ANALYSIS OF PROGRESSIVE COLLAPSE OF STRUCTURE AND ITS RESPONSE

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Abstract - The term 'progressive collapse' can be simply defined as the ultimate failure or proportionately large failure of a portion of a structure due to the spread of a local failure from element to element throughout the structure. Progressive collapse can be triggered by manmade, natural, intentional, or unintentional causes like fires, explosions, earthquakes, or anything else causing large amounts of stress and the failure of a structure's support elements can lead to a progressive collapse failure. The purpose of this study was to describe the process of progressive collapse and to find more methods and approaches to design the structure for preventing different kind of failure. This project involves the use of Sap 2000 to perform analysis of a reinforced concrete structure. SAP 2000 is used to perform analysis and observe the stability of structure with local failure and its effect on the overall structure. Several column failure conditions are studied as per Indian standards and as per General Service Administration (GSA) guidelines, where for these two conditions gravity load combinations are different. As load combinations are different, changes are found in collapse pattern, which indicates Indian standards gives more conservative design than General Service Administration guidelines.

Key Words: Progressive Collapse, General Service Administration Guidelines, SAP2000, Dynamic Process

1. INTRODUCTION

Society expects that the structure of a building is to be sufficiently safe and durable. This safety should be the result of robust design, proper execution, and good material choice. A safe structure should be able to bear the loads acting on it and may not collapse completely when a structural element fails due to an accident or unforeseen action. Unfortunately, there are several instances where this was not the case. The one that is most referred to is the 22-story Ronan Point apartment tower in Newham, east London 1968. When an occupant on the 18th floor of the tower struck a match in her kitchen, which triggered a gas explosion because of gas leakage and that knocked out the load-bearing precast concrete panels near the corner of the building. The loss of the load bearing precast concrete panel at the 18th floor caused the floors above to collapse. The partial collapse of the 22 story Ronan Point apartment building in 1968 is a landmark of progressive collapses in recent history that triggered code changes. It was caused by a gas explosion on the 18th floor. For this building, the exterior cladding panels supported some edges of exterior slab panels. The explosion caused loss of cladding panels leading to the collapse of the slab when edge supports were lost. The weight of the debris from the 18th–22nd floor caused the collapse of the lower parts to the ground. This collapse brought changes to the British codes since the early 1970s and was referenced extensively in literature published in the United States. The impact of these collapsing floors set off a chain reaction of collapses all the way to the ground (see Figure 1). This phenomenon is known as a progressive collapse. Progressive collapse can be defined as a situation where the local failure of a primary structural component leads to the collapse of adjoining members, which in turn leads to additional collapse. In 1995, the Murrah Federal Office Building in Oklahoma City collapsed because of a terrorist bomb explosion at the ground floor. In 2001, the famous World Trade Center, New York, collapsed because of planes impacting the upper levels of the tower. The status of RC structures regarding their vulnerability to progressive collapse has become an important question.

2.OBJECTIVES

1. Formulation OF the problem statement, development of methodology, and possible validation with high-quality research articles.
2. Progressive collapse analysis of reinforced concrete shear wall building of G+9 floors is carried out as per General service administration guideline (GSA) and find out worst location of column removal.
3. To check whether a Reinforced Concrete shear wall structure designed and detailed by Indian codes provides any resistance to Progressive collapse or not.
4. Comparison of Demand capacity ratio values for RC SW structures by GSA guidelines and as per Indian standards.

3.MODELLING AND ANALYSIS

Progressive collapse analysis of A G+9 Reinforced concrete shear wall building is carried out by following the U.S. General Service Administration (GSA) guidelines. These guidelines have suggested three analysis methods: Alternate load path method, Tie force method and Local resistance method.

In this paper linear static and dynamic analysis are performed by Alternate load path method. In Alternate load path method original structure is designed for gravity and seismic loading as per IS 456 and IS 1893: 2016 Subsequently column at ground floor is removed one by one depending on case and perform linear dynamic analysis. The structure is subjected to gravity loading as per guidelines and run analysis is carried out and demand in terms of shear force and bending moment is evaluated from the analysis.
Capacity at critical sections is obtained from original design and strength increase factor and find out the demand capacity ratio of each member. If Demand Capacity Ratio (DCR) exceeds permissible values, the element is considered as failed.
Demand capacity ratio of each element can be calculated by following equation

DCR = Acting force / Ultimate capacity of section Acting force (demand) is in terms of shear, moment axial force

Ultimate capacity of section is in terms of shear, moment, axial force

If the DCR of a member in flexure exceeds 2 for symmetric configuration and 1.5 for asymmetric configuration, the member is considered as failed. In shear and in axial loading acceptable DCR is 1 for symmetric and asymmetric structures
Load combination as per GSA Guideline
Combination GLD = 2(1.2DL + 0.5LL) for column removal region
Combination G = (1.2DL + 0.5LL) for other region

4.1. Single column removal one at a time studied according to GSA guidelines & load combination is 2(1.2DL+0.5LL) to the affected location and for rest of area, it is (1.2DL+0.5LL).

For model A column removal conditions are-

1) C1
2) C2
3) C15
4) C22

In fig.1 and fig.2 shaded area represents the affected area of the structure after removing column. As per GSA guideline two load combination are given. GLD load combination i.e.. 2(1.2DL+0.5LL) are applied on affected area and G load combination i.e. (1.2DL + 0.5LL) are applied on other area of the structure as shown in fig. 1 and fig. 2 & analysis is carried out and find out the Demand capacity ratio. and based on that demand capacity ratio failed member are determined. If DCR is greater than 2 then member is considered as failed member.

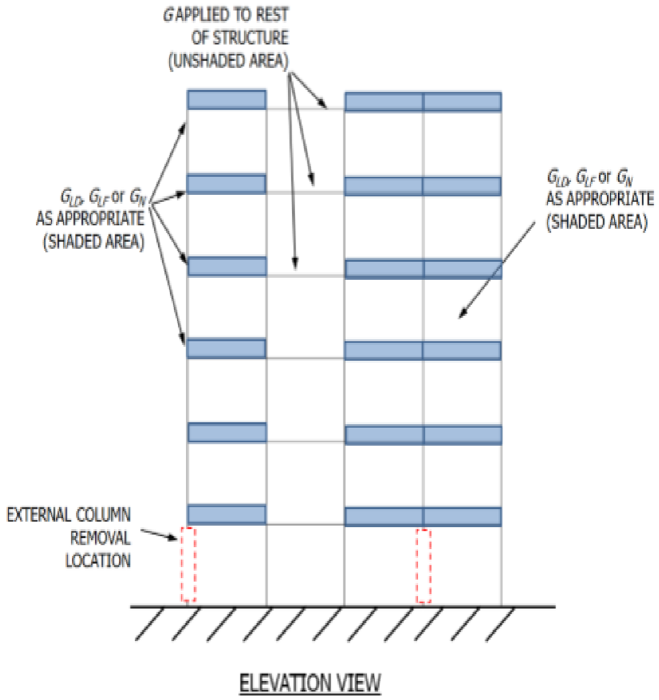
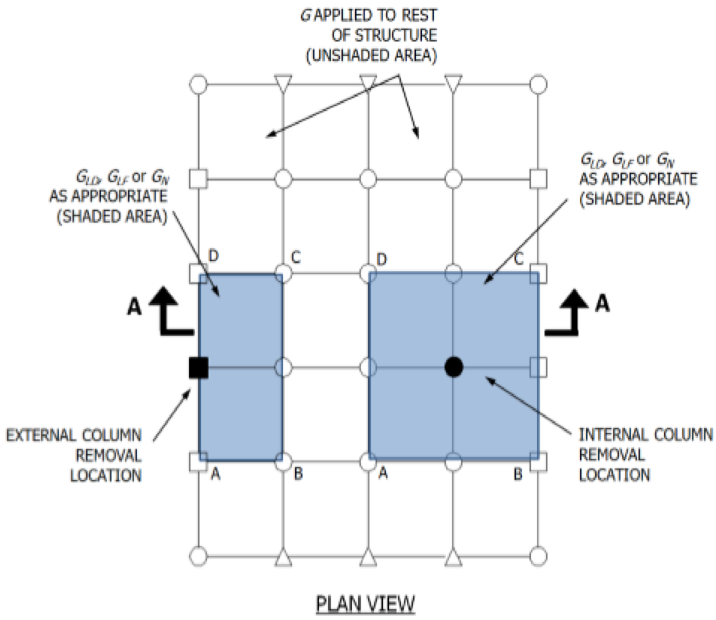


Fig-1



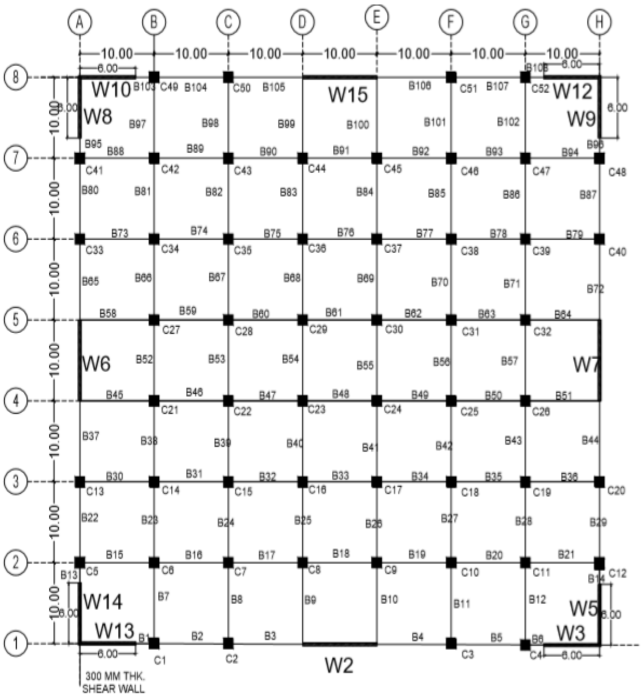


Fig -3. Plan of model

4.2. Result for GSA guideline

Table-1: Column information for model

Column No's. (Removed one at a time)	No. of Column Members failed in Demand / Capacity	Max D/C after removal of column	Type of Collapse
C1	0	0.835	Local
C2	0	0.801	Local
C15	0	0.859	Local
C22	0	0.863	Local

Table-2: Beam information for model

Removed Column No.	Negative Moment (Max D/C)	No. of failed beams	Positive Moment Max D/C	No. of failed beams
C1	3.12	1	1.64	-
C2	2.26	3	2.27	2,3
C15	2.10	24,31,32,39	2.49	24,31,32,39
C22	2.11	39,46,47,53	2.50	39,46,47,53

Tab.1 and tab.2 shows all column removal cases and for each column removal cases how many elements (beam and column) are failed and their maximum Demand capacity ratio are shown in table1 and table 2.

4.3. Steps for analysis for building designed by IS code

1) First, the same structure is analysed and designed in SAP 2000 as per IS 456 for the IS 1893 load combinations and the output results are obtained for moment and shear without removing any column.
2) A vertical support (column) is removed from the position under consideration. load combination 1.5(DL+LL) is selected for the structure and run analysis is carried out and find out the demand capacity ratio (DCR) for each member for all the column removal cases.
3) if the DCR for any member exceeds the allowable limit based upon moment and shear force, the member is expected as a failed member.
4) Compare demand capacity ratio for both the method as per GSA guideline and as per Indian standard method.

4.4. Single column removal case one at a time studied. And load combination is 1.5(DL+LL)

A. For model A column removal conditions are-

a. C1
b. C2
c. C6
d. C7
e. C15
f. C 22

Below table shows Beam and column information for model designed by Indian standard code all column removal cases are given and for each column removal cases how many elements (beam and column) are failed and their maximum Demand capacity ratio are shown in table3 and table 4

4.5. Results for progressive collapse analysis of model designed by Indian standard code for load combination 1.5(DL+LL)

Table-3: Column information for model

Column No's. (Deleted one at a time)	No. of Column Members failed in Demand / Capacity	No. of columns affected	Remark
C1	-	-	
C2	2	7	Each fails at Ground & Story1
C 6	6	7,14	Each fails at Ground, Story1&2
C7	8	6,8,15,	Each fails at Ground, Story1&2
C15	12	7,14,16,22	Each fails at Ground, Story1&2
C22	12	15,21,23,28	Each fails at Ground, Story1&2

Table-4: Beam information for model

Column No.	Negative Moment (Max D/C)	No. of failed beams	Positive Moment Max D/C	No. of failed beams
C1	3.02	1	1.58	1,7
C2	2.83	2,3,8	2.89	2,3,8
C 6	2.43	7,15,16,23	2.96	7,15,16,23
C7	2.49	8,16,17,24	3.1	8,16,17,24
C15	2.58	24,31,32,39	3.07	24,31,32,39
C22	2.53	39,46,47,53	3.12	39,46,47,53

5. CONCLUSIONS

1. In models, adjacent columns and beams are fails in D/C as per Indian standards.
2. But according to GSA guidelines none of columns fail in D/C. Whereas, adjacent beams are failing in D/C.
3. If RC SW building is designed and detailed according to the IS codes, it will prevent progressive collapse. A local collapse will happen, but progressive collapse will not start.
4. Indian Standards give higher load combination than GSA that's why failure will be more. That is showing Indian method for progressive collapse analysis is much more conservative.

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