CENTRAL ASIAN JOURNAL OF THEORETICAL AND APPLIED SCIENCE

https://cajotas.casjournal.org/index.php/cajotas
Volume: 07 Issue: 03 | July 2026 ISSN: 2660-5317

Article

Styding The Behavior of 10-Story Regularly Shaped Frame Buildings Under The Influences of Successive Collapse

Mohammed khalaf Jaddoa*[1]

1. Department of Sciences, College of Basic Education, Sharqat, Tikrit University, Iraq
*Correspondance: mohammed.k.jaddoa@tu.edu.iq

Abstract: Buildings may be exposed to sudden damage that we may think is small, but it may lead to the partial or complete collapse of the building. Through this research, a ten-story building was studied under the effects of the loss of a corner column and the loss of a side column due to vertical loads. Through this research, the mechanism of changing load paths and how loads are distributed on side columns, beams and other joints were identified, in addition to the concentration of damage and large loads on the lowest floor and the one closest to the point of column loss. All these conclusions can be reflected in the design process if they are taken into account to avoid such sudden collapses.

Keywords: 10-Story Regularly Shaped Frame, Vertical Load, Corner Column, Beside Column

Citation: Jaddoa, M. K. Styding The Behavior of 10-Story Regularly Shaped Frame Buildings Under The Influences of Successive Collapse. Central Asian Journal of Theoretical and Applied Science 2026, 7(3), 358-365.

Received: 30th Apr 2026
Revised: 25th May 2026
Accepted: 15th Jun 2026
Published: 30th Jun 2026

1. Introduction

Despite the remarkable scientific progress in recent times and the development of construction techniques and force analysis, construction and design processes still face many difficulties that may suddenly appear. For example, a gas cylinder explosion in one of the kitchens of a ten-story building next to a column could lead to the failure of this column and then its collapse, and the transfer of the load that it was receiving to the surrounding beams, which may be able to bear it and thus the building survives, or they may not be able to bear it and thus a total or partial collapse of the building occurs.

Structures face one of the most dangerous destructive structural phenomena: cascade failure. This occurs when structural elements fail sequentially, with the sudden loss of one element leading to a partial or total collapse of the building.[1] The most famous examples of this were the Ronan Point Tower in 1968 and the Alfred P. Murrah Federal Building in 1995.

Various structural systems suffer from this problem, especially frame structures, which require a surplus of rigidity and ductility to overcome the effects of such collapses. While these structures provide predictable load paths, they still need this surplus of rigidity. For instance, the sudden loss of a column can force a beam from its conventional mechanism to operate under extreme tension, but the supporting beam must be able to withstand such large loads.[2] This study will investigate the behavior of a ten-story frame building with a regular shape, examining the formation of plastic joints, the distribution of different loads, and the resulting findings.

Literature Review

Progressive collapse has received extensive and in-depth attention from structural engineering researchers over the past decades. Research efforts have ranged from advanced numerical analyses to laboratory tests to determine the dynamic and plastic behavior of framed buildings under sudden loss of load-bearing columns.

The first wave of research focused on identifying the most accurate and optimal analytical methodology for dynamically modeling this phenomenon. Marjanishvili and Agnew [3] conducted a critical comparative study of four major analytical procedures adopted by international guidelines (such as GSA and DoD): linear static analysis, nonlinear static analysis, linear dynamic analysis, and nonlinear dynamic analysis. Their results indicated that traditional static methods might underestimate the dynamic amplification factors for structures with greater plasticity and alternate load paths. However, these methods could also overestimate the dynamic amplification factors. On the other hand, Nonlinear dynamic analysis was found to be the most effective and accurate for the representation of inertial forces, damping, and the formation of plastic hinges.

Due to the advancements in structural computing algorithms, more focus has been attributed to the mechanisms and physical phenomena that offer resistance to the propagation of failure in concrete and steel frames. Al-Tawil et al. [4] investigated the cascade failure of reinforced concrete frames and described how the failure of a supporting column and subsequent large movements at the joint shift frame beams from their normal role of providing flexural resistance to that of catenary resistance. This study also acknowledged the importance of connection reinforcement detailing in the structure’s ability to resist high catenary tension forces, as stated by Izardinia et al. [5], that after the frame has attained the maximum ductility, the frame’s stability is influenced by the depth of the beams and the proportion of the longitudinal reinforcements.

Succinctly, the potentially interdependent nature of earthquake resistant design and a building's resistance to cascade failure is one of the hot research topics in the field. Farnoud et al. In [6] performance of multi-story frame buildings designed according the classical codes for resisting lateral load are evaluated. The study found that high ductility moment-resisting frames (MRFs) in reservations always provide alternative load paths due to the presence of a strength part and strong bonds between structural elements. This is very low probability of cascade failure in medium rise buildings (10 stories for example) Likewise, Kim and Kim researchers[7]

studied the dynamic performance of moment-resisting steel frames and demonstrated that frames designed to withstand high seismic intensity possess twice the resistance to successive failure compared to frames designed solely for vertical loads. This is attributed to their superior strength and high energy dissipation capacity.

Regarding the impact of the location of a removed column on the overall stability of the structure, research has shown that the loss of a corner column represents a more critical and dangerous scenario compared to an internal column. Fu [8] demonstrated, through three-dimensional nonlinear dynamic analysis, that the elements surrounding the corner column have less structural restraint, limiting their ability to activate tensile membrane forces and efficiently redistribute loads, thus accelerating the localized failure mechanism. Tsai and colleagues [9] further confirmed this finding through an experimental study that showed that the stiffness of the concrete slabs surrounding the interior columns effectively contributes to creating compressive membrane action in the early stages of settlement, something that corner columns lack due to the nature of their free edges.

Table 1. References

Researcher	Type of Analysis Used	Stories No	Results
Y. Bilal et al.[9]	(Nonlinear Static & Dynamic)	10	Removal of the corner column leads to a sharp drop and rapid formation of ductile joints, and dynamic analysis shows amplification coefficients that exceed the value suggested in the GSA code.
J. Kim & J. Yu[10]	(Nonlinear Dynamic)	10	Structures designed with normal ductility are highly susceptible to collapse when a corner column is lost, whereas frames with high ductility resist collapse efficiently by activating alternative load paths.
M. R. Esfahani et al[11]	(Pushover / Alternative Path)	8	Continuous overhead beam reinforcement plays a crucial role in activating catenary action, which prevents total collapse in mid-rise buildings.
H. R. Tavakoli et a[12]	(Time-History / Column Loss)	10	Nonlinear geometry (P-\Delta) effects increase dynamic slump values by 15% to 22% when columns are removed in the lower floors of 10-story buildings.
N. F. Al-Sharafi et al.[13], [14]	(Macro-modeling Nonlinear)	11	The presence of hollow core slabs or solid slabs designed with good rigidity contributes to reducing the probability of successive collapse by up to 30% thanks to membrane compressive forces (CMA).

Research Objective

To study and understand how a 10-story, uniformly framed building behaves upon the sudden loss of one of its main columns, and to determine the building's ability to redistribute loads to prevent a total collaps.

2. Materials and Methods

To achieve the research objective, a ten-story model of a regular-shaped reinforced concrete frame was constructed and subjected to dead and live loads [15]. This model was then modeled using ETABS software. The loads were modeled, and the column removal process was initiated. Two cases were studied: the first involved the loss of a corner column on the ground floor, and the second involved the loss of a lateral column on the ground floor. The distribution of lateral loads among the remaining elements was then measured to determine their susceptibility to collapse due to the loss process.

The concrete is of type C30. The spans are 5 meters on each side, with four column openings measuring 50 cm square, 30 x 60 cm drop beams, and a 25 cm thick hollow core slab.

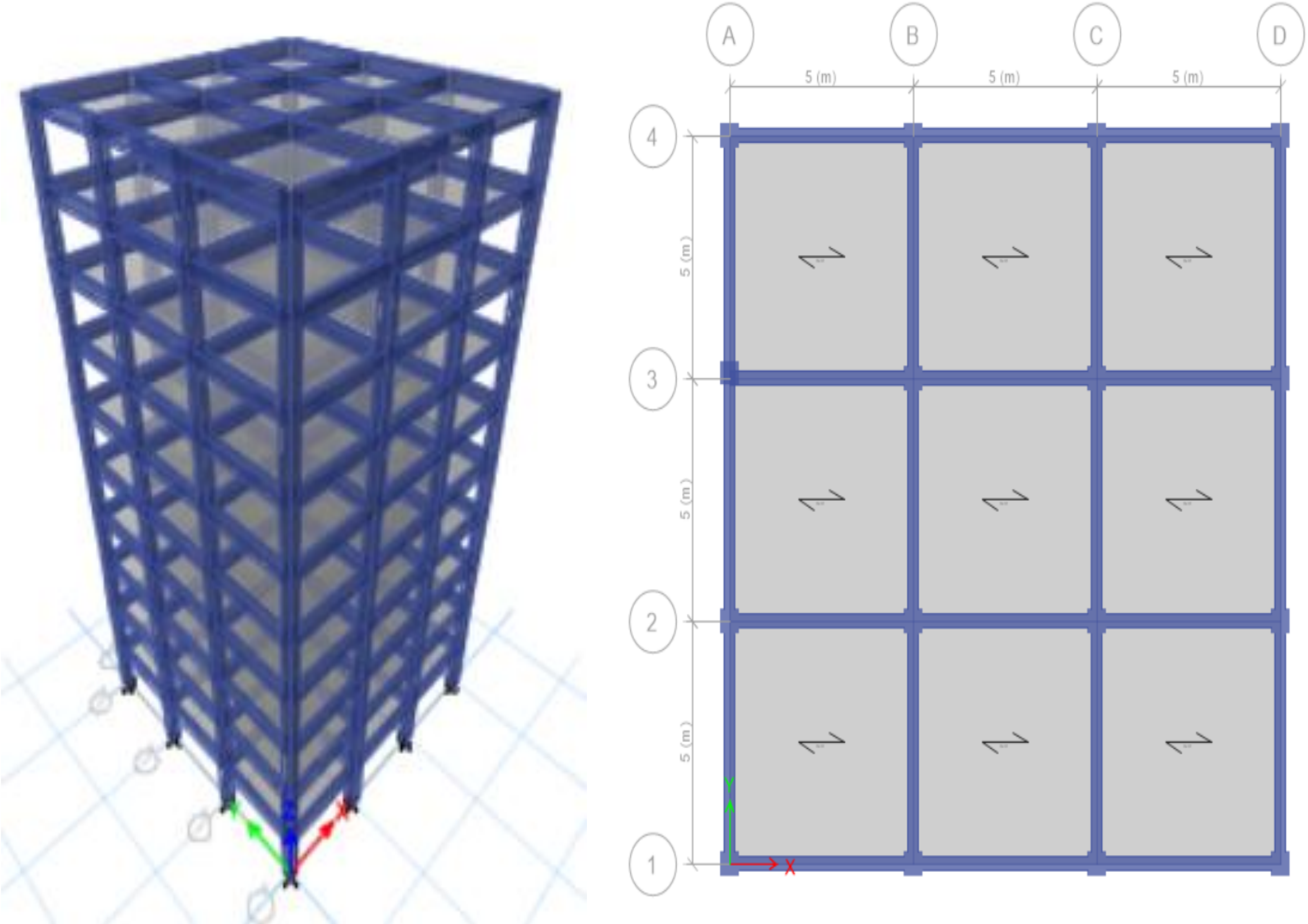


Figure 1. Model

3. Results and Discussion

The model was built and subjected to dead and live loads, and then the building was tested for the condition of column loss and the building remaining under the influence of dead and live loads. We will review the results obtained first through internal forces. We now have three cases, which are as follows: The first case is the building under the influence of dead and live loads, the second case is the building under the influence of dead and live loads and loss of the corner column, the third case is the building under the influence of dead and live loads and loss of the side column. We will review how the internal forces change through these cases.

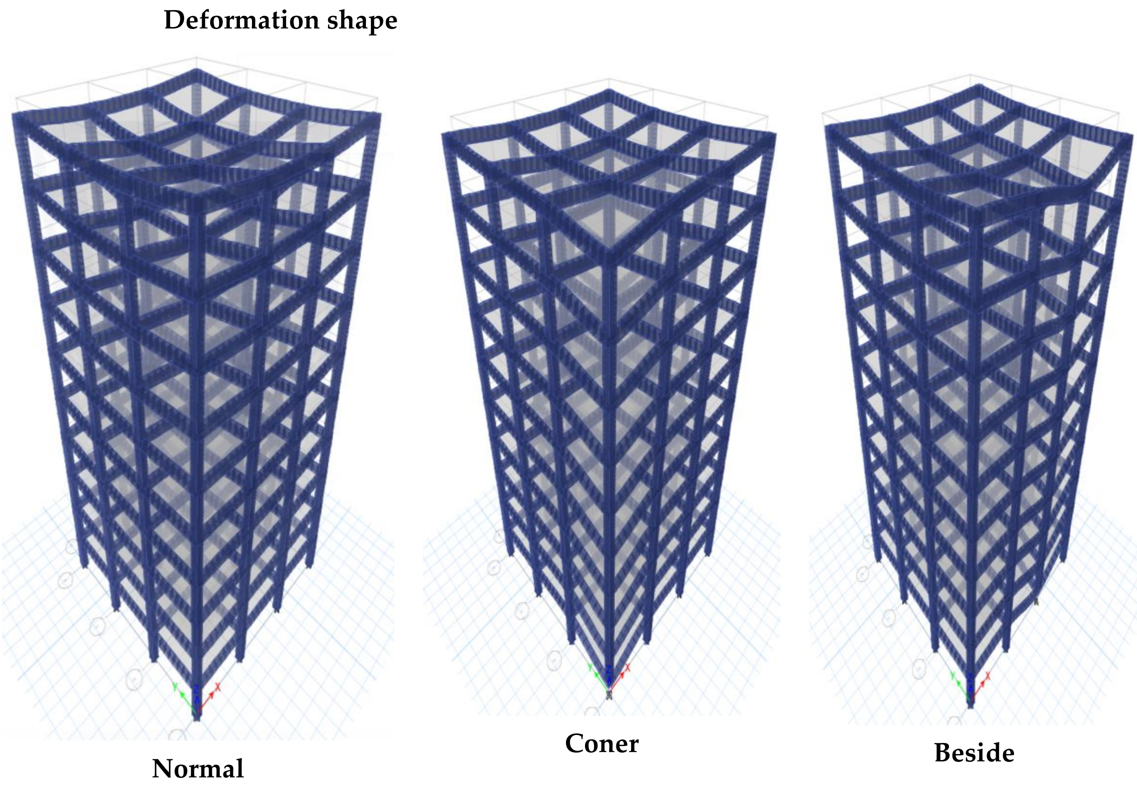
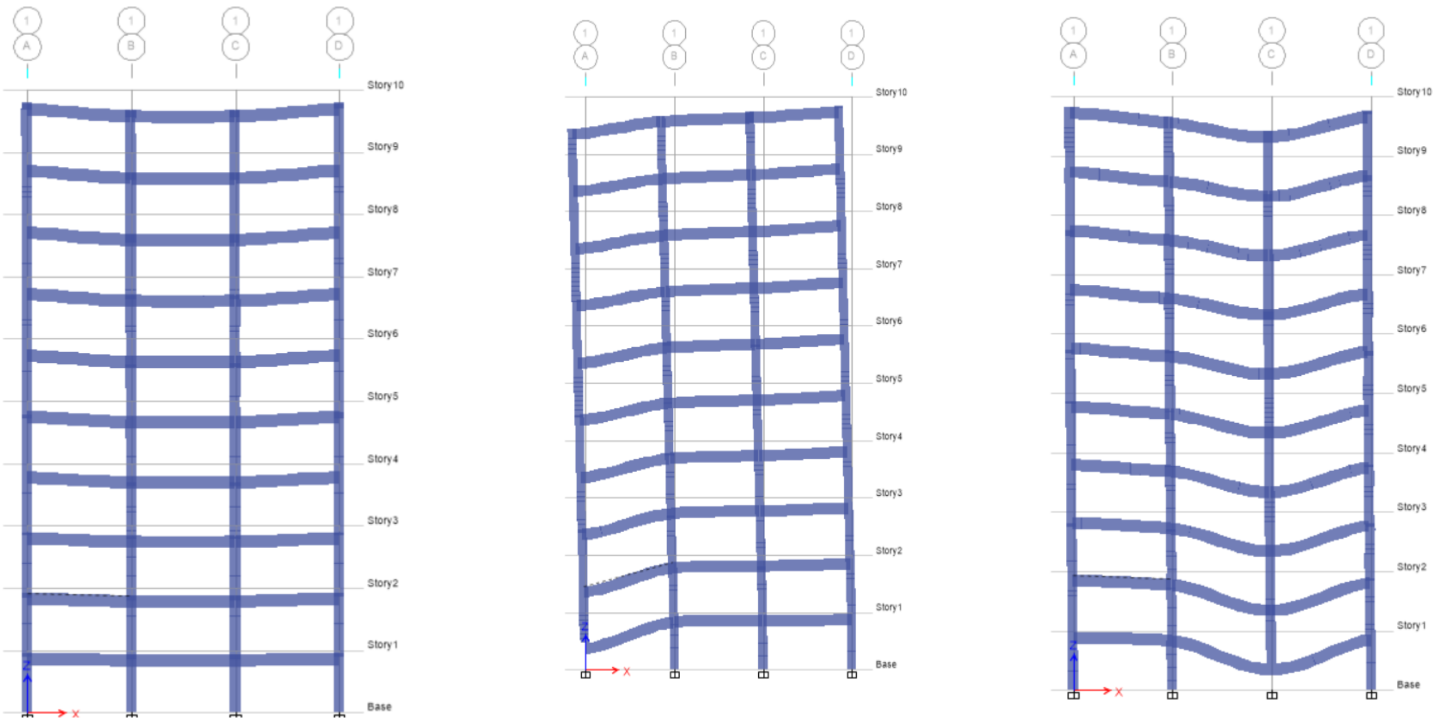


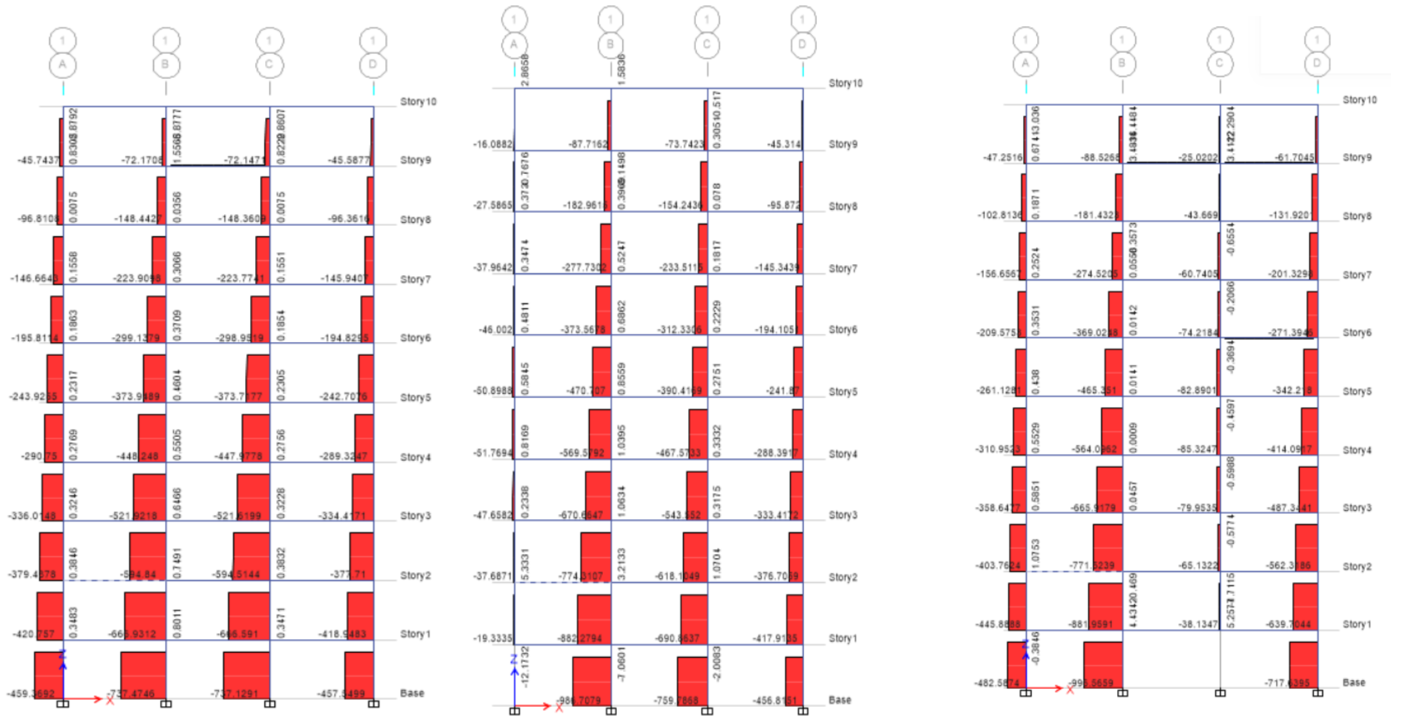
Figure 2. Deformed shape

From the previous figures, we observe that in the normal state, the deformation mechanism is natural and consistent with the expected deformation patterns and load paths, transferring correctly from slabs to beams to columns. However, in the case of a missing corner column, we observe how its loss acts as a tension mechanism for the other elements towards that corner. This is reflected in the share of the transferred forces for each element. The tension is concentrated in the two beams connecting the column, i.e., on two faces and at the height of the building, but its intensity decreases in the upper floors. As for the case of a missing lateral column, we observe that, by the same mechanism, the column's loss leads to its transformation from a load-bearing element to a loaded element, pulling the other elements downwards. This is reflected in the elements connected to it, thus reversing the forces they bear.



Normal Corner Beside

Figure 3. Deformed shape



Normal Corner Beside

Figure 4. Deformed shape

We can see from the figure that in the case of the angle column, most of the load is distributed on the adjacent column, while in the case of the lateral column it is distributed on both sides.

4. Conclusion

After analyzing the impact of removing one or more columns on a typical 10-story building, the following can be summarized:

Changes in Load Redistribution: Research shows that removing a column from the ground floor results in a significant change in the internal force distribution. Specifically, the beams that were connected to the removed column change from their normal curvature to a suspension position, pulling the upper beams downwards to close the structural gaps.

The Critical Importance of Removing a Corner Column: Removing a corner column presents the least acceptable and most dangerous scenario for the safety of a 10-story building. Due to the lack of structural continuity and the reduced building boundary constraints, the remaining corner frame subsystems will exceed their capacity. This will lead to increased avenues for deformation and the rapid failure of the single remaining column.

Resistance to Removing a Side Column: Removing a side frame column or an internal column (between beams) demonstrates a high degree of structural integrity. In this configuration, the frame on either side of the side column is able to support the weights of the top ten stories in two main directions instead of one, thus reducing the impact of a sudden vertical displacement in one of the wings. As height increases, damage becomes increasingly concentrated on the lower levels of the building, especially the lowest levels adjacent to the damage, with the level of damage gradually decreasing as one progresses towards the upper levels of the building.

REFERENCES

[1] M. Marjanishvili and S. Agnew, "Comparison of Various Procedures for Progressive Collapse Analysis," Journal of Performance of Constructed Facilities, vol. 20, no. 4, pp. 365–374, Nov. 2006.

[2] S. El-Tawil, H. Li, and S. Kunnath, "Computational Simulation of Progressive Collapse in Reinforced Concrete Frame Structures," ACI Structural Journal, vol. 111, no. 1, pp. 91–100, Jan. 2014.

[3] M. Marjanishvili and S. Agnew, "Comparison of Various Procedures for Progressive Collapse Analysis," Journal of Performance of Constructed Facilities, vol. 20, no. 4, pp. 365–374, Nov. 2006.

[4] S. El-Tawil, H. Li, and S. Kunnath, "Computational Simulation of Progressive Collapse in Reinforced Concrete Frame Structures," ACI Structural Journal, vol. 111, no. 1, pp. 91–100, Jan. 2014.

[5] M. Ezaddine, O. R. Abu-Hayah, and M. Z. Naser, "Parameters Influencing Catenary Action in Reinforced Concrete Frames Under Column Removal Scenarios," Structures, vol. 32, pp. 1405–1418, Aug. 2021.

[6] F. Farnood, R. S. S. Al-Amiri, and A. J. M. S. Al-Ghabra, "Evaluation of Progressive Collapse Resistance of Multi-Story Steel Frame Buildings Designed to Modern Codes," IEEE Access, vol. 9, pp. 112450–112463, Aug. 2021.

[7] J. Kim and T. Kim, "Assessment of Progressive Collapse-Resisting Capacity of Steel Moment Frames," Journal of Constructional Steel Research, vol. 65, no. 1, pp. 169–179, Jan. 2009.

[8] F. Fu, "3D Nonlinear Dynamic Analysis of Computer-Aided Progressive Collapse Performance of Steel Composite Frame Buildings," Journal of Constructional Steel Research, vol. 65, no. 6, pp. 1260–1268, Jun. 2009.

[9] S. B. Tsai, B. R. Lin, and C. H. Huang, "Experimental and Numerical Study on the Mitigation of Progressive Collapse of RC Frame-Slab Substructures," Engineering Structures, vol. 180, pp. 412–427, Feb. 2019.

[10] Y. Bilal, M. N. S. Anwar, and A. Shah, "Nonlinear Static and Dynamic Analysis of 10-Story Reinforced Concrete Buildings for Progressive Collapse Independent of Code DAF," Structures, vol. 41, pp. 885–899, Jul. 2022.

[11] J. Kim and J. Yu, "Progressive Collapse Evaluation of 10-Story Steel Moment Frames with Different Ductility Level Connections," Engineering Structures, vol. 34, no. 5, pp. 1320–1331, May 2012.

[12] M. R. Esfahani, H. R. Ronagh, and A. B. Shayanfar, "Alternative Path Assessment of an 8-Story RC Frame Structure Against Progressive Collapse," Structures and Buildings, vol. 171, no. 3, pp. 211–224, Mar. 2018.

[13] H. R. Tavakoli, A. Rashidi, and M. Kiakojouri, "Dynamic Response of 10-Story Steel Moment Frame Buildings Under Sudden Column Removal Scenarios Considering P-Delta Effects," International Journal of Civil Engineering, vol. 19, no. 8, pp. 915–928, Aug. 2021.

[14] N. F. Al-Sharafi, M. H. Lai, and J. C. M. Ho, "Evaluation of Compressive Membrane Action in 11-Story Reinforced Concrete Buildings Facing Progressive Collapse," Journal of Building Engineering, vol. 45, p. 103422, Jan. 2022.

[15] J. K. Kim and C. S. Lee, "Time-dependent analysis of RC frame structures considering construction sequences," Building and Environment, vol. 41, no. 10, pp. 1423–1434, 2006.