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Assessment of Progressive Collapse of G+7 RC Building

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Abstract— A simplified framework is proposed for progressive collapse assessment of multi-storey buildings, considering sudden column loss as a design scenario. This framework can be applied at various levels of structural idealisation, and enables the quantification of structural robustness taking into account the combined influences of redundancy, ductility and energy absorption this study aims to provide the designer engineers with wider overview on this topic to minimize the consequences of buildings progressive collapse after the event of column removal scenario. A Seven storey reinforced concrete framed structure is considered in the study to evaluate the Demand Capacity Ratio (D.C.R.), the ratio of the member force and the member strength as per U.S. General Services Administration (GSA) guidelines. The Non Linear static analysis is carried out using software, STAAD PRO according to Indian Standard codes. To study the collapse, typical columns are removed one at a time, and continued with analysis and design. Many such columns are removed in different trials to know the effects of progressive analysis. Member forces and reinforcement details are calculated. From the analysis, DCR values of beams are calculated.

Keywords: RC building, progressive collapse, nonlinear static analysis

I. INTRODUCTION

Progressive collapse is a situation where local failure of a primary structural component leads to the collapse of adjoining members which, in turn, leads to additional collapse. Hence, the total damage is disproportionate to the original cause. Progressive collapse the spread of local damage, from an initiating event, from element to element resulting, eventually, in the collapse of an entire structure or a disproportionately large part of it; also known as disproportionate collapse. This failure occurs when a building loses one or more of its vertical load carrying components. This loss could be the result of an unexpected loading, like a vehicle accident, an explosion, terroristic attack or a construction/ design error. The single element failure can lead to a larger damage in determinate structure, for that this structural system is not robust. In contrast to indeterminate structure, the collapse of one element will not cause building failure as other element can compensate the local damage and bridge out the load of damaged element to undamaged near elements. Structural robustness is a function of structural degree of redundancy, which represents the structure ability to redistribute loads after collapse to intact members.

A. Aim and Objective

To analyse, design G+7 RC structure by using different measures to sustain progressive collapse. To perform analysis for the proposed structure with removal of critical columns fully to know potential for progressive collapse.

The objective of dissertation includes:

- To analyse, design G+7 RC structure by using different measures to sustain progressive collapse.
- To perform analysis for the proposed structure with removal of critical columns fully to know potential for progressive collapse.
- To suggest effective method for design of new building to avoid progressive collapse.

II. OVERVIEW OF PROGRESSIVE COLLAPSE

A. General

All different guidelines identify three basic design methods for progressive collapse prevention: event control, direct design approach and indirect design approach; the three methods are explained as follows:

a) Event control: Protection and isolation of the building from any accident loads that can cause progressive collapse.

b) Direct design approach: focuses on providing building with resisting mechanisms: 1- Alternate Path Method by improving the structure ability to transfer the loads of the damaged elements to intact regions through two mechanisms; Vierendeel and Catenary/ membrane action. 2- Specific Local Resistance (SLR) Method, which focuses on providing sufficient strength to the key elements in the building to withstand these abnormal loads.

c) Indirect design approach: This approach aims to guarantee the minimum level of strength, continuity and ductility for different buildings elements depending on selecting suitable plan layout, horizontal and vertical tie systems, and seismic ductile detailing. For that, indirect design method is the first line of defence towards catastrophic failures.

III. METHODOLOGY

A. Building Configuration

To study the effect of column removal condition on the structure, 7 storey building is considered. Progressive collapse analysis is based on the GSA guidelines. Structure considered in this analysis is hospital building, which is designed for an importance factor 1.5 (IS code 1893-2016).Figure shows typical floor plan

Load Considered Are As Follows:

1. Dead Load as per IS 875 (Part I).

2. Live Load IS 875 (Part II) - on Roof 1.5 KN/m2 and on Floors 3.0 KN/m2

3. Wind Load as per IS 875 (Part III).

4. Self-weight of the Structural elements, Floor Finish =1.5 KN/m2.

5. Seismic loading as per IS: 1893 (Part I): 2016

Zone – III,

Zone factor = 0.16,

Soil Type = Type –I, Rock or hard soil,

Importance Factor = 1.5 and

Response Reduction Factor = 5.0

The characteristic compressive strength of concrete (fck) is 25 N/mm2 and yield strength of reinforcing steel (fy) is 500 N/mm2. Analysis and design of building for the loading is performed in the Staad pro. 7 storey building is designed for seismic loading in Staad pro according to the IS 456:2000.

TABLE I. BASIC LOAD COMBINATION

SR. No	LOAD COMBINATIONS
1	1.5(DL + LL)
2	1.2(DL + LL ± EQ)
3	1.5(DL ± EQ)
4	0.9DL ± 1.5EQ

Fig. 1. Typical floor plan of hospital building

B. Analysis

To evaluate the potential for progressive collapse of a 7 storey reinforced concrete building using the nonlinear static analysis column removal conditions is considered. First building is designed in STAAD PRO for the IS 1893 (Part-I) load combinations. Demand capacity ratio for the moments and forces at all storeys is calculated for each cases of column failure. Capacity of the member at any section is calculated as per IS 456:2000 from the obtained reinforcement details after analysis and design. Member forces are obtained by analysis results carried out in Staad pro.

C. Modeling

The 7 storied reinforced concrete framed structures is modelled using Staad pro software.

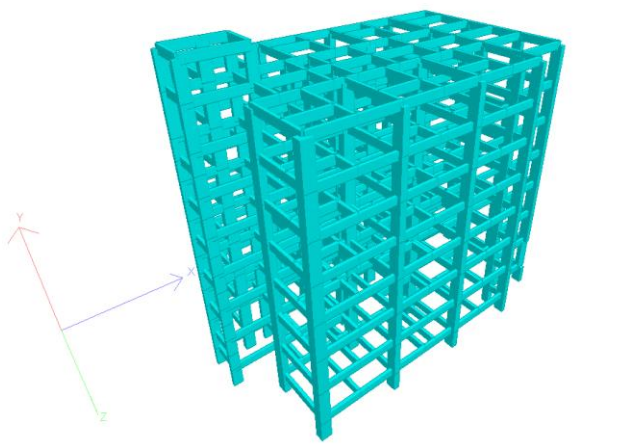

Fig. 2. Render view of 7 storied Hospital Building

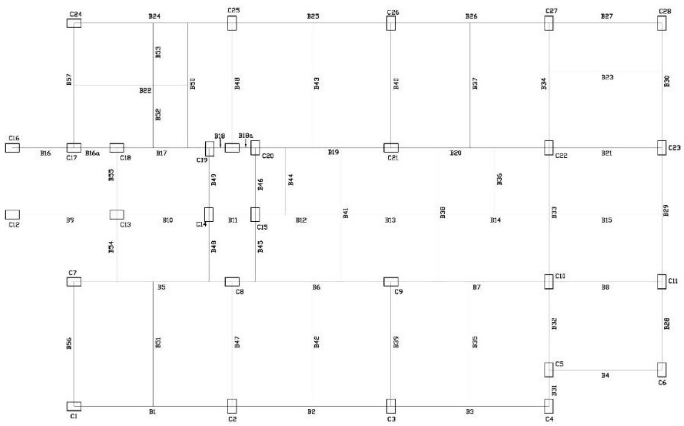

Fig. 3. Typical Floor Plan (Showing Beam & Column Numbering)

Fig. 4.

5 models will be prepared. Each separate model will be prepared by considering various preventive measures such as,

Model 1 – With corner removal column.

Model 2 – Providing inverted 'V' type bracing at ground and roof floor level.

Model 3- By considering beam above column removal to be designed as cantilever beam.

Model 4- By considering load combination as suggested by GSA.

Model 5- By increasing column and beam sizes by 20 % at column removal location.

After analysis and design of the building by using above mentioned options nonlinear analysis will be carried out to check effectiveness of options against progressive collapse. After studying various literature survey it seems that corner column removal is quite critical case, so worked on only corner column removal case.

Steps for analysis

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Step-l. First, the building is designed in Staad pro for the IS 1893 load combinations and the output results are obtained for moment and shear without removing any column.

Step-2. A vertical support (column) is removed from the position under consideration and linear static analysis is carried out to the altered structure with above mentioned preventive measures.

Step-3. The load combinations are entered into the staad pro program. Each case of different Column removal location on the model and the results are reviewed.

Step-4. Further, from the analysis results are obtained and if the DCR for any member exceeds the allowable limit based upon moment and shear force, the member is expected as a failed member.

Step-5. If DCR values surpass its criteria then it will lead to progressive collapse.

IV. RESULT AND DISCUSSION

A. General

- Five building models of 7 storey are generated using software staad pro.
- Each models of 7 storey are analysed for corner column removal case. The progressive collapse analysis is done according to the G.S.A. guidelines. Linear static analysis has been carried out.
- Comparison of all cases is done on the basis of Demand Capacity Ratio.
- Obtained results have been presented in form of graphs/charts, indicating the trends and pattern of Demand Capacity Ratio.
- Four different mitigation approaches like providing bracing at bottom and top floors, by considering beam above column removal to be designed as cantilever beam, by considering load combination as suggested by GSA and by increasing column and beam sizes by 20 % at column removal location.

B. Render view for different cases with 4 mitigation provided

Case 1 – With corner column removal

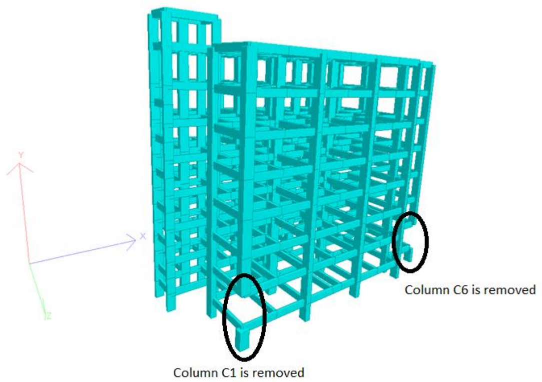

Fig. 5. Render view showing corner column removal case (Front view)

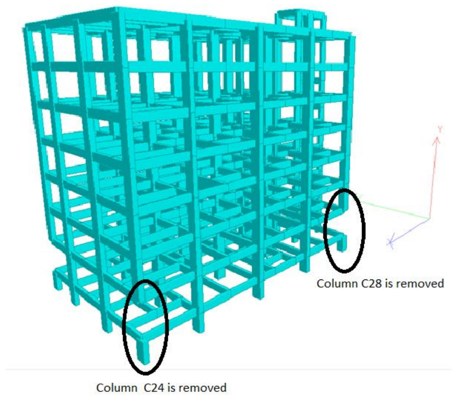

Fig. 6. Render view showing corner column removal case (Back view)

Figure 4 & 5 shows the 100% corner column removal i.e. all corner column are removed at a time for considering the critical case.

Case 2 – Providing inverted 'V' type bracing at ground and roof floor level

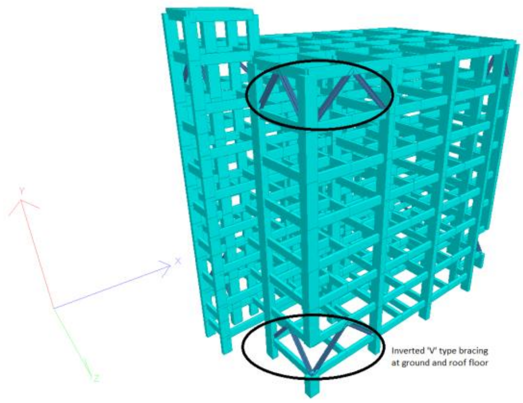

Fig. 7. Render view showing bracing member provided as ground and roof floor level

Case 3 -By considering beam above column removal to be designed as cantilever beam.

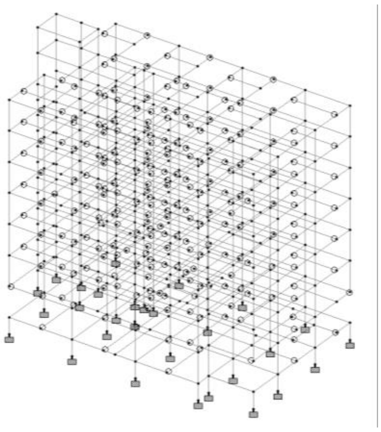

Fig. 8. Showing beam no B1, B4, B24, B30 released at end.

Case 4:- By considering load combination as suggested by GSA

LOAD COMBINATION AS PER GSA INCLUDED IN STAAD ANALYSIS

LOAD COMB 301 2(DL+0.25LL)

3 2.0 4 2.0 5 2.0 6 0.5

Case 5:- By increasing column and beam sizes by 20 % at column removal location.

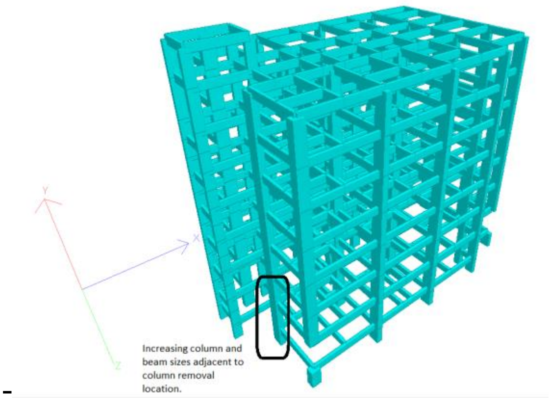

Fig. 9. Showing increasing column sizes adjacent to column removal location

C. Node displacement for various cases

TABLE II. BASE MODEL

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	803	206 1.0(DL+EQX)	5.167	-0.761	3.323	6.19	0.001	0	-0.001
Min X	803	208 1.0(DL-EQX)	-4.713	-0.518	-2.971	5.595	-0.001	0	0.001
Max Y	659	201 1(DL+LL)	0	0	0	0	0	0	0
Min Y	841	201 1(DL+LL)	0.182	-13.281	-0.002	13.283	0	0	0
Max Z	797	207 1.0(DL+EQZ)	2.331	-0.089	6.447	6.856	0.002	0	0
Min Z	797	209 1.0(DL-EQZ)	-2.124	-0.947	-6.036	6.469	-0.002	0	0
Max rX	798	207 1.0(DL+EQZ)	2.728	-1.034	6.447	7.077	0.002	0	-0.001
Min rX	797	209 1.0(DL-EQZ)	-2.124	-0.947	-6.036	6.469	-0.002	0	0
Max rY	769	207 1.0(DL+EQZ)	0.754	-1.386	1.527	2.196	0	0	0.001
Min rY	769	209 1.0(DL-EQZ)	-0.703	-1.937	-1.51	2.555	0	0	0
Max rZ	849	201 1(DL+LL)	0.182	-10.328	-0.036	10.329	0	0	0.002
Min rZ	826	201 1(DL+LL)	0.182	-4.58	0.091	4.585	0	0	-0.002
Max Rst	841	202 1.0DL+0.8LL+0.8EQX	3.741	-12.809	1.834	13.47	0	0	0

TABLE III. CASE 1 – CORNER COLUMN REMOVAL

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	803	206 1.0(DL+EQX)	5.241	-22.772	2.63	23.515	0.001	0	-0.001
Min X	803	208 1.0(DL-EQX)	-5.349	-15.772	-2.388	16.825	0	0	0.001
Max Y	659	201 1.0(DL+LL)	0	0	0	0	0	0	0
Min Y	799	205 1.0DL+0.8LL-0.8EQZ	1.452	-26.524	-4.95	27.021	-0.002	0	0
Max Z	797	207 1.0(DL+EQZ)	1.613	-0.313	7.089	7.277	0.002	0	0
Min Z	797	209 1.0(DL-EQZ)	-1.892	-1.148	-6.806	7.157	-0.002	0	0
Max rX	798	207 1.0(DL+EQZ)	2.075	-1.12	7.089	7.471	0.002	0	0
Min rX	800	205 1.0DL+0.8LL-0.8EQZ	1.09	-15.126	-4.95	15.952	-0.005	0	0
Max rY	803	207 1.0(DL+EQZ)	3.869	-23.407	6.497	24.598	0.002	0	-0.001
Min rY	803	209 1.0(DL-EQZ)	-3.978	-15.137	-6.255	16.855	-0.001	0	0.001
Max rZ	812	205 1.0DL+0.8LL-0.8EQZ	1.452	-9.581	-4.174	10.551	-0.001	0	0.005
Min rZ	826	201 1.0(DL+LL)	-0.126	-4.517	0.063	4.52	0	0	-0.002
Max Rst	799	205 1.0DL+0.8LL-0.8EQZ	1.452	-26.524	-4.95	27.021	-0.002	0	0

TABLE IV. CASE 2 – PROVIDING INVERTED 'V' TYPE BRACING AT GROUND AND ROOF FLOOR LEVEL

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	1300	206 1.0(DL+EQX)	4.407	-0.896	-1.428	4.719	0.001	0	-0.001
Min X	1300	208 1.0(DL-EQX)	-4.231	-1.394	1.457	4.687	0.002	0	0.001
Max Y	796	207 1.0(DL+EQZ)	-0.699	0.007	0.744	1.021	0	0	0
Min Y	841	201 1(DL+LL)	0.12	-13.26	0.026	13.261	0	0	0
Max Z	1303	207 1.0(DL+EQZ)	-1.589	-0.424	3.606	3.963	0.001	0	-0.001
Min Z	1303	209 1.0(DL-EQZ)	1.756	-0.689	-3.57	4.037	0	0	0
Max rX	1300	204 1.0DL+0.8LL-0.8EQX	-3.345	-1.538	1.171	3.863	0.002	0	0.001
Min rX	799	209 1.0(DL-EQZ)	1.32	-4.587	-3.099	5.691	-0.002	0	0
Max rY	866	209 1.0(DL-EQZ)	1.853	-4.125	-2.052	4.966	0	0.001	-0.001
Min rY	866	207 1.0(DL+EQZ)	-1.663	-1.285	2.079	2.956	0.001	-0.001	0
Max rZ	849	201 1(DL+LL)	0.12	-10.318	0.024	10.319	0	0	0.002
Min rZ	826	201 1(DL+LL)	0.12	-4.544	0.032	4.545	0	0	-0.002
Max Rst	841	201 1(DL+LL)	0.12	-13.26	0.026	13.261	0	0	0

TABLE V. CASE 3 – BY CONSIDERING BEAM ABOVE COLUMN REMOVAL TO BE DESIGNED AS CANTILEVER BEAM.

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	803	206 1.0(DL+EQX)	5.393	-23.104	2.761	23.885	0.001	0	-0.001
Min X	803	208 1.0(DL-EQX)	-5.378	-16.091	-2.648	17.172	0	0	0.001
Max Y	797	206 1.0(DL+EQX)	4.596	-0.176	2.905	5.44	0.001	0	-0.001
Min Y	799	205 1.0DL+0.8LL-0.8EQZ	1.717	-26.982	-5.054	27.505	-0.002	0	0
Max Z	797	207 1.0(DL+EQZ)	1.92	-0.294	7.065	7.327	0.002	0	0
Min Z	797	209 1.0(DL-EQZ)	-1.941	-1.16	-6.942	7.301	-0.002	0	0
Max rX	798	207 1.0(DL+EQZ)	2.383	-1.122	7.065	7.54	0.002	0	-0.001
Min rX	800	205 1.0DL+0.8LL-0.8EQZ	1.413	-15.305	-5.054	16.18	-0.005	0	0
Max rY	803	207 1.0(DL+EQZ)	4.18	-23.969	6.47	25.176	0.002	0	-0.001
Min rY	803	209 1.0(DL-EQZ)	-4.164	-15.226	-6.356	17.017	-0.001	0	0.001
Max rZ	812	205 1.0DL+0.8LL-0.8EQZ	1.717	-8.643	-4.218	9.769	-0.001	0	0.004
Min rZ	826	201 1(DL+LL)	0.003	-4.529	0.052	4.529	0	0	-0.002
Max Rst	799	205 1.0DL+0.8LL-0.8EQZ	1.717	-26.982	-5.054	27.505	-0.002	0	0

TABLE VI. BY CONSIDERING LOAD COMBINATION AS SUGGESTED BY GSA

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	803	206 1.0(DL+EQX)	5.303	-22.767	2.58	23.518	0.001	0	-0.001
Min X	803	208 1.0(DL-EQX)	-5.318	-15.801	-2.423	16.847	0	0	0.001
Max Y	659	201 1(DL+LL)	0	0	0	0	0	0	0
Min Y	799	205 1.0DL+0.8LL-0.8EQZ	1.555	-26.511	-5.003	27.024	-0.002	0	0
Max Z	797	207 1.0(DL+EQZ)	1.681	-0.313	7.047	7.252	0.002	0	0
Min Z	797	209 1.0(DL-EQZ)	-1.831	-1.148	-6.858	7.19	-0.002	0	0
Max rX	798	207 1.0(DL+EQZ)	2.144	-1.12	7.047	7.451	0.002	0	0
Min rX	800	205 1.0DL+0.8LL-0.8EQZ	1.201	-15.121	-5.003	15.973	-0.005	0	0
Max rY	803	207 1.0(DL+EQZ)	3.938	-23.421	6.456	24.611	0.002	0	-0.001
Min rY	803	209 1.0(DL-EQZ)	-3.954	-15.147	-6.299	16.874	-0.001	0	0.001
Max rZ	812	205 1.0DL+0.8LL-0.8EQZ	1.555	-9.557	-4.209	10.558	-0.001	0	0.005
Min rZ	826	201 1(DL+LL)	-0.054	-4.522	0.033	4.522	0	0	-0.002
Max Rst	799	205 1.0DL+0.8LL-0.8EQZ	1.555	-26.511	-5.003	27.024	-0.002	0	0

TABLE VII. TABLE 6.6 - CASE 5:- BY INCREASING COLUMN AND BEAM SIZES BY 20 % AT COLUMN REMOVAL LOCATION.

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	803	206 1.0(DL+EQX)	4.747	-20.769	3.102	21.529	0.001	0	-0.001
Min X	803	208 1.0(DL-EQX)	-4.781	-13.954	-2.946	15.042	0	0	0.001
Max Y	659	201 1(DL+LL)	0	0	0	0	0	0	0
Min Y	799	205 1.0DL+0.8LL-0.8EQZ	1.611	-24.228	-4.428	24.682	-0.002	0	0
Max Z	797	207 1.0(DL+EQZ)	1.899	-0.296	6.294	6.581	0.002	0	0
Min Z	797	209 1.0(DL-EQZ)	-2.093	-1.102	-6.099	6.542	-0.002	0	0
Max rX	798	207 1.0(DL+EQZ)	2.262	-1.1	6.294	6.778	0.002	0	0
Min rX	800	205 1.0DL+0.8LL-0.8EQZ	1.383	-13.488	-4.428	14.263	-0.005	0	0
Max rY	775	207 1.0(DL+EQZ)	0.385	-1.963	1.68	2.612	0	0	0
Min rY	777	209 1.0(DL-EQZ)	-0.566	-1.5	-1.68	2.322	0	0	-0.001
Max rZ	812	205 1.0DL+0.8LL-0.8EQZ	1.611	-8.171	-3.688	9.109	-0.001	0	0.004
Min rZ	861	208 1.0(DL-EQX)	4.06	-12.911	-1.267	13.593	-0.001	0	-0.002
Max Rst	799	205 1.0DL+0.8LL-0.8EQZ	1.611	-24.228	-4.428	24.682	-0.002	0	0

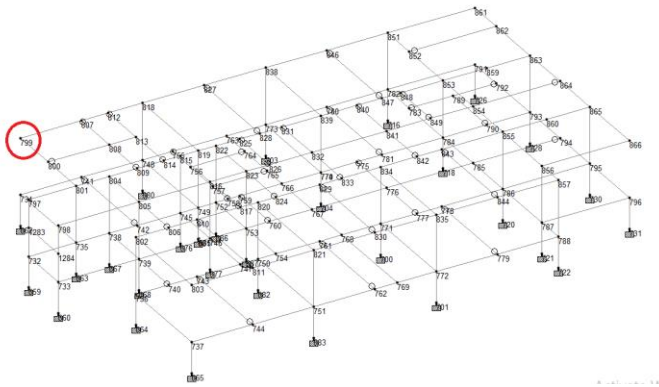

Fig. 10. Showing node no 799 where maximum displacement occurs at column removal floor level

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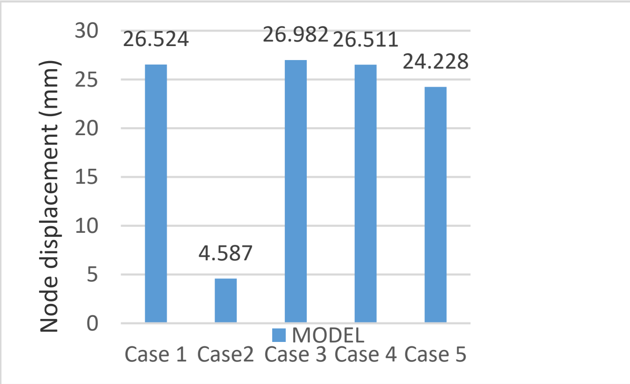

Fig. 11. Chart showing maximum displacement in node no 799

Referring table II to VII, maximum displacement in node no 799 results are summarized in figure 10 which shows node displacement in respective 5 cases. Only in case 2 i.e by providing bracing, vertical displacement is within limit i.e 20 mm. In all other case vertical displacement is exceeding the limit.

D. Flexural demand for various cases

Obtained results have been presented in form of graphs, charts and tables indicating the trends and pattern of DCR ratio in flexure.

TABLE VIII. FLEXURAL DEMAND FOR BASE MODEL (ALL VALUES IN KN-M)

STOREY NO	BEAM B1	BEAM B56	BEAM B4	BEAM B28	BEAM B30	BEAM B27	BEAM B24	BEAM B57
1	546.21	509.52	377.46	264.67	327.93	295.87	585.14	556.74
2	559.16	523.41	315.99	228.91	289.53	249.31	505.30	536.26
3	539.32	458.83	285.68	195.13	272.83	223.13	485.25	512.72
4	566.56	599.39	280.68	169.08	251.67	214.04	481.96	520.11
5	509.27	444.35	245.13	137.98	227.92	188.79	459.93	482.89
6	469.40	387.95	227.23	113.73	218.37	176.72	425.46	434.14
7	300.21	285.55	146.73	70.47	146.61	115.87	289.16	333.66

TABLE IX. FLEXURAL DEMAND FOR CASE 1–CORNER COLUMN REMOVAL (ALL VALUES IN KN-M)

STOREY NO	BEAM B1	BEAM B56	BEAM B4	BEAM B28	BEAM B30	BEAM B27	BEAM B24	BEAM B57
1	1055.54	1280.85	549.77	547.41	615.30	639.23	1147.11	1274.03
2	1073.55	1323.37	515.90	502.87	716.05	638.14	1061.45	1277.99
3	1061.35	1212.30	455.57	462.13	662.43	557.08	1020.65	1180.31
4	1079.22	1303.25	445.37	423.00	618.07	535.00	1002.76	1185.61
5	1026.87	1148.44	407.21	390.15	583.62	497.79	984.71	1139.04
6	1022.55	1112.09	401.90	384.48	590.04	525.66	985.07	1143.91
7	770.34	930.15	279.33	314.53	483.75	414.92	785.24	960.18

TABLE X. FLEXURAL DEMAND FOR CASE 2 – PROVIDING INVERTED 'V' TYPE BRACING AT GROUND AND ROOF FLOOR LEVEL. (ALL VALUES IN KN-M)

STOREY NO	BEAM B1	BEAM B56	BEAM B4	BEAM B28	BEAM B30	BEAM B27	BEAM B24	BEAM B57
1	200.09	470.43	245.81	280.02	243.39	95.54	150.03	341.90
2	703.57	773.71	394.82	347.78	441.62	382.31	679.36	746.41
3	669.05	690.81	333.85	307.80	402.4	332.14	645.70	695.94
4	684.24	783.28	328.19	263.18	369.21	308.35	629.54	678.02
5	602.30	601.59	281.18	213.73	320.83	263.01	580.28	607.05
6	527.82	466.19	238.77	176.12	284.09	228.30	506.42	453.10
7	160.16	251.81	114.25	100.68	126.80	158.03	202.13	284.33

TABLE XI. FLEXURAL DEMAND FOR CASE 3 – BY CONSIDERING BEAM ABOVE COLUMN REMOVAL TO BE DESIGNED AS CANTILEVER BEAM. (ALL VALUES IN KN-M)

STOREY NO	BEAM B1	BEAM B56	BEAM B4	BEAM B28	BEAM B30	BEAM B27	BEAM B24	BEAM B57
1	900.76	1290.85	444.04	552.18	616.3	632.22	1034.26	1281.57
2	1098.42	1331.80	514.08	504.30	715.79	631.40	1077.22	1286.06
3	1083.90	1219.76	472.74	465.80	663.18	552.95	1039.06	1185.71
4	1099.71	1307.05	457.71	423.45	618.90	531.13	1016.27	1191.25
5	1046.92	1152.23	417.07	388.48	584.56	497.65	994.29	1144.38
6	1040.77	1127.06	411.95	381.09	591.05	528.40	994.63	1158.31
7	784.78	943.33	287.43	319.12	483.76	417.00	799.67	976.31

TABLE XII. FLEXURAL DEMAND FOR CASE 4 – BY CONSIDERING LOAD COMBINATION AS SUGGESTED BY GSA. (ALL VALUES IN KN-M)

STOREY NO	BEAM B1	BEAM B56	BEAM B4	BEAM B28	BEAM B30	BEAM B27	BEAM B24	BEAM B57
1	1059.64	1279.51	547.25	556.73	718.13	627.55	1143.60	1276.99
2	1076.31	1322.36	514.38	509.72	692.96	625.51	1058.43	1280.30
3	1061.49	1212.67	455.39	461.07	638.94	545.09	1019.97	1181.22
4	1079.19	1303.83	445.32	419.42	601.07	526.31	1002.48	1186.45
5	1026.65	1148.94	407.07	385.52	568.29	490.05	984.37	1139.76
6	1022.21	1112.29	401.77	379.52	576.87	516.11	984.78	1144.22
7	769.87	930.35	279.29	311.02	471.14	407.49	785.22	960.38

TABLE XIII. FLEXURAL DEMAND FOR CASE 5:- BY INCREASING COLUMN AND BEAM SIZES BY 20 % AT COLUMN REMOVAL LOCATION. (ALL VALUES IN KN-M)

STOREY NO	BEAM B1	BEAM B56	BEAM B4	BEAM B28	BEAM B30	BEAM B27	BEAM B24	BEAM B57
1	1416.07	1787.04	661.68	794.30	1002.38	765.56	1481.26	1687.13
2	1050.85	1246.29	494.37	493.93	679.32	611.75	1032.66	1228.06
3	1017.03	1151.80	435.66	444.62	637.74	529.54	995.81	1127.93
4	1050.42	1262.98	432.40	409.87	603.35	514.43	985.51	1146.44
5	1002.29	1106.27	394.58	378.18	573.49	477.95	9555.23	1100.95
6	990.90	1065.02	388.43	376.63	578.79	500.13	957.64	1097.72
7	754.21	934.98	269.28	328.61	483.04	382.23	776.35	948.41

E. DCR for various cases

From the analysis results demand at critical points are obtained and from the designed section the capacity of the member is determined. The DCR of each member is calculated from the following equation.

$$DCR = \frac{QUD}{QCE}$$

Where,

Qud = Acting force (demand) determined in member or connection.

Qce = Expected ultimate, un-factored capacity of the member

$Qce = 0.133 f_{ck}\, b\, d^2 = 0.133 \times 25 \times 300 \times 712^2 = 505.68$ kN-m.

Referring table VIII to XIII, DCR values are calculated and results are summarized in figure 11 to 18

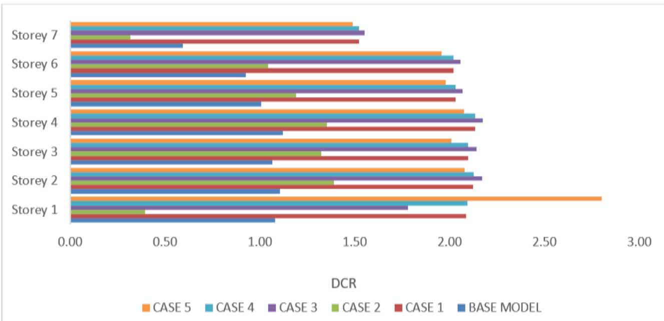

Fig. 12. DCR for beam B1

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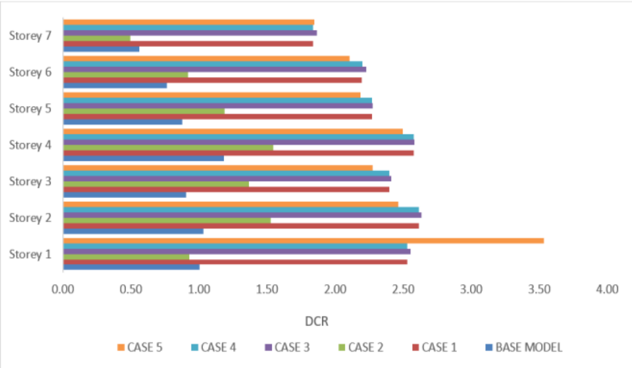

Fig. 13. DCR for beam B56

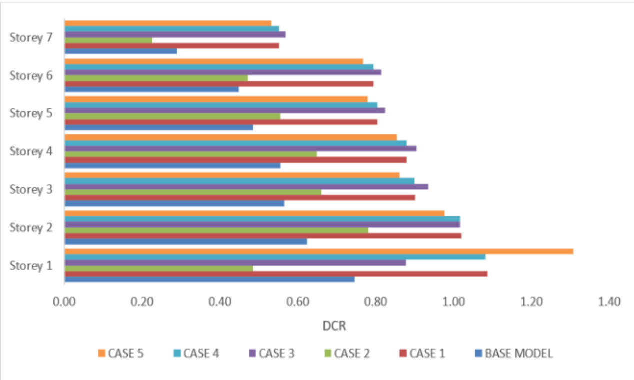

Fig. 14. DCR for beam B4

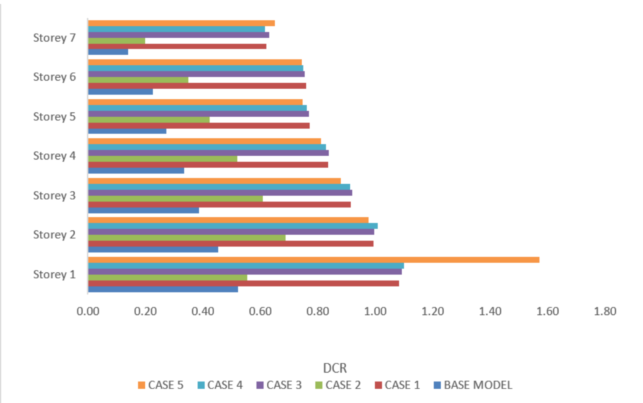

Fig. 15. DCR for beam B28

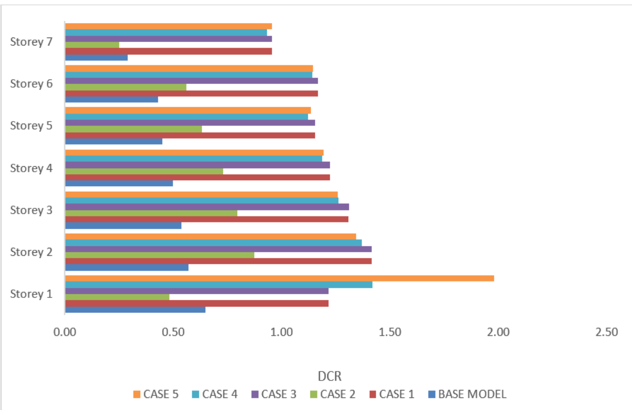

Fig. 16. DCR for beam B30

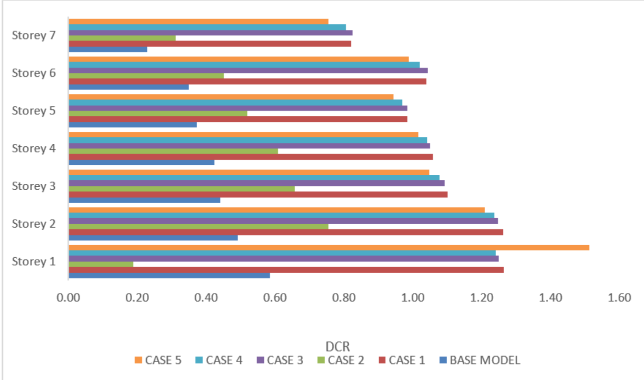

Fig. 17. DCR for beam B27

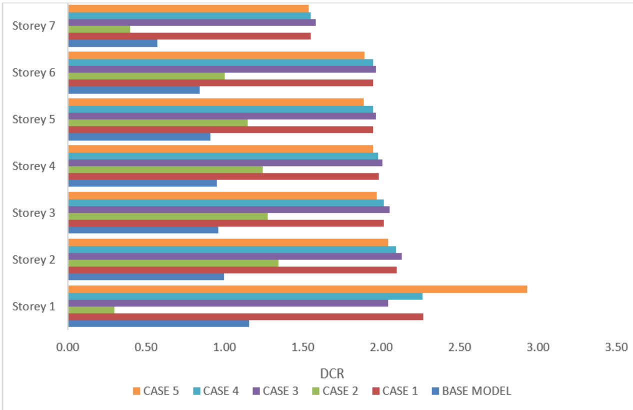

Fig. 18. DCR for beam B24

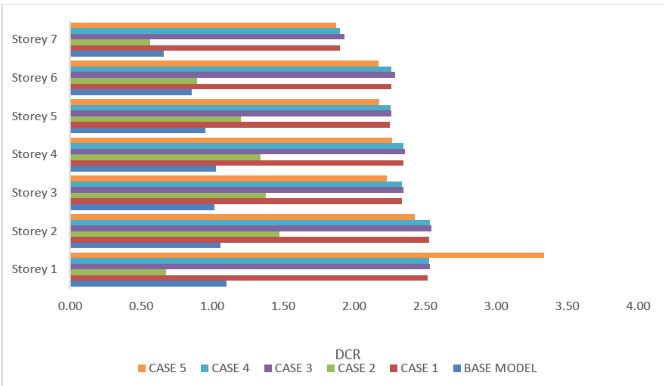

Fig. 19. Fig:-6.15 DCR for beam B57

V. 7.0 CONCLUSION

A. Progressive Collapse Analysis of Building

The analytical study on both 7-storey building is done by creating the 3D model and the analysis is done for all corner column removal cases by following GSA guidelines. Progressive collapse potential of building is found out by considering column removal cases. Demand Capacity Ratio in flexure is calculated for all the cases. From the study, the following conclusions can be drawn out:

1. DCR in flexure of beam exceeds permissible limit of 2.0 in all storey of for case 3, 4 & 5. The DCR values in beams in case 2 i.e by providing inverted ‘V’ type bracing at ground and roof floor level are within limit indicate that building considered for the study is having very low potential to resist the progressive collapse when column is considered as fully damage/removed.

2. The adjacent beam to the damaged/removed column joint experienced more damage as compared to the beams which are away from the removed column joint.
3. Corner column case is found critical in the event of progressive collapse.
4. The beams adjacent to the damaged/removed column joint experienced more damage as compared to the beams which are away from the removed column joint.
5. Four different alternatives are used to mitigate the progressive collapse. When mitigation alternatives are adopted, DCR value is reduced within permissible limit. From four mitigation alternatives presented, provision of bracing in the building is economical solution to reduce the potential of progressive collapse.

B. Scope of Future Work

There is a scope of extending this work to include the following for future:-

1. The present work has been carried out to calculate the DCR for a symmetric building. The work can be extended to asymmetric buildings.
2. In this study STAAD Pro has been used other software like SAP, and ANSYS etc. can be used.
3. Here linear static and linear dynamic (response spectrum method) analysis have been performed; Push over Non-linear analysis can be done for same building.

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