STUDY OF PROGRESSIVE COLLAPSE ON RCC 15 STOREY BUILDING

As Per GSA Guidelines

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Abstract : **Study of progressive collapse of building structures has attracted great attention all over the world. The nature of progressive collapse is catastrophic and the cost of constructing or retrofitting buildings to resist progressive collapse is very high. Hence progressive collapse analysis is essential for the economic and safe design of building structures against progressive collapse. For engineers, their technique to complete progressive collapse analysis need not exclusively be precise and brief, but in addition, be effectively utilized and works quick. Recently many researchers have been spending bunches of effort in creating dependable, productive and clear progressive collapse analysis strategies. In this paper, progressive collapse analysis strategies accessible in the literature are reviewed. For the study of progressive collapse, RCC 15 storey building is analysed using ETABS 2016. In this system, critical columns removed from analysis and the capacity of the model to effectively absorb member loss is analysed.**

Index Terms **- Acceptance Criteria, Column Removal Study, Demand - Capacity Ratio (DCR), General Service Administration (GSA) guidelines, Progressive Collapse.**

I. INTRODUCTION

Progressive collapse means consecutive destruction of structures, due to the initial local damage of the individual bearing structural components and leading to the collapse of the building or its significant part (two or more spans and two or more floors). As per American standard ASCE 7-02: the spread of local damage, from an initiating event, in the form of a chain-reaction from element to element resulting, eventually, in the collapse of an entire building.

Progressive collapse during a structure happens when major structural load carrying members are removed suddenly, and therefore the remaining structural parts cannot support the load of the building. When a column is removed, the building's weight (gravity load) transfers to neighboring columns within the structure. If these neighboring columns are not properly designed to resist and distribute the extra gravity load that a part of the structure fails. Progressive collapse usually happens in a domino impact.

The idea of progressive collapse can be represented by the well-known 1968 breakdown of the Ronan Point apartment tower in Newham, East London, (Fig. 1). The structure was a 22-story load-bearing precast concrete panels building. A gas blast in a corner kitchen on the eighteenth floor extinguished the exterior wall panel and failure of the corner bay of the structure spread upward to the rooftop and downward nearly to ground level. In this manner, the fact that the whole structure did not fall, the degree of failure was disproportionate to the initial damage.

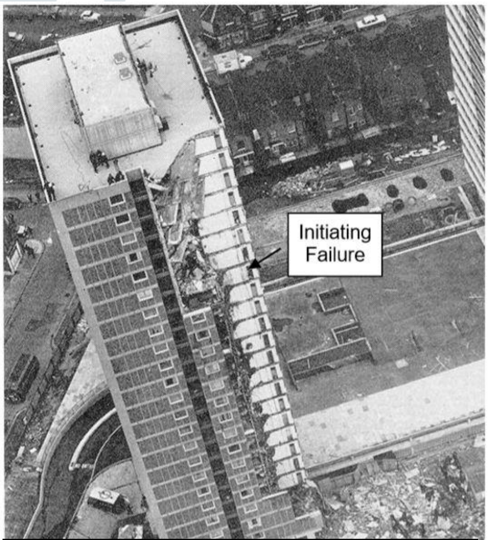

Figure 1 : Ronan Point collapse: a gas explosion on the 18th floor

II. GSA GUIDELINES

The GSA Progressive Collapse Analysis and Design Guidelines (2003) characterize analysis techniques to assess the weakness of a structure against progressive collapse. GSA suggests that a structure be analysed by promptly removing a column as shown in figure 2.

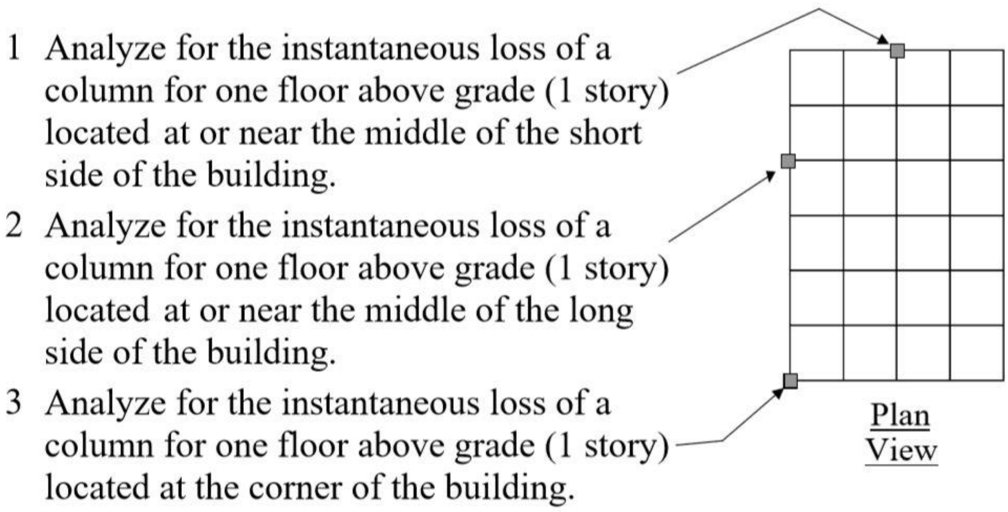

Figure 2 : GSA Recommendation for Column Removal in Structure

Analysis Loading

While analysing the structure for progressive collapse, GSA prescribes a general load combination for each structural element in the structure being tested. This load combination is as follows:
Load = 2(Dead Load + 0.25*Live Load)

Acceptance Criteria

An examination of the linear elastic analysis results will be performed to identify the magnitudes and distribution of potential requests on each primary and secondary structural components for evaluating potential breakdown areas. The magnitude and distribution of these demands will be shown by Demand-Capacity Ratios(DCR).
Acceptance criteria for the primary and secondary structural components shall be determined as:

$$DCR = Q_{ud} / Q_{ce}$$

Where,
Q_{ud} = Acting force (demand) determined in component or connection/joint (moment, axial force, shear, and possible combined forces)
Q_{ce} = Expected ultimate, un-factored capacity of the component and/or connection/joint (moment, axial force, shear and possible combined forces)
The allowable DCR values for primary and secondary structural elements are:

- DCR < 2.0 for typical structural configurations
- DCR < 1.5 for atypical structural configurations

Analysis Procedure

The static linear elastic analysis approach may be used to assess the potential for progressive collapse in all newly constructed facilities.
The detailed procedure for linear static analysis method is given in the GSA. In this study same procedure is followed. The steps are as:

1. Analyze and design of the building for the seismic loading.
2. Create a column lost by removing a column from the location.
3. Carry out linear static analysis with the gravity load on the structure.
4. Check demand capacity ratios for flexure and shear at critical locations.

III. Configuration and Modelling of Structure

The present work is to study the behavior of conventional RC G+15 Storey framed building subjected to column loss. The studies comprise of DCR values of structural members. For these cases, models has been created for conventional RC framed building with column removed at different position. Building are modelled in the ETABS 2016 software. Plan size is 20m X 40m and grid spacing is 5m in both direction. All storey height is 3.2m.

Element Sizes

Storey	Beam	Column
All Storey	230 x 500 mm	550 x 550 mm
	Slab = 150 mm Thick	

Material Properties

Material	Grade
RCC	M 30
Steel	Fe 415

Earthquake Parameters

Eq. Parameters	Value
Zone factor (Zone 5)	0.36
Type of soil	Medium
Importance Factor	1.2
Response Reduction Factor	5
Damping Ratio	0.02

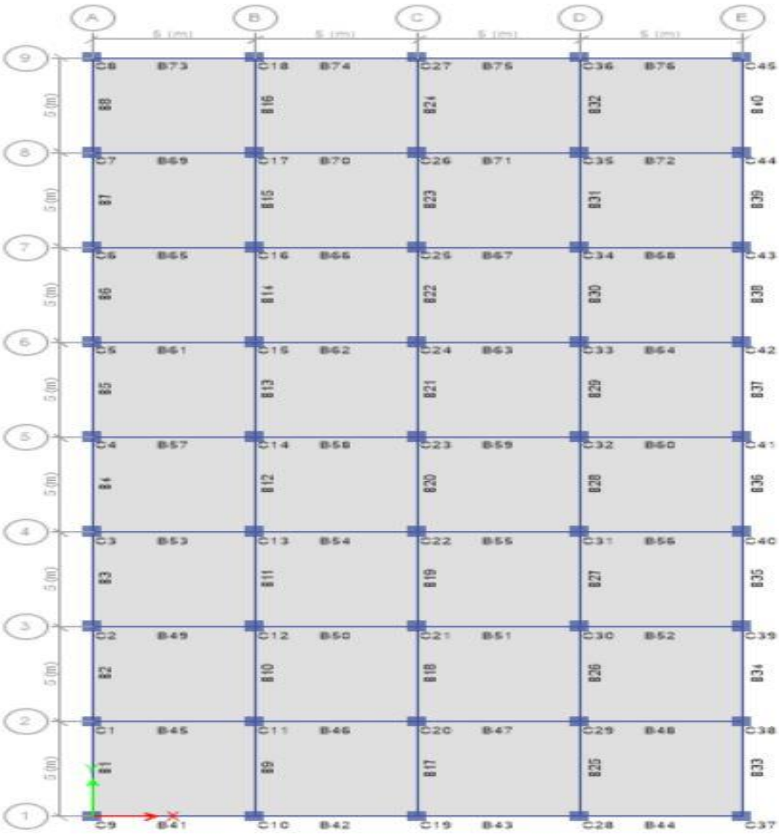

Figure 3 : Plan of G+15 storey

Element Loading

No.	Load Type	Element Name	Load Specification	Load
1	Dead Load	Beam	Wall Load	13.25 kN/m (230mm) 6.62 kN/m (115mm)
		Slab	Floor Finish	1.5 kN/m^2
2	Live Load	Beam	---	---
		Slab	Live Load	3 kN/m^2

The following exterior analysis cases should be considered.
1. Analyze for the bare frame model of the building
2. Analyze for the removal of a corner column (C9) (Case-1)
3. Analyze for the removal of a column located at the middle of the longer side of the building (C4) (Case-2)
4. Analyze for the removal of a column located at middle of the short side of the building (C27) (Case-3)

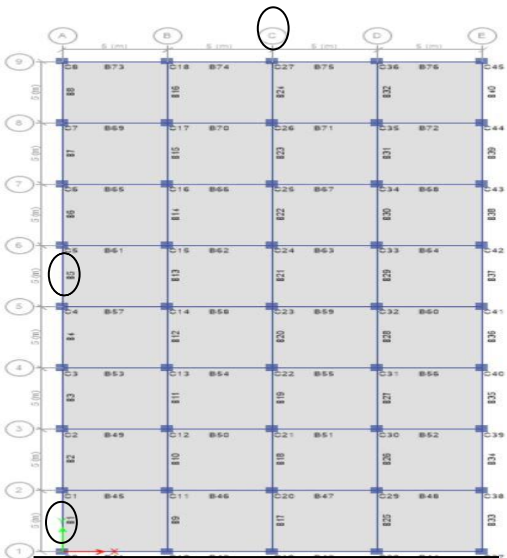

Figure 4 : Location of removal of column

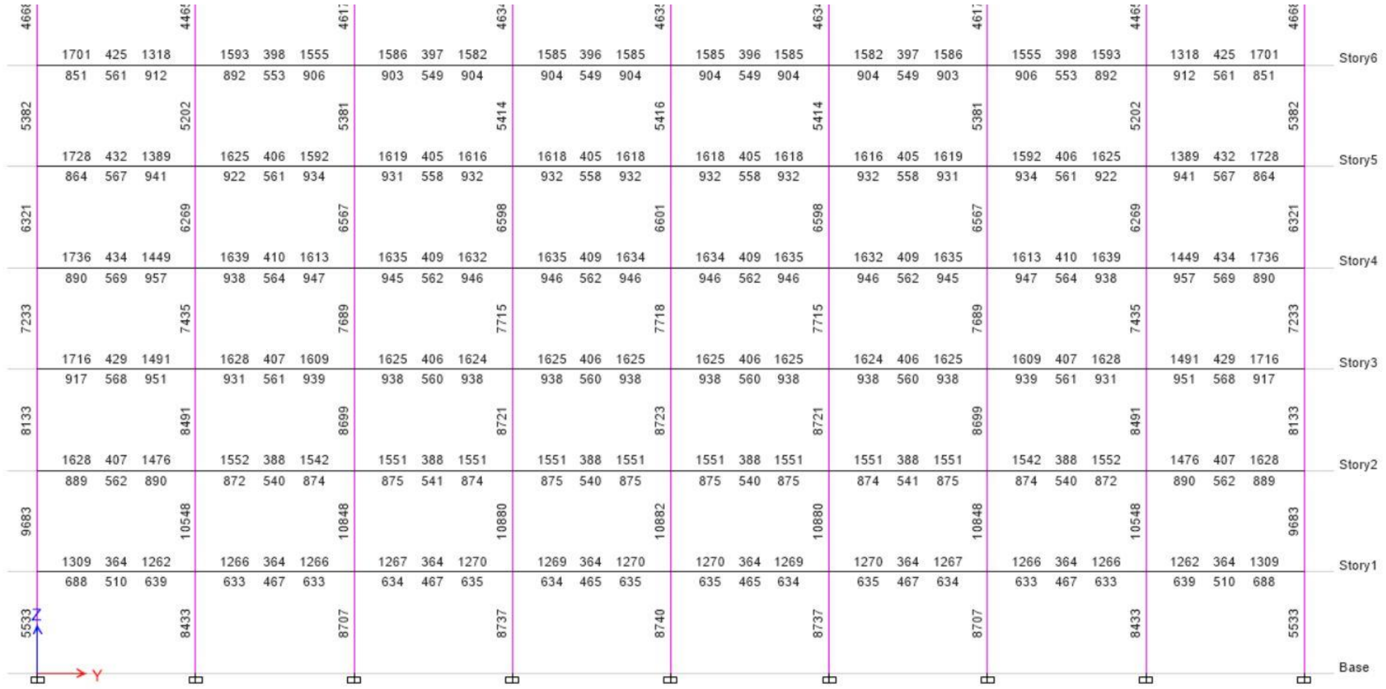

Figure 5 : Reinforcement detailing of bare frame

Case – 1 Corner Column Removed (C9)

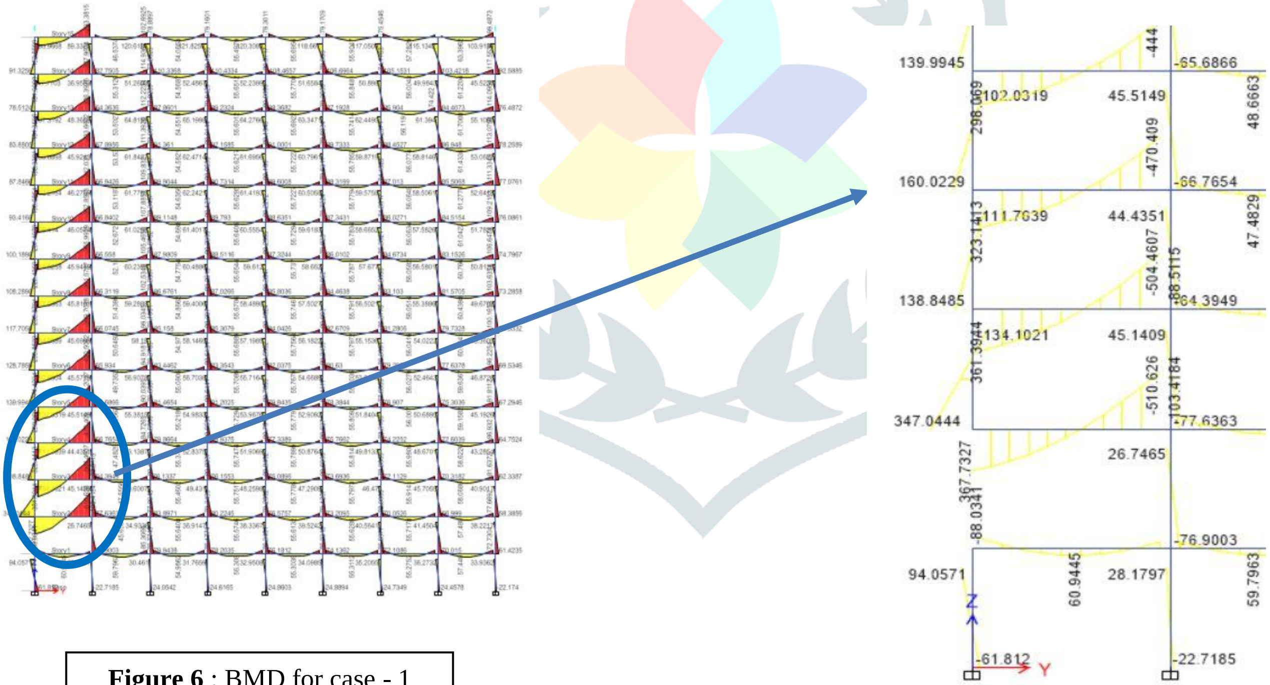

Figure 6 : BMD for case - 1

Similarly analysis done for case – 2 and case – 3.

IV. Calculation of DCR for Flexure

Area of steel in beam located above failed column is,
A_{st} = 1628 mm^2 (Taken from figure 5)

(1.25 is the strength increase factor as per GSA Guidelines)
$F_{ck} = 1.25 \times 25 = 31.25$ N/mm^2

$F_y = 1.25 \times 415 = 518.75$ N/mm^2

Hence for B = 230mm and d = 450 mm

Moment capacity of beam above column removed,

$Mu = 0.87\ Fy\ Ast\ d\ (1 - \frac{Ast\ Fy}{B\ d})$

Mu = 258 kN.m^2

Demand for flexure 510.63 is taken from figure 6.

DCR for flexure in beam $= \frac{510.63}{258.69} = 1.97$

V. Calculation of DCR for Shear

A_{sv}/S_v = 699.58 mm^2/m (Taken from ETABS results)

Shear resisted by shear reinforcement = V_s

$Vs = \frac{0.87\ Fy\ Asv\ d}{Sv}$ = 142.08 kN

Shear resisted by concrete $V_c = \tau_c$ x B x d = 79.70 kN

τ_c is taken from IS 456:2000 for different f_{ck} and P_t values.

Total shear resisted by section $V_u = V_s + V_c$ = 221.77 KN

DCR for shear in beam = 301.30 / 221.77 = 1.359

VI. Results

DCR Value for Flexure

Case – 1 Corner Column Removed (C9)

Storey	Member	A_{st}	Mu (Capacity)	M	DCR
1	B1	1628	258.69	510.63	1.974
	B2	1552	249.81	103.42	0.414
	B41	1684	265.03	497.65	1.878
	B42	1606	256.15	116.45	0.455
2	B1	1716	268.57	504.46	1.878
	B2	1628	258.69	88.51	0.342
	B41	1792	276.77	427.23	1.544
	B42	1701	266.92	106.28	0.398
3	B1	1736	270.76	470.41	1.737
	B2	1639	259.95	84.73	0.326
	B41	1822	279.92	452.72	1.617
	B42	1723	269.34	99.46	0.369

DCR Value for Shear

Storey	Member	A_{sv}/S_v (mm^2/m)	V_s(kN)	τ_{cd}	V_c(kN)	V_u(kN)	V(kN)	DCR
1	B1	699.58	142.08	0.77	79.70	221.77	301.30	1.359
	B2	671.34	136.34	0.76	78.66	215.00	116.44	0.542
	B41	718.42	145.90	0.78	80.73	226.63	295.27	1.303
	B42	690.63	140.26	0.77	79.70	219.96	122.31	0.556
2	B1	737.85	149.85	0.79	81.77	231.62	303.37	1.310
	B2	699.29	142.02	0.77	79.70	221.71	111.18	0.501
	B41	762.24	154.80	0.80	82.80	237.60	295.48	1.244
	B42	724.13	147.06	0.78	80.73	227.79	119.18	0.523
3	B1	751.52	152.63	0.79	81.77	234.39	287.12	1.225
	B2	703.74	142.92	0.77	79.70	222.62	107.97	0.485
	B41	778.94	158.20	0.80	82.80	241.00	279.00	1.158
	B42	731.87	148.64	0.79	81.77	230.40	116.25	0.505

Similarly values of DCR for case – 2 and case – 3 are calculated.

VII. Conclusion

In this study, the progressive collapse potential was researched utilizing the linear static analysis techniques suggested in the GSA guidelines. The progressive collapse analysis were conducted using ETABS 2016 software. Even though the linear static analysis technique has a benefit that it is theoretically easy as well as analysed without advanced nonlinear modelling, a lot of manual works were required to assess DCR in every analysis step and to redesign the structure until DCR of any element does not exceed a given limit state.

It was additionally discovered that the potential for the progressive collapse was highest when a corner column was suddenly removed, it had been additionally discovered that beams at the lower floor were affected in flexure and columns at the higher stories. altogether cases, beams and columns were safe in shear as DCR values are within the permissible limit for shear. For central column removal case, DCR values for flexure and shear are lower compared to corner column removal case as distribution of load when column removal is symmetrical In central column case.

To avoid the progressive collapse of structural members, caused by the failure of a specific column, adequate steel bars are needed to restrain the DCR inside the acceptance limit. The sufficient reinforcement gave in additional to beams which are hazardous can create alternative load paths and prevent progressive collapse because of the loss of an individual member.

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