Progressive Collapse Analysis of R.C.C Building under Seismic Load

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Abstract: *After several disastrous building collapses, concepts such as progressive collapse and robustness of structures have been reflected in many research papers and resulted in new codes and guidelines available in Europe and in the United States. The collapse of an entire structure or an essential part of it that is disproportionately large compared to the initiating local damage is considered a progressive collapse. In addition to the design guidelines, the mentioned standards provide provisions for the progressive collapse analysis of newly designed and existing structures. Therefor this study concerned with collapse behaviour of RCC building and various recent studies associated with it.*

Keywords: Collapse, RCC, Axial Force, Staad Pro, Shear wall.

1. INTRODUCTION

Prevention or mitigation of progressive collapse appears to be an important issue in the development of several structural design codes. They highlight the necessity of providing sufficient structural integrity, ductility, and redundancy to indirectly compensate the risk of disproportional collapse.

Awareness on the issue of progressive collapse took place after the structural failure of Ronan point in 1968. After the terrorist attack on Murrah federal office building in 1995 more and more research efforts were put to understand the progressive collapse. But it is important to note that collapse of the World Trade Centre (commonly known as 9/11) has led to the detailed investigations for the enhancement of robustness of structures in order to save precious loss of life and property under such attacks.

As per ASCE progressive collapse is defined as “The spread of local damage, from an initiating event, from element to element, eventually resulting in the collapse of entire structure or a disproportionately large part of it; also known as disproportionate collapse”. The General Services Administration, USA adopts the basic definition of that “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”. Department of defence (DoD) offers another definition as “A progressive collapse is a chain reaction of failure of building members to an extent disproportionate to the original localized damage”. Progressive collapse is deformation of any load bearing element which initiate the local failure and transfer of additional load progression to the adjoining elements to generate disproportionate collapse. An increasing number of progressive collapse around the world lead more disastrous event leading to loss of life, injuries and large number of death.

Considering this an important issue, United States Department of Defence (DOD) and United States General Services Administration (GSA), and Euro codes published a string of various guidelines and specifications. Alternate load path analysis is more adoptable because of its risk free approach and mainly focus on the performance of building after removal of critical support to ensure the safety of the building. There are four substitute analytical techniques drawn in alternate load path approach i.e. linear static analysis, nonlinear static analysis, linear dynamic and nonlinear dynamic analysis. In linear static analysis full factored load is applied on the damaged structure at once. After the static analysis DCR (Demand capacity ratio) can be computed to determine the extent of damage zone. This method is inconvenient if structure elements and joints connection have the DCR value less than 2 i.e. the structure have possesses several cracks and damage in that case other method is suitable . The advantage of this conservative method lie in its simplicity, fast to complete it and this method is applicable for the building with maximum of 10 floors. Nonlinear static analysis accounts for the nonlinearity of material and geometry, consist step by step iteration thus making this method time consuming. Hence analysis is done based on load history from zero to full factored load applied on the structure and iterations are continued until the structure model gets stabilized whereas nonlinear dynamic analysis represent the nonlinearities of material and geometry and express the actual behaviour of structure while undergoes inelastic deformation.

2. Progressive collapse guidelines

American Society of Civil Engineers (ASCE 7, [3]), General Services Administration [8], Department of Defense (Unified Facilities Criteria, [4], and National Institute of Standards and Technology[12] have developed criteria and guidelines to evaluate, design and improve structural integrity and progressive collapse resistance of existing and new buildings. ASCE 7 [3] provides design load combinations including abnormal loads and associated probabilities. It also presents general direct and indirect design approaches to ensure structural integrity following local damage to a primary load-carrying member

3. ANALYTICAL MODEL

A RCC building with or without shear wall is designed according to Indian codes. Fig. 4.2 shows a 3 storey building and the plan of building is asymmetric throughout the height. The height of building is 3.2m at each floor and the elevation of building with or without shear wall is shown in fig. 2. For each storey the size of all beams is designed and kept constant with a dimension 230 mm x 300 mm and column size is 230 mm x 450 mm. Building is designed according to IS codes for dead and live load condition.

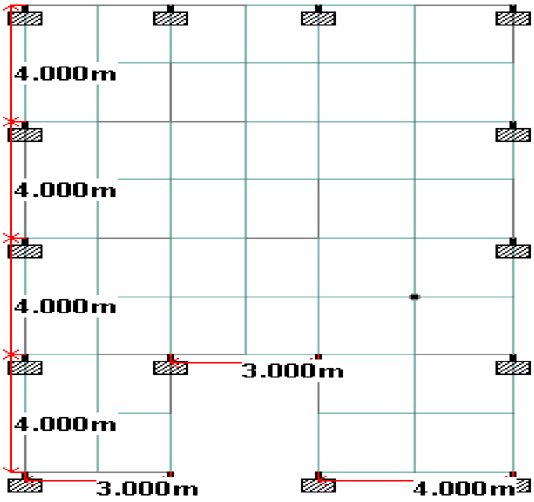

Fig. 1: Floor plan

Dead load = 4 KN/m^2

Live load = 3 KN/m^2

Member dead load (wall load) = 15 KN/m^2

Parapet wall dead load = 5 KN/m^2

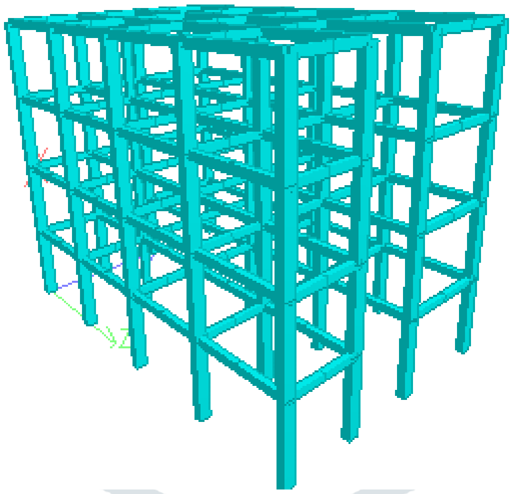

Fig. 2: Elevation of building without shear wall: FRAME 1

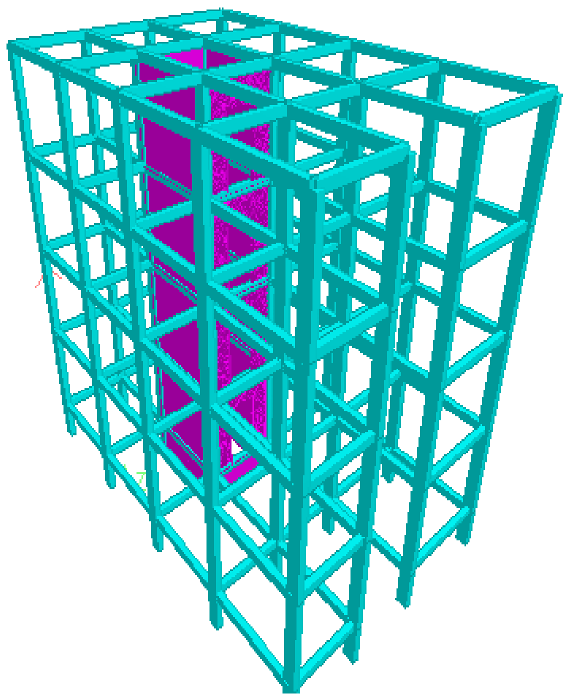

Fig. 3: Elevation of building with shear wall: FRAME 2

4. RESULTS AND DISCUSSION

A RCC building is designed according to Indian code. We consider 4 storey building along with floor height of 3.2 m and the depth of foundation is to be 1.5 m. All column sizes are 230 mm x 450 mm. All beam sizes is 230 mm x 300 mm. Consider two loads i.e. dead load and live load. In dead load consider the self-weight of the structure, wall weight of 15 KN/m, parapet wall weight of 5 KN/m, floor weight of 4 KN/m^2 and in live load consider load of 4 KN/sqm. A combination of both the Loads is considered according to Indian standards. Concrete grade considered is M25 along with steel grade Fe 415. The exterior column of ground floor is removed one by one in a series to find out the results. Similarly with the same loading specification and same beam and column section a RCC G+3 building with shear wall (with opening) is also designed and analyzed in same way by removing exterior column one by one .Comparative study of various parameters like axial forces of column, node displacement at top nodes of removed column and support reactions in vertical direction of both the frame (without and with shear wall) is carried out.

4.1 Comparison of Forces in X-Direction

Considering this scenario, column number 51 is removed as shown in Fig. 5.3 and it is observed that larger distribution of forces is observed in the nearest column number 52 and 55 which took place due to removal of this single column. The increase in percentage of additional loading due to the accidental collapsing of structural member number 51 and results in transfer of load to adjacent member number 52 is about 53% in case of frame 1 i.e. frame without shear wall while increase in axial load in adjacent column number is 51% in case of frame 2 i.e. frame with shear wall.

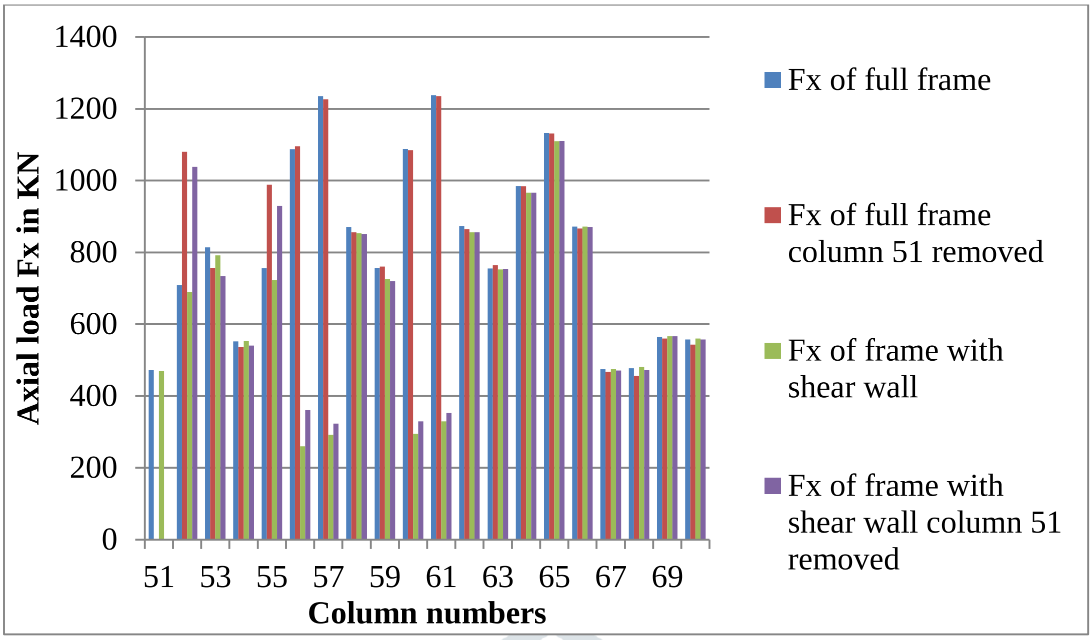

Fig. 4: Comparison of forces in X direction of all column of GF when column no. 51 removed

Considering this scenario, column number 51 is removed as shown in Fig. 4 and it is observed that larger distribution of forces is observed in the nearest column number 52 and 55 which took place due to removal of this single column. The increase in percentage of additional loading due to the accidental collapsing of structural member number 51 and results in transfer of load to adjacent member number 52 is about 53% in case of frame 1 i.e. frame without shear wall while increase in axial load in adjacent column number is 51% in case of frame 2 i.e. frame with shear wall.

Fig. 5: shows the percentage increase of force at adjacent column number 51 due to removal of column number 52 and it is found to be 58% in case of frame 1 while it is 55% in case of frame 2

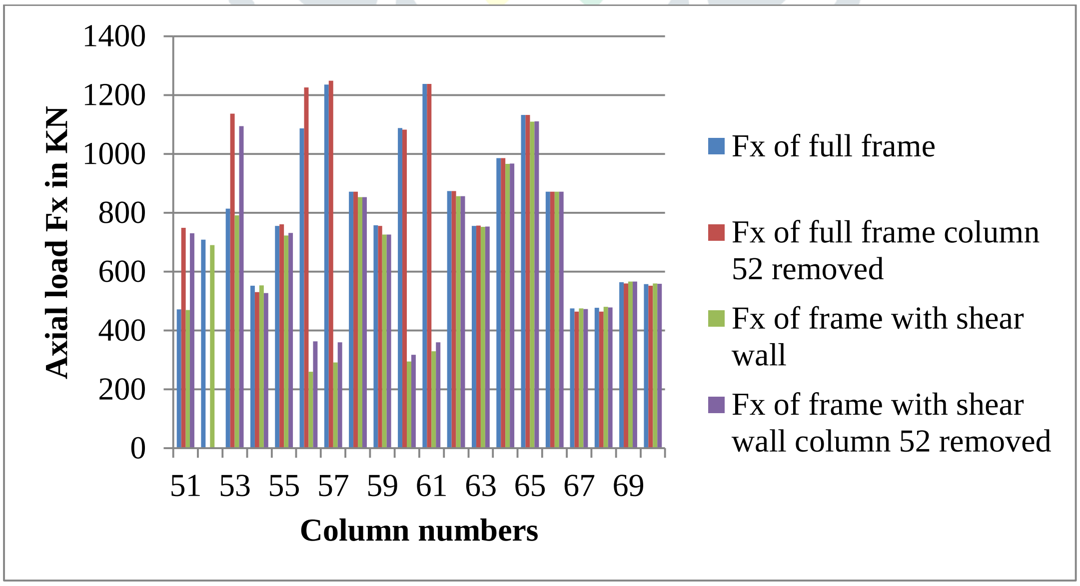

Fig. 5: Comparison of forces in X direction of column of GF when column no. 52 removed

4.2 Determination of Reaction at Support

The graph shows the support reaction in vertical direction of all the supports columns of the frame 1 i.e. without shear wall and frame 2 i.e. with shear wall. It is found that values of reaction at support number 26, 27, 30 &31 is more. Because these are the support of shear wall.

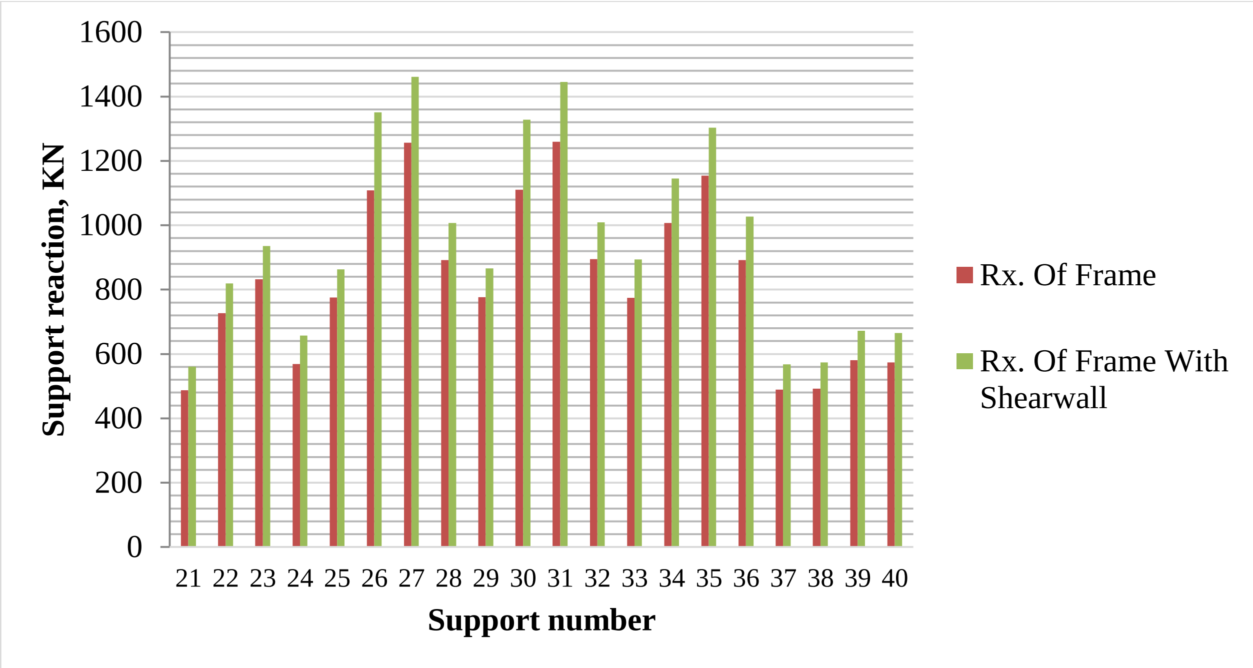

Fig. 6: Comparison of support reaction values

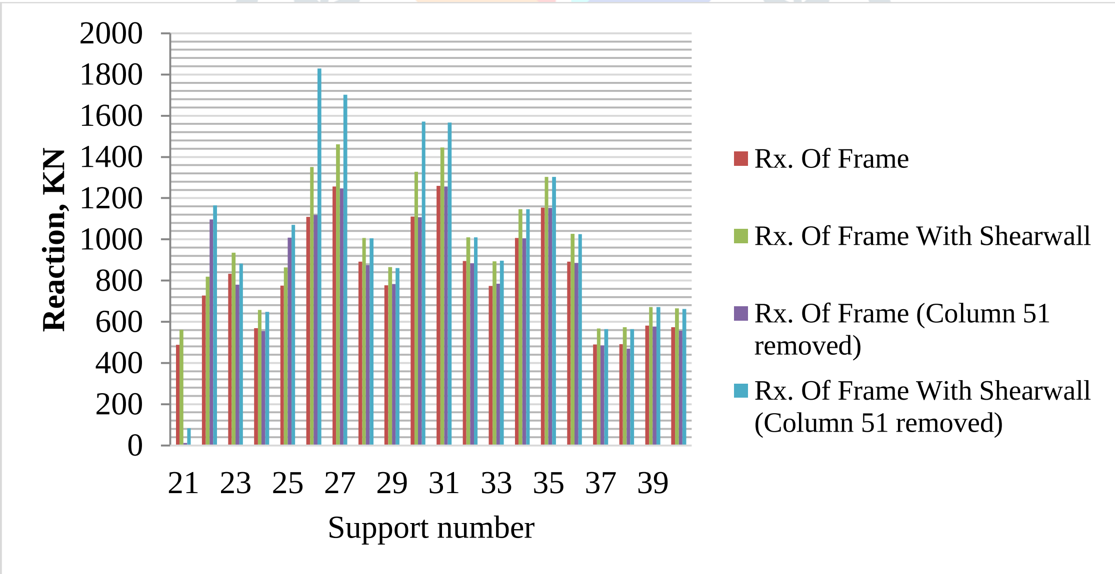

Fig. 7: Reaction comparison when column no. 51 is removed

From the above graph when the column number 51 is removed the support reaction (Y direction) is increased in the adjacent support number 22 and 25 by 51% & 30% respectively in case of frame without shear wall while it is 42% & 24% in case of frame with shear wall.

5.3 Comparison of Node Displacement

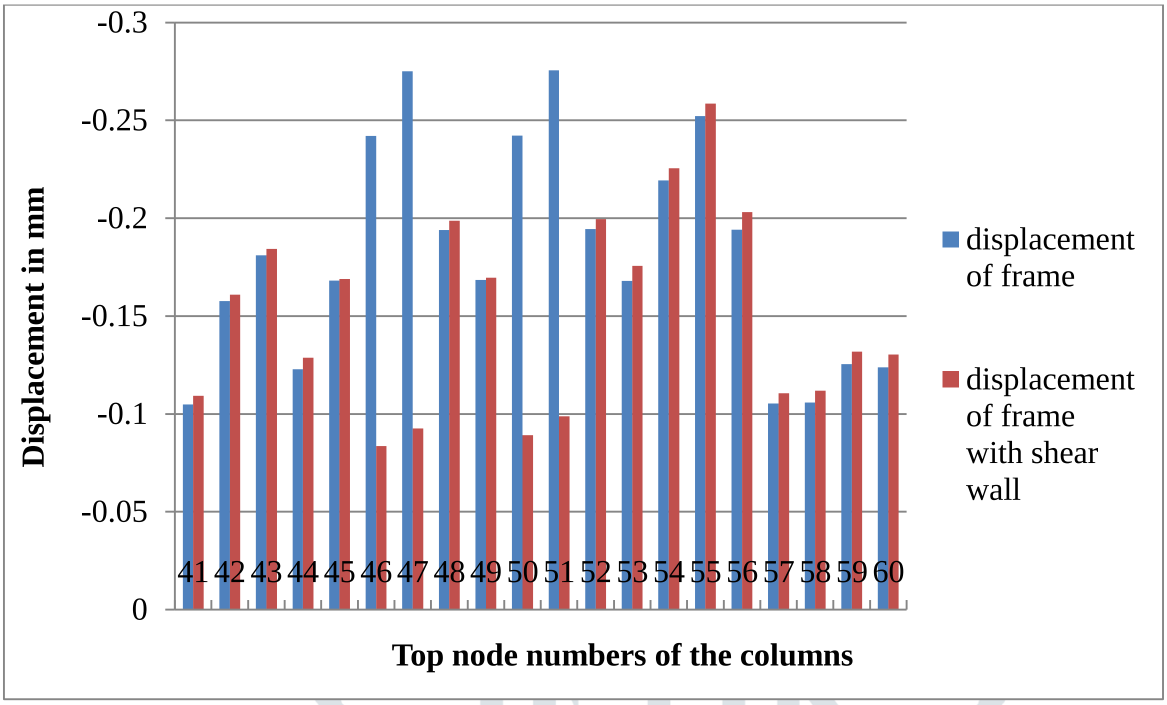

Fig. 8: Comparison of Displacement of the top nodes of columns of GF

The above graph shows the node displacement at the top of columns of the frame 1 i.e. without shear wall and frame 2 i.e. with shear wall. It can be concluded from the above graph that the displacement of the frame with is shear wall is little more than the displacement of the frame without shear wall except the nodes at which shear wall support .The node displacement at node number 46, 47, 50 and 51 is reduced tremendously.

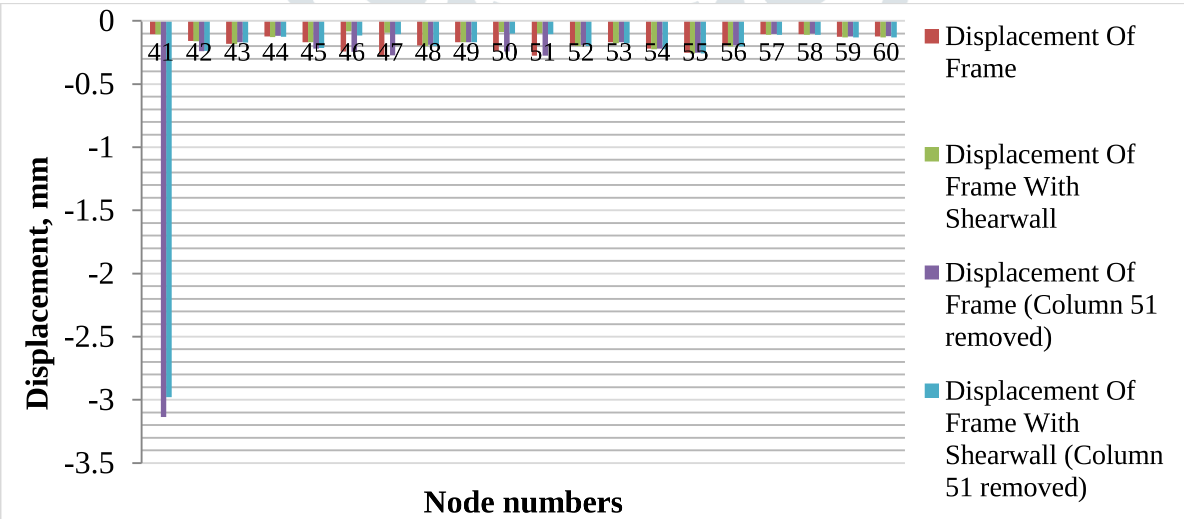

Fig. 9: Comparison of displacement when column no. 51 is removed

The above graph shows that when the column 51 is removed the node displacement at the top node of removed column 51 is increased by 30 times of the displacement from the initial condition (without column removed condition) in case of frame 1 i.e. without shear wall and 27 times of the displacement from the initial condition (without column removed condition) in case of frame 1 i.e. with shear wall.

6. CONCLUSION

In this work, the main objective was to investigate the behaviour of the four storey asymmetric RCC building with and without shear wall due to progressive collapse. Studies are carried out to investigate the behaviour of progressive collapse for axial forces in columns, support reactions and node displacement subjected to sudden loss of a vertical support member. Ground floor columns are removed one by one, and the study of progressive collapse initiation on a typical reinforced concrete frame is done with the help of a STAAD Pro. This simple analysis can be used to quickly analyse the structures for different failure conditions and then optimize it for various threat scenarios. Based on this investigation following conclusions are drawn:

1. From the axial force scenario larger redistribution of axial forces is more in adjacent columns of removed column than the columns located far from the removed column. Removal of column number 53,66,58 exhibit most critical condition in case of axial force redistribution shows that columns of mid part of frame is critical than other column of building.
2. Percentage of increase in axial forces is more in frames of without shear wall than the frames with shear wall.
3. Redistribution of axial force is also depending on the distance and symmetry of the structure. If the adjacent columns with same property and specification are located at same distance from the removed column than the percentage increase in axial load is also same.
4. From the support reaction scenario larger redistribution of support reaction is more in adjacent support of the support of removed column than the supports located far from the support of removed column. Removal of column number 53,52,58 exhibit most critical condition in case of support reaction redistribution shows that columns of mid part of frame is critical than other column of building.
5. Percentage of increase in support reaction is more in frames of without shear wall than the frames with shear wall.
6. From the joint displacement scenario the displacement of the top nodes of the removed column increases tremendously and it is more for the frame of without shear wall than the for the frame of with shear wall.

It can be concluded that from node displacement criteria maximum change occurs in node number 53, 54 and 44 in both the frame cases i.e. frame without shear wall and with shear wall due to removal of column 54, 63 and 64. Hence from the node displacement criteria critical columns are 54, 63 and 64.

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