NUMERICAL SIMULATION OF PROGRESSIVE COLLAPSE OF STRUCTURES UNDER BLAST LOADS

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The growing need for blast-resistant designs in structural engineering is driven by the rising threat of terrorism, accidental explosions, and the significant risk of progressive collapse. This study presents a numerical procedure for analyzing the progressive collapse of Reinforced Concrete (RC) framed structures due to blast loads, addressing the gap in current methodologies. Traditional approaches such as the Alternate Load Path method, which are code-based and threat-independent, mainly focus on sudden column loss scenarios but do not fully capture the dynamic nature of blast-induced, threat-dependent collapses. Hence this study addresses the need for a computationally efficient and reliable method to predict and model progressive collapse under blast loading. This study employs a comprehensive numerical investigation using Finite Element Method where a seven-storeyed RC building is assessed for progressive collapse under blast loading. Progressive collapse analysis was executed using a commercially available Finite Element Analysis software, adhering to the Linear Static Procedure specified in the General Services Administration (GSA) guidelines, while blast load scenarios were examined through a nonlinear direct integration time history analysis. Different blast parameters, including charge weight and standoff distances, are varied to evaluate their impact on the structural integrity of the building. The study differentiates between threat-independent analysis, considering four column removal locations, and threat-dependent (blast-induced) scenarios with three distinct column removal positions. The scope of this study delves only into the perimeter blast scenarios neglecting the internal explosions. Demand Capacity Ratios (DCR) of columns were calculated to determine the susceptibility of the building to progressive collapse, with a DCR greater than 1 indicating failure. The numerical model was validated against the GSA baseline model. In threat-independent analysis, 30%, 60%, 22%, and 44% of the considered columns under corner, long side, short side, and interior column removal scenarios respectively exceeded the acceptable DCR criteria. In threat-dependent analysis, 100% of the considered columns under each blast induced column removal scenario exceeded the acceptable DCR criteria. This emphasizes the need for scenario-based planning in structural design to reduce collapse risks. The identification of critical columns, for threat-independent analysis as those directly above the removed column and on the topmost floor and for threat-dependent analysis as ground floor columns adjacent to the removed column, reveals potential weak points for progressive collapse initiation. The analysis of blast-induced progressive collapse reveals significantly higher DCR values than threat-independent assessments. Even the minimum percentage increases of DCRs when transitioning from threat-independent to threat-dependent analysis reaches high values up to 995%, 325%, and 981% for corner, long side, and short side column removal scenarios respectively. This specifies the importance of integrating blast resistance into the structural design of high-risk buildings. As a result, this study contributes to the understanding of structural dynamics under blast loads and offers a framework for the analysis of progressive collapse in RC buildings.

Keywords: Alternate load path method, Demand capacity ratio, Progressive collapse, Threat-dependent, Threat-independent

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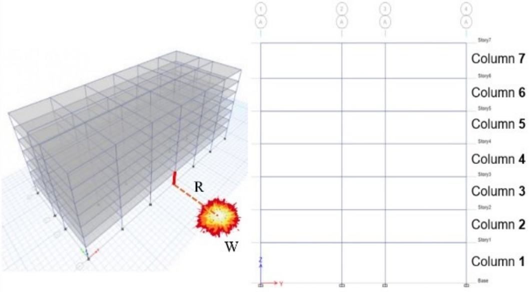
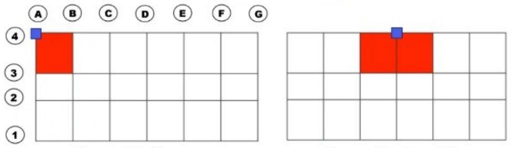
METHODOLOGY

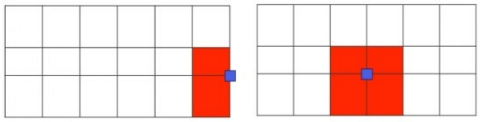


7 storeyed RC building



Removal 1 – Corner Column Condition

Removal 2 – Long Side Column Condition



Removal 3 – Short Side Column Condition

Removal 4 – Interior Column Condition

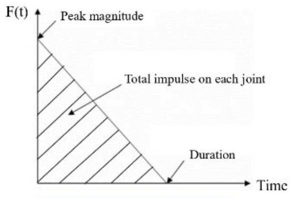
G_{LF} applied to the shaded area

G applied to the rest of the structure (unshaded area)

$$\boxed{G_{LF} = \Omega_{LF}\,[1.2\,D + 0.5\,L]} \Rightarrow \Omega_{LF} = 2$$

$$\boxed{G = 1.2D + 0.5L}$$

Gravity load assignment after column removal

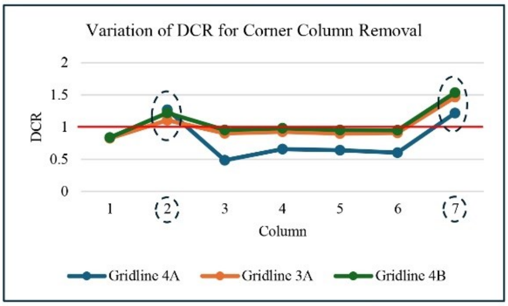


Blast loading function

RESULTS

Demand Capacity Ratio (DCR)

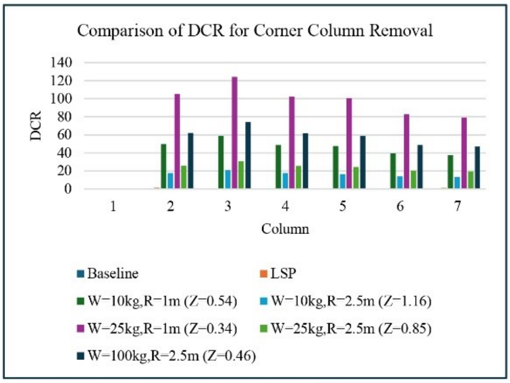
THREAT-INDEPENDENT



***for all 4 scenarios**

THREAT-DEPENDENT (BLAST INDUCED)

BLAST LOAD PARAMETERS	
Type of blast	Surface blast
Explosive yield (W)	TNT equivalent 10 kg, 25 kg, 100 kg 
Standoff distance (R)	1 m, 2.5 m



***only for perimeter blasts**

CONCLUSIONS

OBSERVATION	THREAT-INDEPENDENT	THREAT-DEPENDENT	CONCLUSION
DCR > 1 (Acceptance criteria)	**30%, 60%, 22%, and 44% of the considered columns under corner, long side, short side, and interior column removal scenarios**	**100% of the considered columns**	**Need for scenario-based planning in structural design to reduce collapse risks**
Critical columns	**Directly above the removed column and on the topmost floor**	**Ground floor columns adjacent to the removed column**	**Potential weak points for progressive collapse initiation**