International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Study of Progressive Collapse of RC Structure

A.K.L. Srivastava[a], *Md Mozaffar Masud*[b]

[a]*Professor, NIT Jamshedpur, India*
[b]*Student, NIT Jamshedpur, India*

A B S T R A C T

The present study deals with the prevention of the progressive collapse of existing storey building structure after the failure of column by using different types of bracing system and different types of arrangement. Progressive collapse of structures refers to local damage due to occasional and abnormal events such as gas explosions, bomb attacks and vehicular collisions. The local damage causes a subsequent chain reaction mechanism spreading throughout the entire structure, which in turn leads to a catastrophic collapse. The main objective of this study is critical investigation of result in terms of displacement, drift and vertical displacement and to show that bracing system mechanism significantly prevent the progressive collapse.

Keywords: Progressive collapse, bracing, displacement, RC structure

1. Introduction

In general, the size of resulting collapse is disproportionate with the triggering event. Progressive collapse might be concluded in two outcomes either partial collapse or global collapse. Moreover, the ratio of total destroyed volume or area to the volume or area damaged by the originated event could be defined as the degree of progressivity in a collapse. The buildings and infrastructures have been designed to resist the normal loading such as those due to self-weight, occupancy, wind load, seismic effect, and other loading scenarios stipulated in building design codes. However, the accidental partial collapse of the multi-story large-panel apartment building at Ronan Point in the UK in 1968, which was caused by a gas explosion (human-error) drew the attention of structural engineering community to the issue of progressive collapse.

The structural engineers have begun to refocus on the problem of progressive collapse. The design societies and researchers have shown a vast interest in the performance of the buildings under the situation of progressive collapse. Progressive collapse is a situation in which a local failure in a structure leads to load redistribution, resulting in an overall damage to an extent disproportionate to the initial triggering event [1]. While the disproportionate collapse is associated with local failure of a structural component leading to the total failure of the entire structure or a significant portion of the structure, that is, the extent of final failure is not proportional to the original local failure.

B.M. Luccioni et al, [2] noted that due to different abnormal loadings in the recent years has become a great attention. The construction and design of buildings enables life safety in case of explosion have become the design concern for the structural engineers for many years. S M Marjanishvili [3] evaluated that progressive collapse is a dynamic event in which building element shows vibrations which results in dynamic feature of inertial force. In a general manner he discussed analysis for estimating the progressive collapse behavior of the structures such as linear and nonlinear static and linear and nonlinear dynamic analysis. The nonlinear dynamic analysis shows the most realistic output, but due to high complexity of this, it is giving incorrect assumptions and modelling errors.

Sezen, H. and Brian, S [4] to test the progressive collapse potential of the Ohio State Union scheduled for demolition in 2007. They followed the GSA (2003) guidelines and calculated the DCR values as four exterior columns were removed from the structure. The computer program SAP2000 was used in the study to generate a computer model simulation of the Ohio State Union. Abruzzo et al. [5] performed a study describing the assessment of an existing building. It shows through usage of the alternate path method, the building meets the ACI 318 (2008) integrity requirements; it is still significantly vulnerable to progressive collapse failure. This study is also closely related to this project and should be useful in analyzing real buildings

* *Corresponding author.*
E-mail address: masud0768@gmail.com

Abhay A. Kulkarni and Rajendra R. Joshi [6] performed an analytical modeling of 12 storey building using ETAB v9.6 and SAP2000. The demand capacity ratios(DCR) of 12 story framed structure are assessed as per GSA guidelines. Linear and nonlinear static analysis is performed for comparison purpose. R. Jayanthi and S. Mohan Kumar [7] evaluate the progressive collapse analysis multi storey RC building using pushover analysis with the guidance of GSA. They found that if corner column fail then potential of progressive collapse increase. The beams that are adjacent to the removed column have maximum Bending Moment compared to the beams which are away from the damaged column joint. LiZhongxianansdShiYanchao [19] deal with methods of progressive analysis of building structure under the blast loading and impact loading i.e, direct simulation method and alternate path method.

2. Modelling of Structure

To study the effect of progressive collapse, the structure is modeled using SAP2000 in the sense that certain members are to be removed. Progressive collapse and dynamic effects is evaluated using time-history analysis as follows:

1. A model is createdwhich contains the entire structure, including the column to be removed which is shown in Fig. 1. Analyze this model to obtain the internal forces of the column which will be removed.

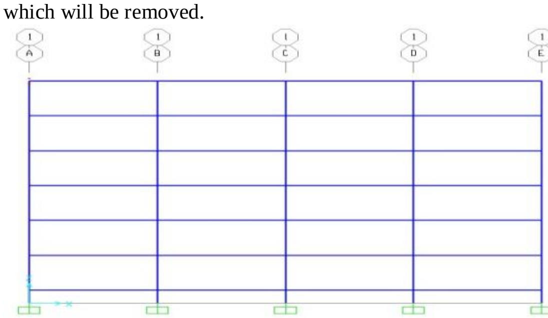


Fig. 1 - Model to be analyzed.

2. Another model is created in which the column is removed in three different positions which is in Fig. 2 to Fig. 4. In first model E1 column in X direction is removed, in 2nd model E1 & E2 column removed in Y direction and in third model B1, C1, D1, C2 & D2 is removed in X direction. Apply the column end forces, obtained during the analysis of Model A, to simulate the presence of the removed column.

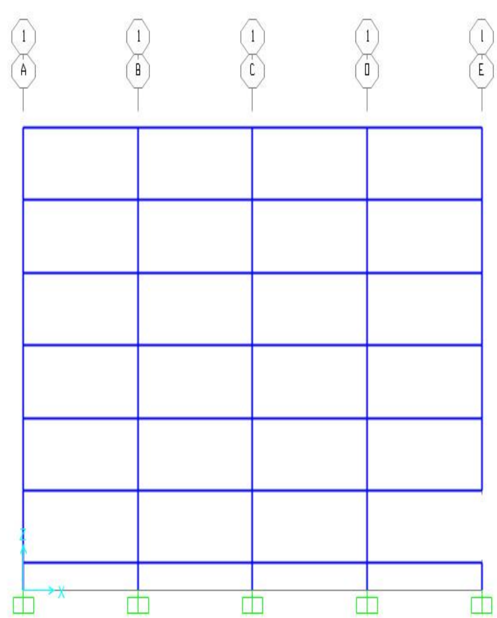


Fig. 2 – Model 1, E1 column removed

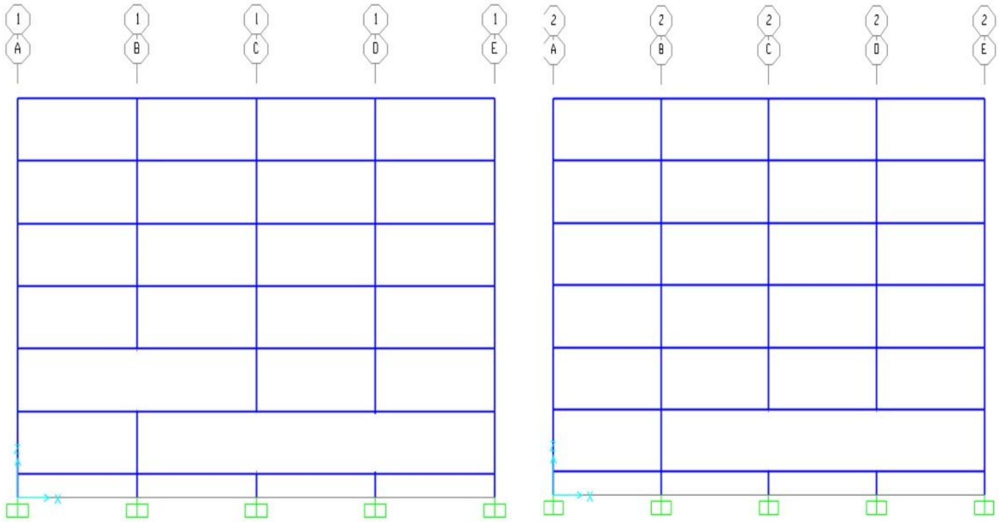


Fig.3. Model 2, E1 and E2 column removed

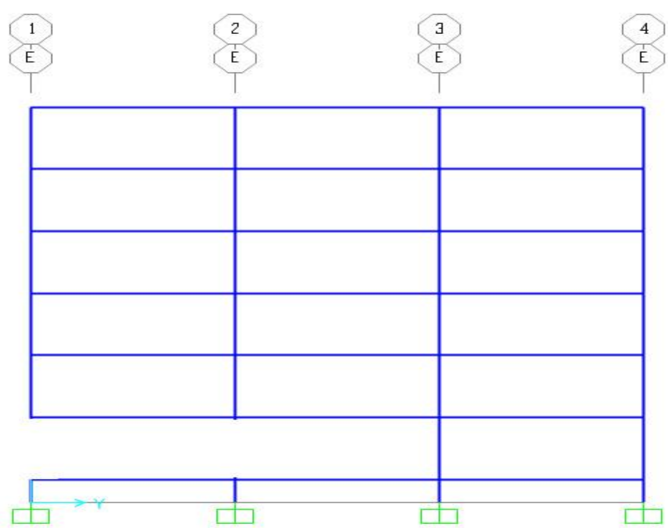


Fig. 4. Model 3, Removed column B1, C1, D1, C2 and D2

3.Simulate the removal of the column by running a time-history analysis in which these equivalent column loads are reduced to zero over a short period of time. This is done by applying a ramp time function in which loads opposite to those of the equivalent column loads are scaled from zero to the full value.

4. Another model is created with X and V Bracing systems of different arrangements in which the column is removed which is in Fig. 5 & 6. “ISA 200mm x 200mm x18 mm” angle section bracing is used in this analysis. Analyze the model and compare the results obtained.

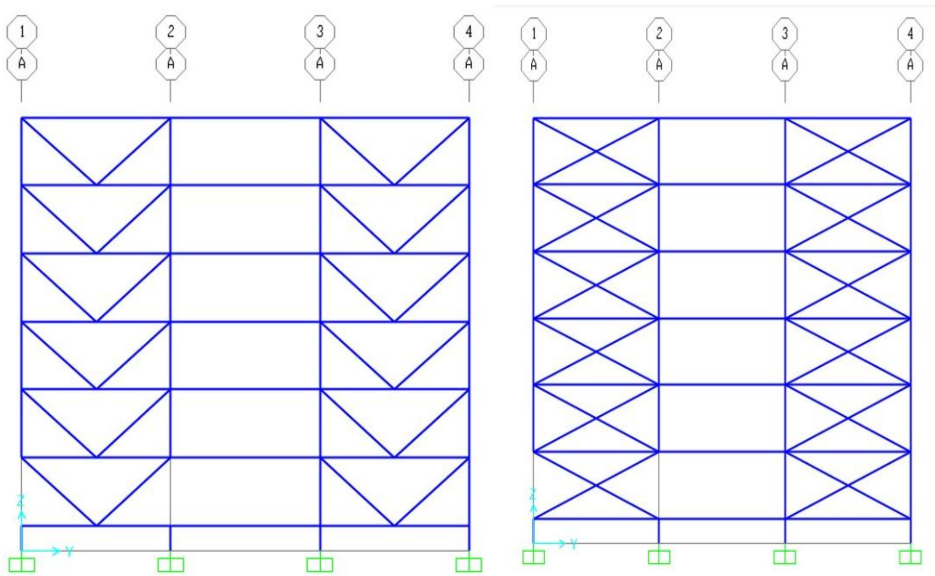


Fig. 5. Neighbor arrangement of X and V shape bracing

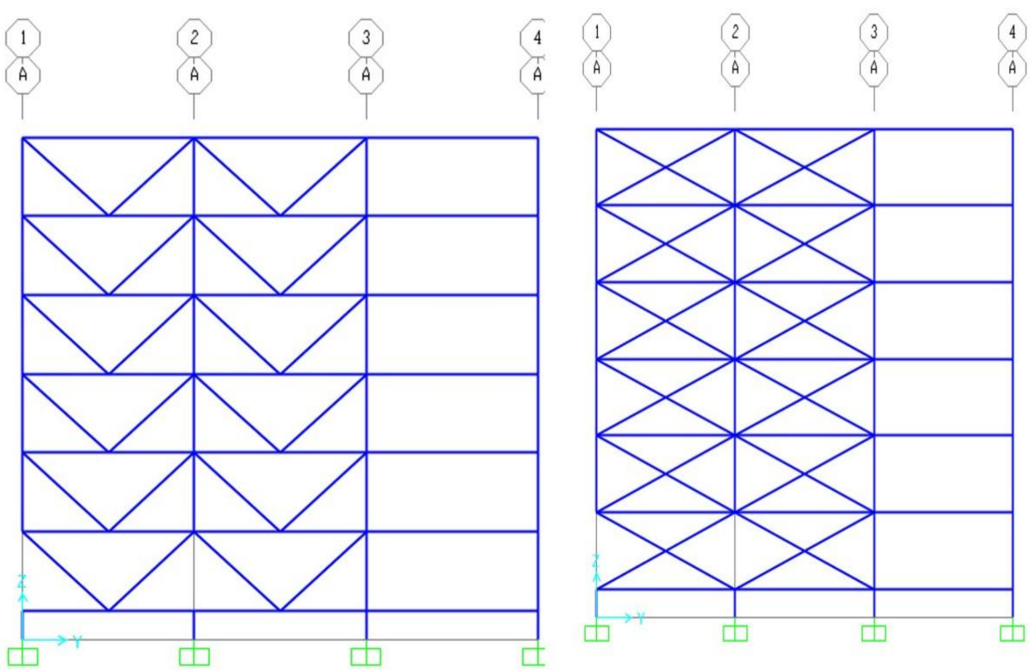


Fig. 6. Alternate arrangement of X and V shape bracing

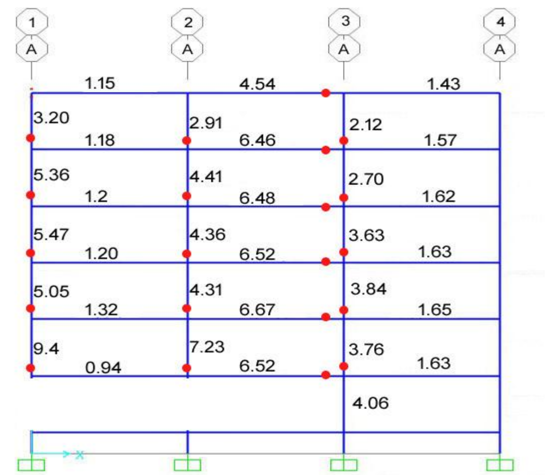
3. Results and Discussion

(a) Fig. 7(a) to 7(d) shows the demand-capacity ratio (DCR) for nearby member of removed column in the building using the formula for all three model.

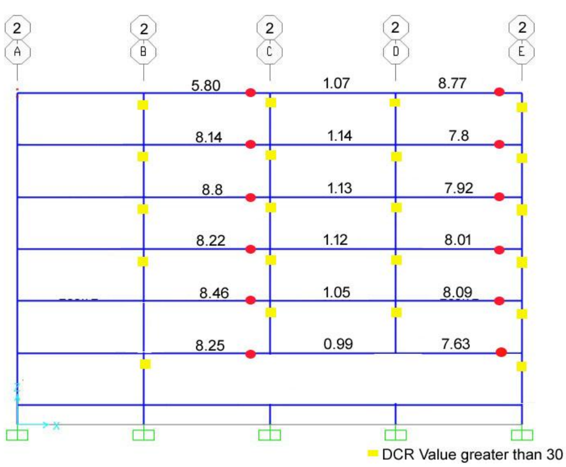
$$DCR = Q_{UD}/Q_{CE}$$

Red dots indicate the DCR value exceeds the acceptable value of 2.0, it means those members are not safe. Yellow dots indicates DCR value greater than 30.

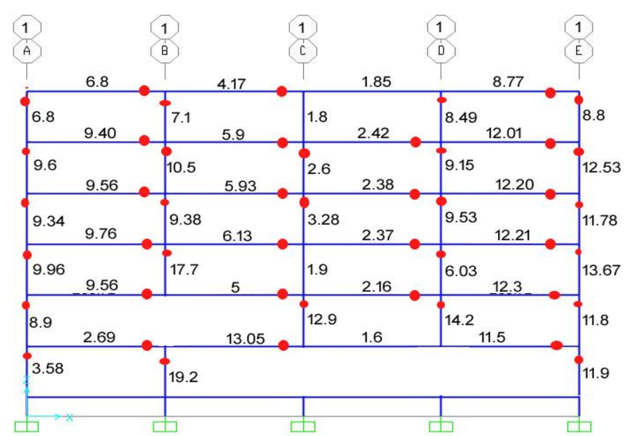
(a)



(b)



(c)

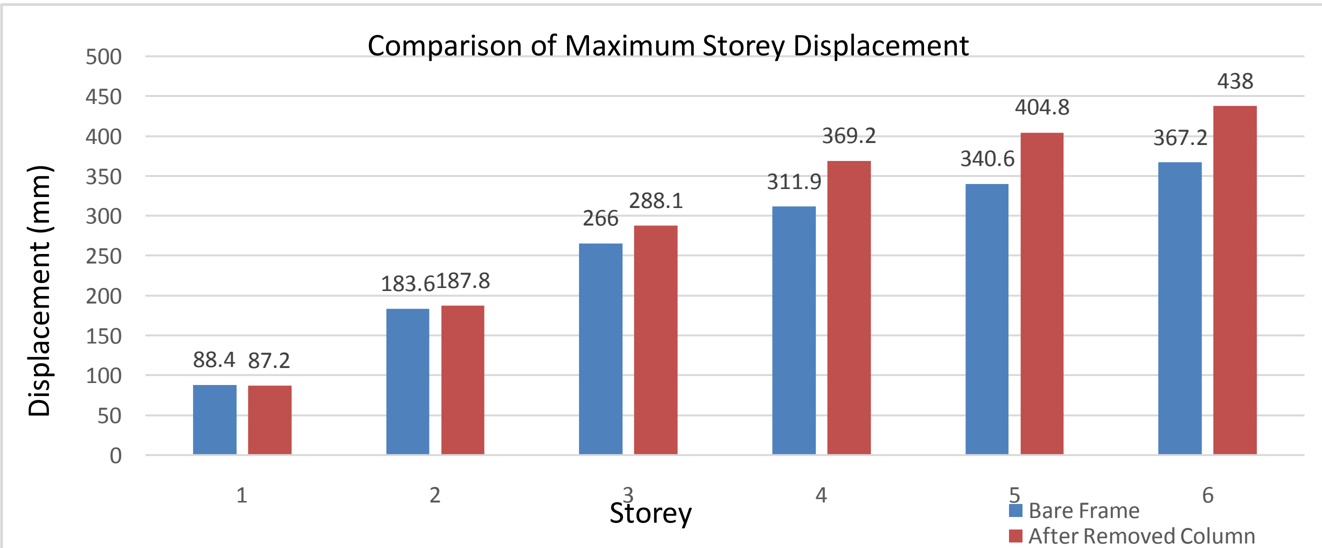


(d)

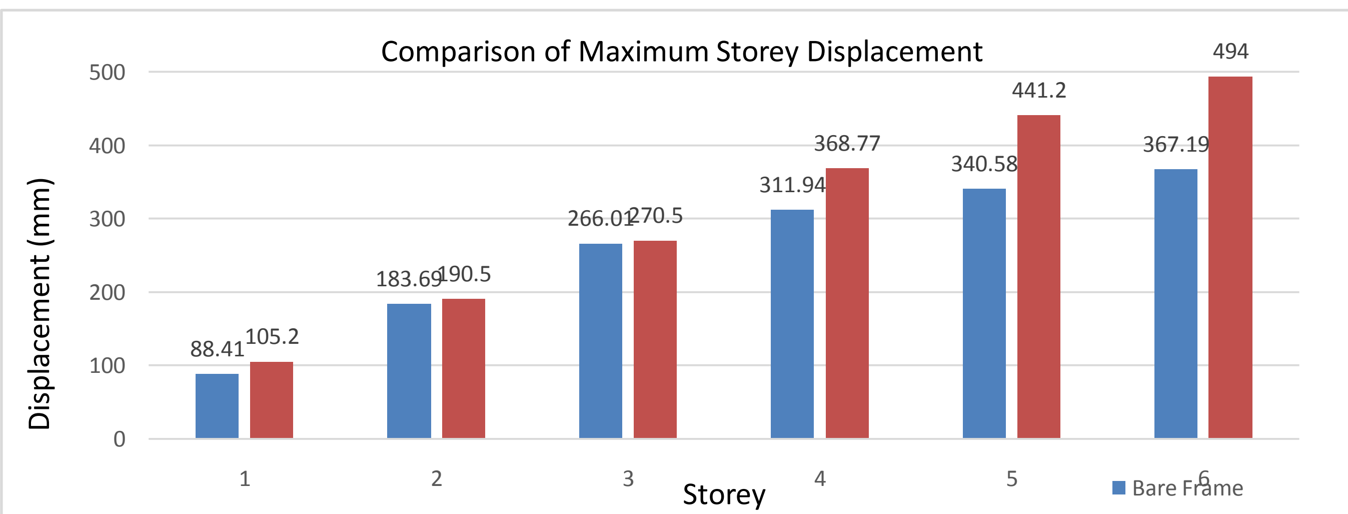
Fig. 7. (a) Model 1, DCR value of nearby element of removed column (b) Model 2, DCR value of nearby element of removed column

(c) Model 3, DCR value of inner frame of nearby element of removed column (d) Model 3, DCR value of outer frame of nearby element of removed column

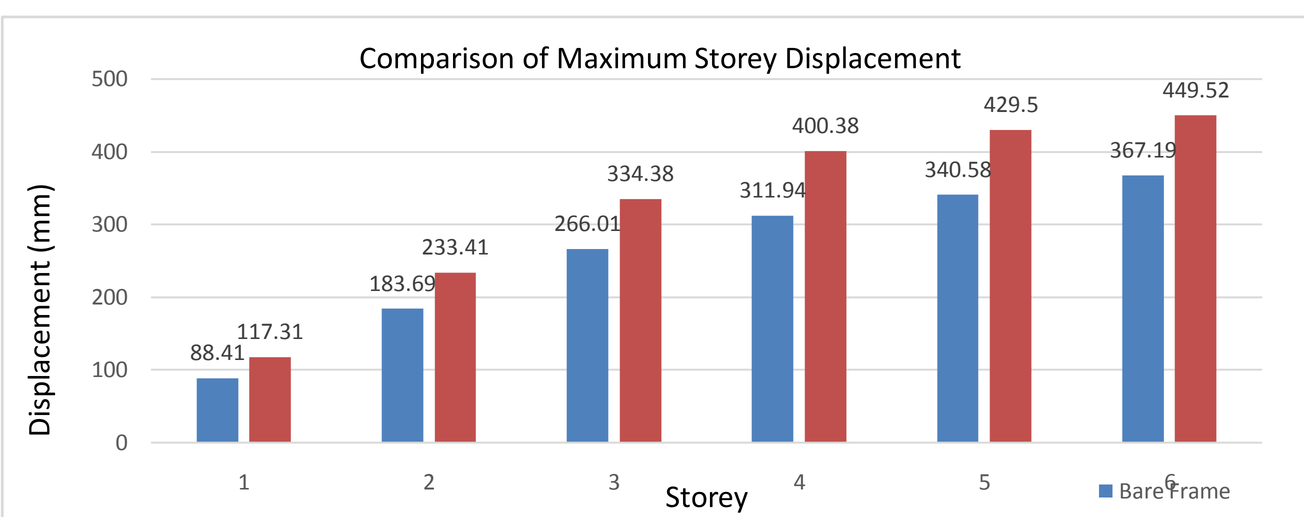
(b) Fig. 8 (a) to 8 (d) shows the comparative results of maximum storey displacement for all the three models before and after removal of column.



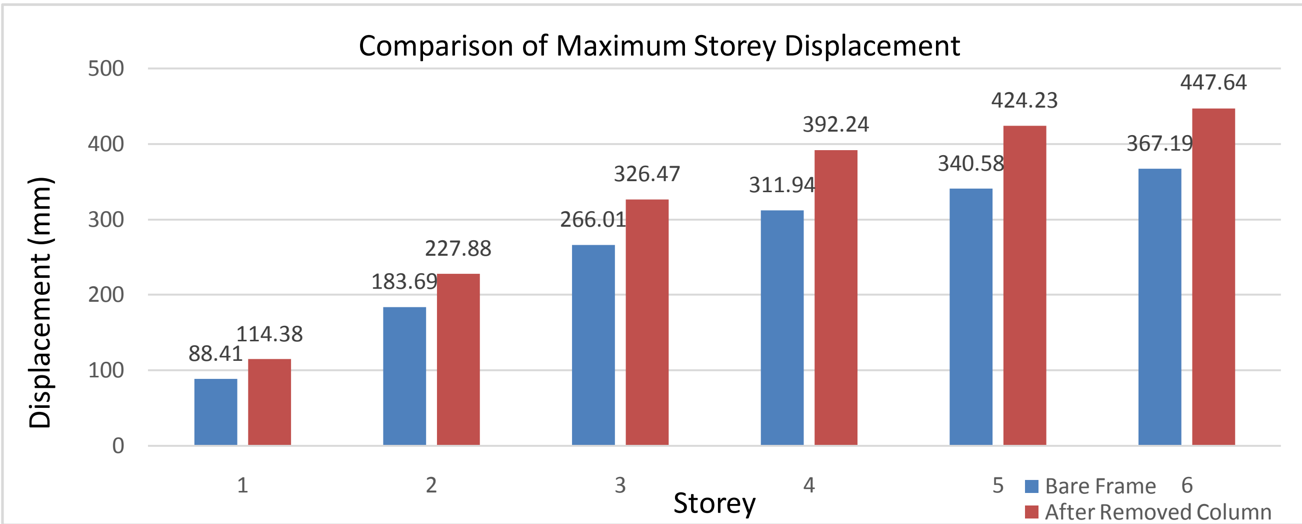
(a)



(b)



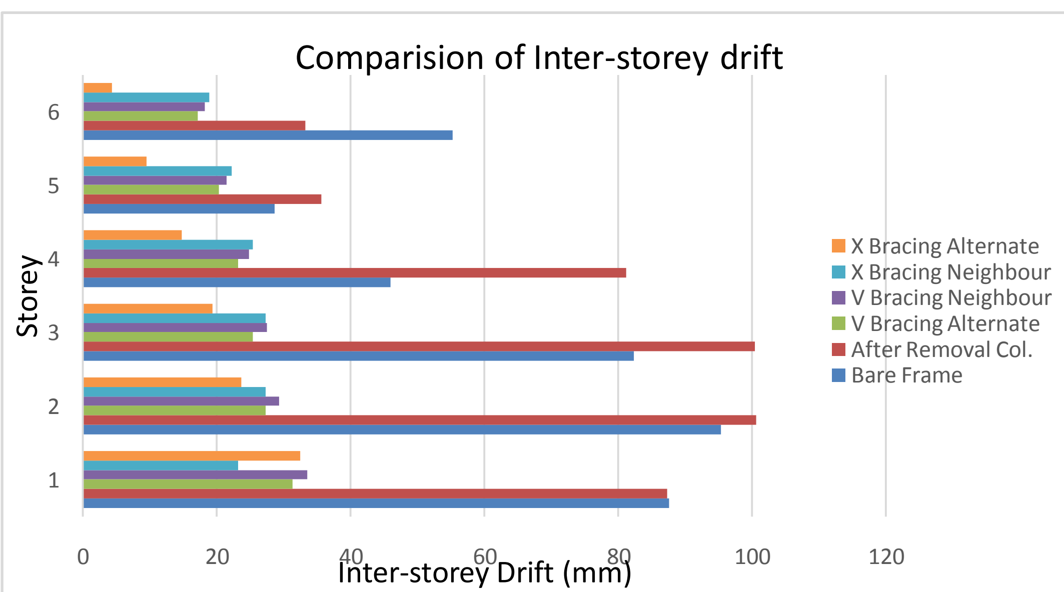
(c)



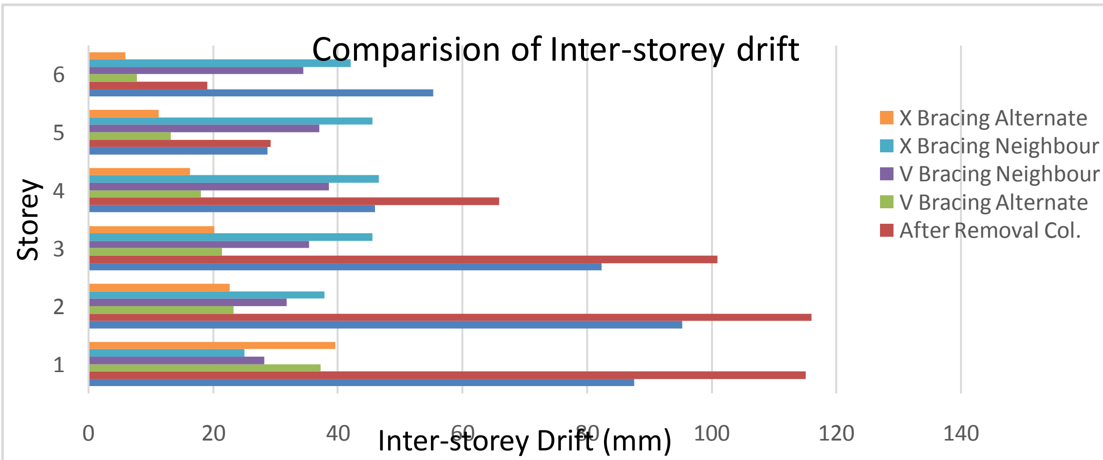
(d)

Fig. 8. Comparison of maximum storey displacement for Time History Analysis of (a) Model 1 (b) Model 2 (c) Model 3, outer frame (d)Model 3, inner frame

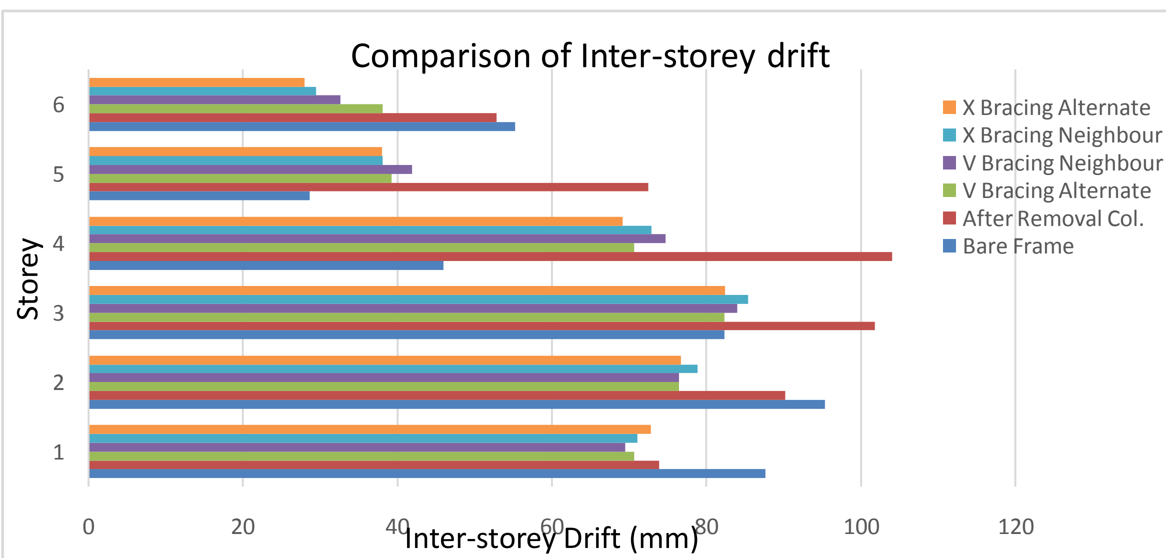
(c) Fig. 9 (a) to 9(d) shows the comparative results of inter-storey drift for all the models without and with different types of bracing arrangement for time history analysis.



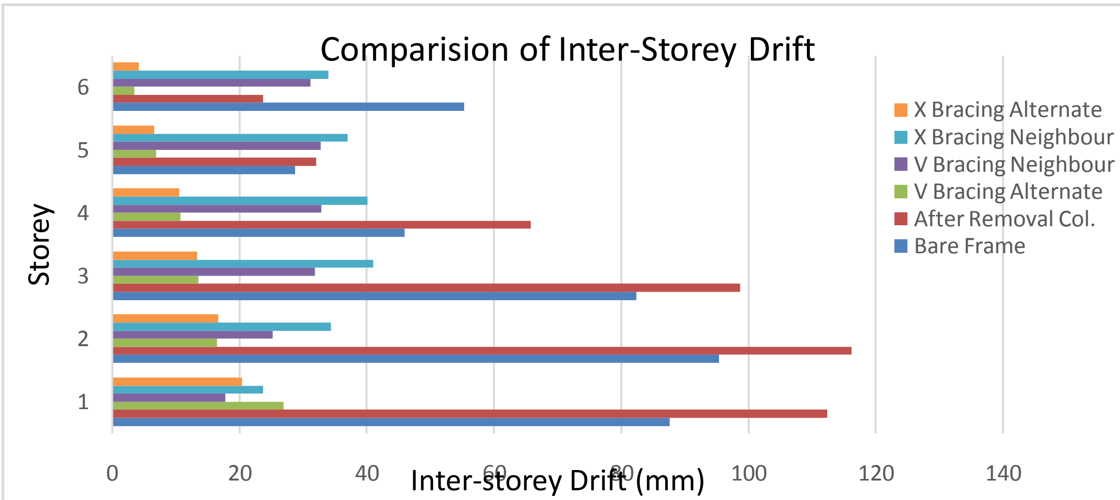
(a)


Comparision of Inter-storey drift
Storey
6
5
4
3
2
1
0
20
40
60
80
100
120
140
Inter-storey Drift (mm)
X Bracing Alternate
X Bracing Neighbour
V Bracing Neighbour
V Bracing Alternate
After Removal Col.

(b)


Comparison of Inter-storey drift
Storey
6
5
4
3
2
1
0
20
40
60
80
100
120
Inter-storey Drift (mm)
X Bracing Alternate
X Bracing Neighbour
V Bracing Neighbour
V Bracing Alternate
After Removal Col.
Bare Frame

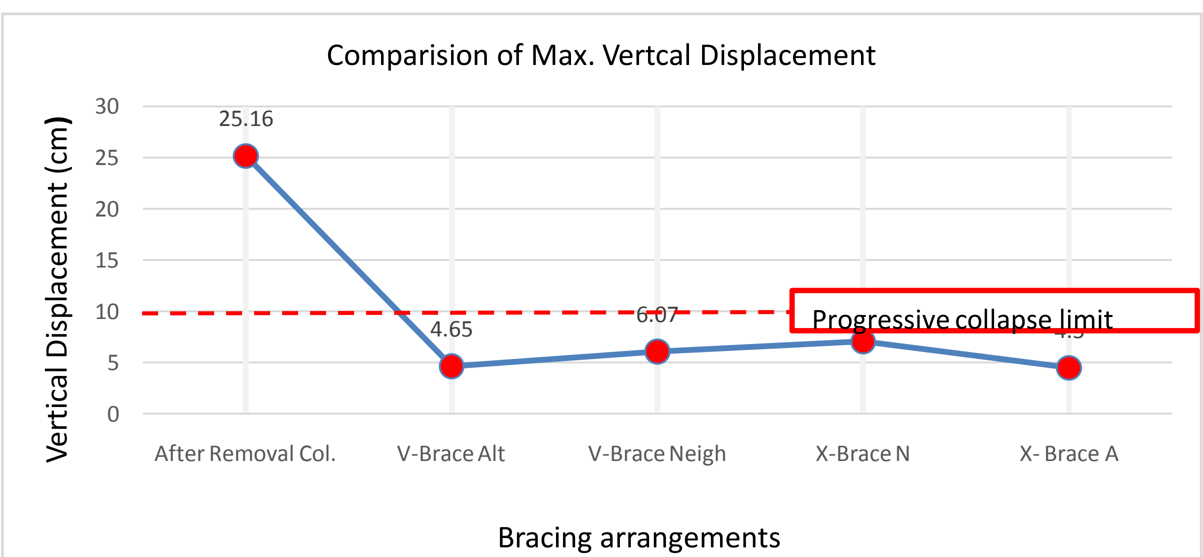
(c)



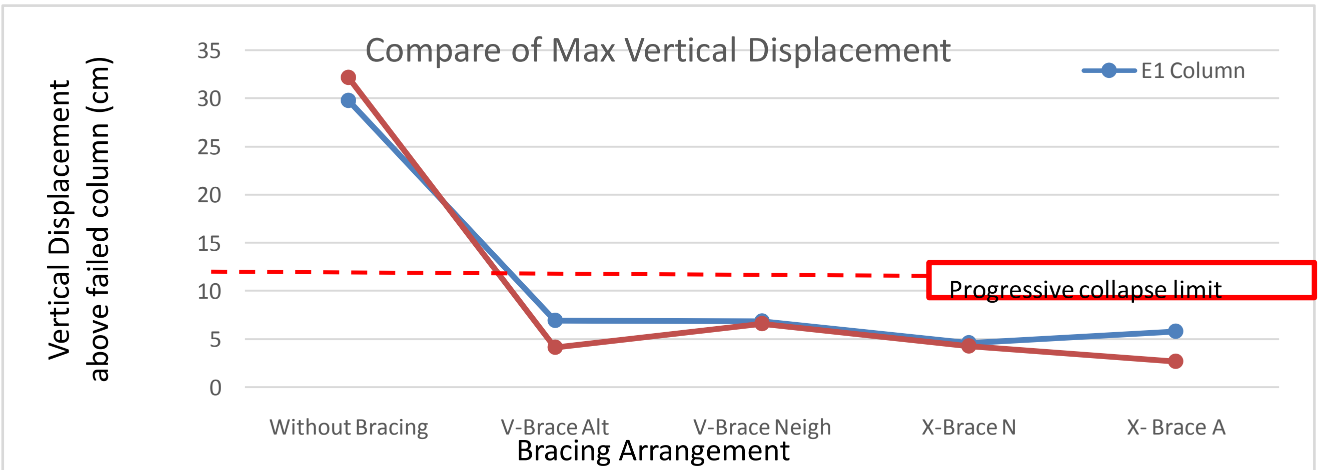
(d)

Fig. 9. Comparison of inner storey drift for various bracing arrangements for Time History Analysis of (a) Model 1 (b) Model 2 (c) Model 3, outer frame (d) Model 3, inner frame

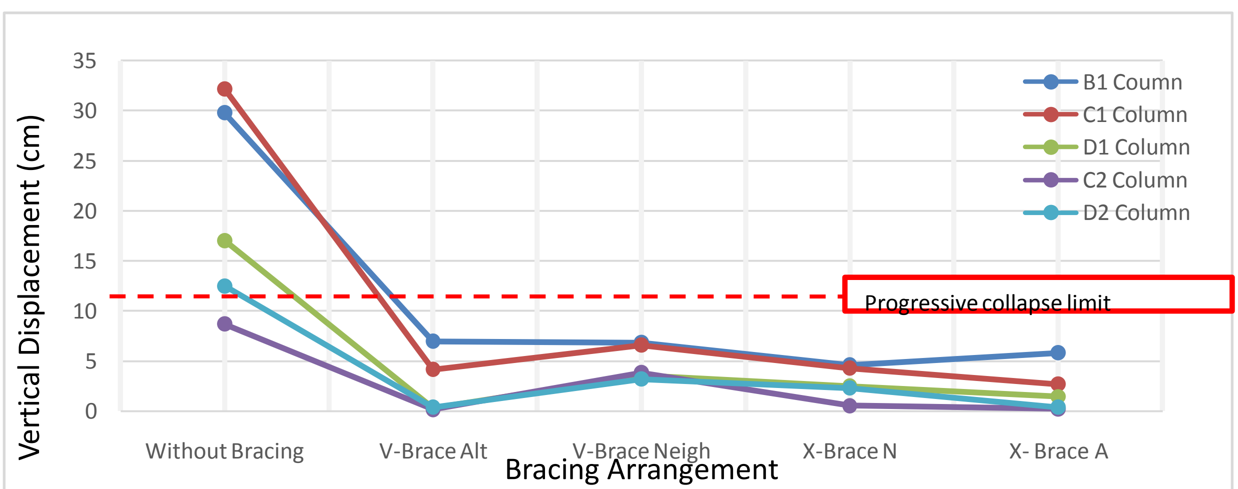
(d) Fig. 10(a) to 10 (c) shows comparative results of vertical displacement above the removed column with & without bracings.



(a)



(b)



(c)

Fig. 10. Comparison of vertical displacement above removed column (a) E1 (b) E1 and E2 (c) B1, C1, D1, C2 & D2, for time history analysis

we can see that the maximum story displacement increased by 19%, 34%,21% & 22% after column removed in model 1, model2 & model 3(outer & Inner) respectively for time history analysis. An effective decrease of 75%, 25%, 91% & 76% has been observed in maximum storey displacement after using bracing system in model 1, model 2 & model 3(outer & inner) respectively for time history analysis.

Reduction in maximum storey drift by 76%, 17%, 59% & 64% has been observed after using bracing system in model 1, model 2 & model 3(outer & inner) respectively for time history analysis.

4. Conclusion

Bracing System is one of the most important mitigation scheme used to control the progressive collapse of structure. Performance of the bracing system vary by the shape and arrangements. It also controls storey displacement.

1. The bracing system can be successfully used to prevent progressive collapse of RC structure.
2. RC structure has more potential for progressive collapse when the corner column is removed, hence the bracing system is necessary.

REFERENCES

[1] Choi., J., & Chang., D. (2009). Prevention of Progressive Collapse for BuildingStructures to Member Disappearance by Accidental Actions. Journal of Loss Prevention in the Process Industries. 22, 1016–1019.

[2] Luccioni, B.M. (2003). Analysis of building collapse under blast load, CONICET, Structure institute, National University of Tucuman, Av. Roca 1800, 4000 SM Tucuma Argentina.

[3] Marjanishvili, S.M. (2004). Progressive Analysis Procedure for Progressive Collapse", Journal of Performance of Constructed Facilities, Vol. 18, No. 2, May 1, 2004. ©ASCE, ISSN 0887- 3828/2004/2, pp. 79–85

[4] Sezen, H. and Brian, S. (2008). Progressive Collapse Analysis of the Ohio, Union Steel Frame Building. Euro Steel 2008. V. 3, No.5, 2008

[5] Abruzzo, J., Matta, A., and Panariello, G. (2006). Study of mitigation strategies for progressive ecollapse of a reinforced concrete commercial building", Journal of Performance of Constructed Facilities 20, V. 4, pp. 384-390.

[6] Abhay A. Kulkarni, Rajendra R. Joshi (2011). Progressive Collapse Assessment of Structure, International Journal of Earth Sciences and Engineering ISSN 0974-5904.

[7] Jayanthi, R. and Mohan Kumar, S. (2016). Progressive Collapse Analysis of a Multistorey RCC building using Pushover Analysis, International Journal of Engineering Research & Technology (IJERT), Vol. 5 Issue 03.

[8] Li Zhongxianansd Shi Yanchao. (2008). Methods for Progressive Collapse Analysis of Building Structures Under Blast and Impact Loads, Transactions of Tianjin University Vol.14 No.5.