	0.567	11.786
Story2	6	Top	0.295	6.678
Story1	3	Top	0.079	2.229
Base	0	Top	0	0

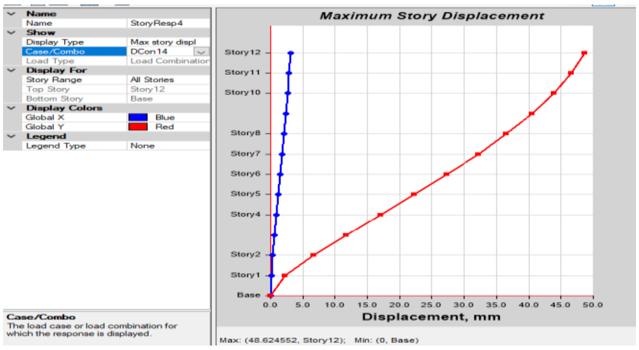


Figure 6 maximum storey displacement curves for Y direction

4.1.4 Storey Response (maximum storey displacement) Graphs for Interior column C 10 of GF removal-

TABLE: Story Response In X Global direction

Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	mm
Story12	36	Top	50.22	9.003
Story11	33	Top	47.956	8.142
Story10	30	Top	45.049	7.297
Story9	27	Top	41.496	6.47
Story8	24	Top	37.388	5.66
Story7	21	Top	32.831	4.863
Story6	18	Top	27.929	4.078
Story5	15	Top	22.779	3.3
Story4	12	Top	17.472	2.527
Story3	9	Top	12.118	1.758
Story2	6	Top	6.906	1.003
Story1	3	Top	2.312	0.301
Base	0	Top	0	0

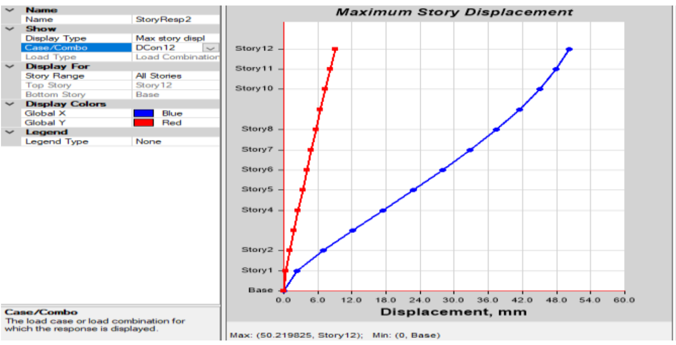


Figure 7 maximum storey displacement curves for X direction

TABLE: Story Response in Global Y direction

Story	Elevation	Location	X-Dir	Y-Dir
	m		mm	mm
Story12	36	Top	11.993	50.822
Story11	33	Top	10.91	48.59
Story10	30	Top	9.828	45.691
Story9	27	Top	8.74	42.116
Story8	24	Top	7.646	37.956
Story7	21	Top	6.547	33.321
Story6	18	Top	5.445	28.321
Story5	15	Top	4.344	23.058
Story4	12	Top	3.249	17.632
Story3	9	Top	2.175	12.164
Story2	6	Top	1.158	6.866
Story1	3	Top	0.297	2.261
Base	0	Top	0	0

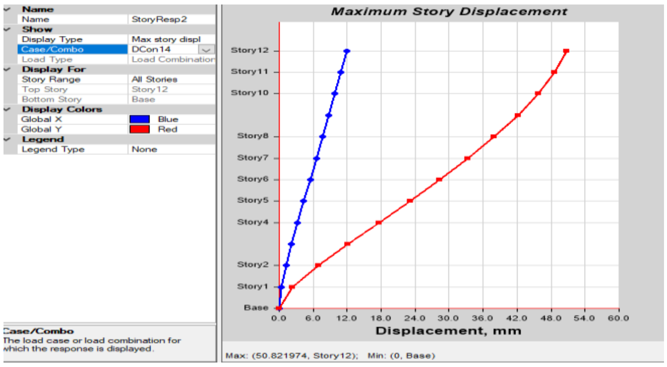


Figure 8 maximum storey displacement curves for Y direction

4.2 BASE SHEAR FOR THE STRUCTURE

Table 2 maximum Base Shear Values for X & Y direction

Building parameter	For Asymmetrical building when no column is lost	For Asymmetrical building when Interior column **C-10** is lost	Increment in Percentage
Base Shear in X direction (KN)	1079.53	1742.64	61.44%
Base Shear in Y direction (KN)	1112.31	1767.39	58.59 %

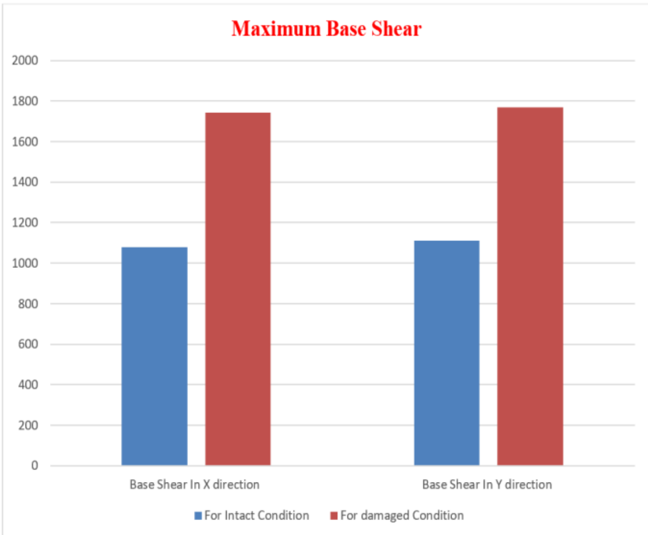


Figure 9 Maximum Base Shear in X &Y direction

V.CONCLUSIONS

1. For Ground Floor column removal cases beams up to the topmost storey are going to fail for any column

removal case since DCR ratio is more than limiting value (2.0) for shear as well as flexure.

2. For most of the column PMM values are less than 2, hence columns are not critical in progressive collapse process of building for all column removal cases.

3. The maximum displacement at all the stories is lowest in corner column removal case and increased by 28.23% if interior column is lost. The displacement at the base of the structure at all nodes for all cases is zero.

4. Redesigning of beams in flexure is required to prevent the progressive collapse of building.

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