Analysis and Design of RC Building by Considering the Progressive Collapse

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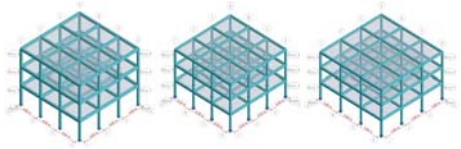
Abstract

Several accidents of building collapse around the world happened due to abnormal loads such as earthquakes, vehicle collisions, and any explosion due to any civilian reason that cause a column failure. 3-story RC buildings with different span lengths were analyzed. The same buildings were analyzed after removing the interior, exterior, and corner columns. After that, the effect of column removal on the bending moment, shear force, and axial force are presented in terms of factors. It is found that a critical case of column removal is exterior column removal. After finding the data before and after columns removal for the different cases from Robot Structural Analysis software, the data was plotted using the Excel software. Then from the graphs, the simple equations were developed to determine the increase in bending moment, shear force, and axial force for both beams and columns. Finally, these three different buildings are designed to satisfy the code safety requirement.

Problem Statement

This project will present the analysis and design of three different reinforced concrete buildings with a different dimension by using Robot Structure Analysis Program, also will provide the effect of the progressive collapse phenomena to the three buildings, therefore the results before and after the removal of columns will be discussed.



4m span building 4.5m span building 5m span building

Objectives

❖ Analysis of the reinforced concrete structure by Autodesk Robot Structural Analysis.

❖ Design the reinforced concrete building by Autodesk Robot Structural Analysis.

❖ Applying the different cases of the column removal and select the critical results.

❖ Discuss the results of the column after removal cases.

❖ Develop equation to determine the increase of the bending moment, shear force, axial force after different column removal cases (exterior, interior, and interior).

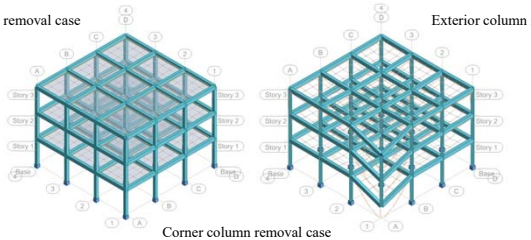
Buildings Information

Building Information	
Beam	400x300 mm
Column	300x300 mm
Concrete Strength	25 MPa
Steel strength	420 Mpa
Dead Load	8 kN/m² Floor , 4 kN/m² Roof
Wall Load	14.82 kN/m Floor
Live Load	1.92 kN/m² Floor , 1.5 kN/m² Roof
Slab thickness	120 mm (shell)
Story height	3 m

Methodology

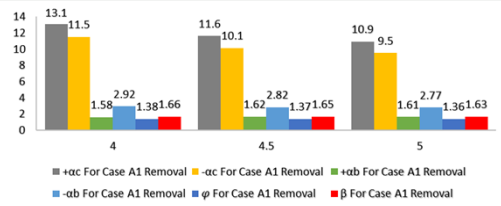
Robot Structural Analysis Professional is design and analysis software that gives an engineer with advanced Building Information Modeling (BIM)- integrated skills in design and analysis to assist you in construction process. It is verifying code compliance. Given that this project involves a three-story residential building, the robot was chosen for it. The different columns removal cases (interior, exterior, and corner) were applied to the three buildings as shown below.

Interior column removal case Exterior column removal case

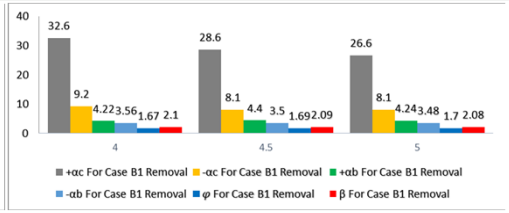


Corner column removal case

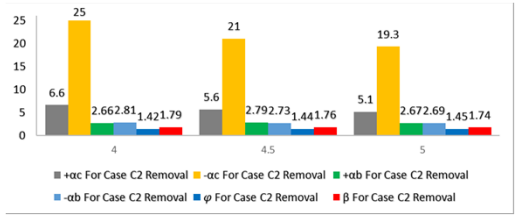
Results



Bending moment, Shear force, and Axial force factors after corner column removal.



Bending moment, Shear force and Axial force factors after exterior column removal.



Bending moment, Shear force, and Axial force factors after interior column removal.

$$\alpha_c \text{ and } \alpha_b = \frac{\text{Bending moment after removal}}{\text{Bending moment before removal}}$$

$$\beta_b = \frac{\text{Shear force after removal}}{\text{Shear force before removal}}$$

$$\varphi_c = \frac{\text{Axial force after removal}}{\text{Axial force before removal}}$$

Where:

α_c : Bending moment factor for column.

α_b : Bending moment factor for beam.

φ_c : Axial force factor for column.

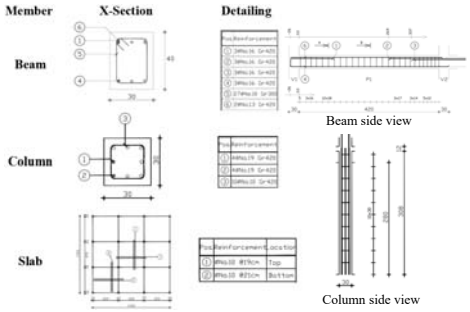
β_b : Shear force factor for beam.

The most critical case is the exterior column (B1) removal case

Equations for Bending Moment Factors		
Case A1 (Corner) Column Removal		
Column A-2	Positive moment $\alpha_c = 1.6x^2 - 16.6x + 53.9$	Negative moment $\alpha_c = 1.6x^2 - 16.4x + 51.5$
Beam A-1-2	Positive moment $\alpha_b = -0.1x^2 + 0.93x - 0.54$	Negative moment $\alpha_b = 0.1x^2 - 1.05x + 5.52$
Case B1 (Exterior) Column Removal		
Column C-1	Positive moment $\alpha_c = 4x^2 - 42x + 136.6$	Negative moment $\alpha_c = 2.2x^2 - 20.9x + 57.6$
Beam B-C-1	Positive moment $\alpha_b = -0.68x^2 + 6.14x - 9.46$	Negative moment $\alpha_b = 0.08x^2 - 0.8x + 5.48$
Case C2 (Interior) Column Removal		
Column B-2	Positive moment $\alpha_c = x^2 - 10.5x + 32.6$	Negative moment $\alpha_c = 4.6x^2 - 47.1x + 139.8$
Beam C-2-3	Positive moment $\alpha_b = -0.5x^2 + 4.51x - 7.38$	Negative moment $\alpha_b = 0.08x^2 - 0.84x + 4.89$
Where: x is span length before column removal		

Equations for Axial and Shear Force Factors	
Case A1 (Corner) Column Removal	
Column A-2	$\varphi_c = 1.4193x^{-0.023}$
Beam A-1-2	$\beta_b = 1.7997x^{-0.06}$
Case B1 (Exterior) Column Removal	
Column C-1	$\varphi_c = 1.5437x^{0.0587}$
Beam B-C-1	$\beta_b = 2.2341x^{-0.045}$
Case C2 (Interior) Column Removal	
Column B-2	$\varphi_c = 1.2462x^{0.094}$
Beam C-2-3	$\beta_b = 2.1024x^{-0.118}$
Where: x is span length before column removal	

Design



Conclusion

❖ After analysis, it was found that the critical case of column removal is the exterior column removal for all three buildings.

❖ After finding the data before and after column removal for the different cases from Robot Structural Analysis software, the data was plotted and the simple equations were developed using the trendline approach to determine the increase in bending moment, shear force, and axial force for both beams and columns.

❖ Reinforcement of the three different buildings is designed to satisfy the code safety requirement. The building with a 5m span length requires more reinforcement because the load and the span length have a direct relationship. The reinforcement in columns for the buildings with (4m, and 4.5m) span lengths is increased to satisfy the ACI minimum steel ratio requirement.