

BEHAVIOUR OF REINFORCED CONCRETE STRUCTURE SUBJECTED TO BLAST LOADS

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Abstract

Frequent unintentional explosions in industrial facilities and deliberate demolition of commercial buildings have resulted in significant financial damages, leading to increased demands on structural engineers to enhance blast resistance design methods. Therefore, comprehending the impact of blasts on structure performance is crucial. The study examined how a standard 21-storey reinforced concrete building structure responded to blast loads from TNT explosives of varying charge weights (100, 300, and 500 kg) at different standoff distances (10, 20, and 30 m). The research focused on the effects of structural walls at the core as well as peripheral infill walls. Using a three-dimensional finite element approach with nonlinear dynamic analysis via SAP2000 software based on Indian Standard specifications (IS:4991, 1968), key response parameters such as acceleration, displacements, and velocities were analyzed over time. It was observed that acceleration and velocity reached peak values earlier than displacement. The building's blast resistance with structural walls was deemed satisfactory; furthermore, it improved with the installation of infill walls.

Keywords: Blast load, dynamic response, impulse load, SAP2000, tall building, time history

Introduction

Recent events have suggested that terrorists are more likely to target taller buildings, prompting structural engineers to re-focus on designing and constructing high-rise buildings with an emphasis on life safety in the event of an explosion. The primary causes of injury to people in these situations are the pressures and heat from the explosion. Following an explosion, casualties often result from falling debris, shattered windows, and potential partial or complete building collapse. Therefore,

it is essential for structural engineers to assess how structures behave when exposed to explosive forces. Enhancing a building's resistance to blasts can help save lives up to a certain degree - where structural elements should withstand minor blasts without failure and sustain moderate damage in case of moderate blasts. In major blast scenarios, efforts are made to minimize sudden structure collapses as much as possible.

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The blast pressure's strength is also impacted by the structure and its elements' geometry. Curved structures like domes, choirs, and columns reflect the blast wave, while columns and piers diffract it. Re-entrant building corners are particularly susceptible to diffraction effects that extend the air blast duration (Remennikov and Carolan, 2015; Shirbhate and Goel, 2020). In a study conducted by Luccioni *et al.* (2004) an analysis of a reinforced concrete building's structural failure due to a blast load found that numerical simulation effectively replicated the collapse under the blast load, with gravitational mechanisms leading to lower column degradation as a primary cause for the collapse revealed through photographic evidence.

The displacement variation differs throughout the height of the building and is distinct for earthquakes and wind. When subjected to blast load, the building does not exhibit behavior characteristic of a cantilever structure. The extent of damage to structural elements depends on unabsorbed residual energy. While structural designs meant to resist lateral loads like wind or earthquakes may yield satisfactory results, they may not be adequate in withstanding blast attacks involving large explosive charges at close distances (Drakatos and Dritsos, 2014; Ibrahim and Nabil, 2019). Jayatilake *et al.* (2010) suggested a response for tall buildings with symmetric setbacks under blast loading; their conclusion highlighted those structures with setbacks offering protection from blast loading showed better performance in terms of peak displacement, acceleration levels and inter-story drift compared to structures without such setback features. Ngo *et al.* (2007) delved into investigating blast loading and its impacts on buildings using empirical methodologies including formulae analysis as well as explosion visuals alongside numerical examples solved through computer programs specifically designed for analyzing blast effects.

The research involves practical methods, equations, explosion simulations, analysis, computer programs to assess blast effects and numerical illustrations solved using computer software. Coffield and Adeli (2014) examined the effectiveness of three bracing methods for seismic steel frame structures under blast loading and concluded that braced frames offer higher resistance to blast forces with fewer instances of plastic hinge formation compared to MRF. Taha *et al.* (2021) explored the impact of blast waves on entire structures with varying wall thicknesses and observed that increasing wall thickness decreases deflection. The presence of an air gap between walls negatively affects deflection and impulse by significantly increasing them; however, incorporating aluminium foam as a filler reduces both deflection and impulse.

The numerical model has demonstrated reliability for unreinforced walls due to the acceptable approximation between experimental data and numerical results while also showing good agreement in failure patterns with field testing.

Blast Phenomena

Blasting involves the use of explosive materials, which can be detonated rapidly or deflagrated slowly. The resulting blast produces pressure waves that propagate as a function of time. Due to its brief duration in milliseconds compared to the natural period of structures, it falls under an impulse problem (Shirbhate and Goel, 2020; Zhao *et al.*, 2020). Structures affected by blast loads present explicit dynamic challenges. Blast load is equivalent to an impulsive dynamic load or pressure and resembles a ground motion time-history record.

A significant amount of energy is released during a blasting or explosion event. Some of this energy takes the form of thermal radiation, and the remaining energy is released as high-pressure waves that move outward, shock up, and eventually combine the effects of ground shock and air blast to create a blast wave. A blast phenomenon is the mechanism by which a blast wave forms following an explosive occurrence. The principal effect is airblast, which is the main source of damage mechanism; drag load and dynamic pressure are considered secondary effects.

The blast load, as an explicit dynamic concept, is influenced by various parameters. These include features of the blast wave, blast-structure interaction, Mach stem phenomenon, method of decomposition, types of explosions, types of explosives, TNT equivalence, standoff distance, and scaling law. Blastwave characteristics can be delineated in two phases: an initial positive phase followed by a negative phase (Figure 1). Prior to the explosion event, the structure experiences a uniform ambient pressure (P_0). Upon the initiation of an explosive charge (at $t = 0$), a shock wave rapidly

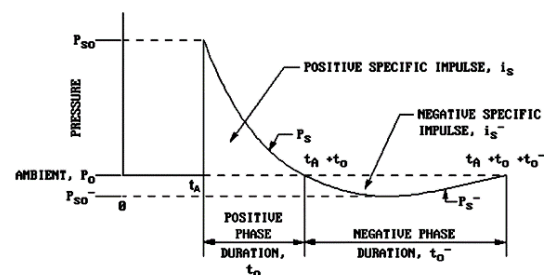


Figure 1. Typical blast wave profile

reaches the target surface of the structure within milliseconds (t_A), instantly elevating the ambient pressure on the surface to an amplified over-pressure (P_{SO}).

The amplified over-pressure undergoes a rapid decay over a brief duration (t_o), returning to ambient pressure at $t = t_A + t_o$, marking the completion of the positive phase of the blast load. Throughout the positive phase, the shock wave interacts with the structure, transferring a significant amount of released energy, and leading to anticipated bending, spalling, and cracking scenarios. Following the conclusion of the positive phase, the pressure-time curve continues its descent, falling below ambient pressure to reach the negative peak over-pressure (P_{SO-}). The negative phase concludes when the over-pressure returns to ambient pressure at $t = t_A + t_o + t_{o-}$. During this negative phase, vacuum or suction forces emerge, resulting in drag pressure and the extraction of debris fragments from the explosion source. Examining the pressure-time-history graph illustrated in Figure 1 (Sevim and Toy, 2020), it is evident that the over-pressure is highest during the positive phase ($P_O > P_{SO-}$), and the negative phase persists for a longer duration than the positive phase ($t_{o-} > t_o$).

Utilizing the blast wave relations and profiles for analysis and design purposes entails intricate calculations. Therefore, many proposed methodologies and standards have opted for simplifying the positive phase of the blast wave. This involves idealizing it as a straight line that starts at the maximum pressure value and decreases to zero at the conclusion of the positive phase duration. This approach ensures that the impulse value remains constant, resulting in a triangular profile for the pressure-time history of the blast wave, as depicted in Figure 2. The idealization to a triangular profile streamlines the analysis and design process. The complexity of determining blast load pressure is compounded by the nature of the detonation, explosion, and explosive involved, rooted in various scientific disciplines such as chemical, mechanical, electrical, or nuclear science. Parameters like TNT equivalence, standoff distance, and scaling laws help alleviate this complexity by establishing connections between an explosion and reference or standard explosions (Jeremić *et al.*, 2006; Shirbhatte and Goel, 2020).

The determination of blast loads is significantly influenced by two key variables: standoff distance and TNT equivalent. The energy released in an explosion is primarily contingent upon the detonated explosive's energy output, a factor that varies based on the distance between the source and the target. Standoff distance refers to the unobstructed and direct distance between

the target structure's surface and the midpoint of the explosive charge. Notably, blast over-pressure intensity is inversely proportional to standoff distance. This parameter holds economic importance in blast mitigation strategies, as a larger standoff distance reduces blast over-pressure intensity, making the design of blast-resistant barriers or structures more cost-effective.

The complexity of determining energy output arises from the diverse characteristics of available explosives and relevant theories. However, establishing a reference explosion benchmark with well-known explosives simplifies this process. Trinitrotoluene (TNT) is often employed as the standard explosive in numerous studies and research due to its widespread use in military, mining, and industrial applications. The extensive experimental data available on TNT's blast characteristics facilitates the assessment of other explosives. The TNT equivalent serves as a conversion factor; when multiplied by the mass-specific energy of TNT, it represents the corresponding mass-specific energy of the considered explosive.

Blast scaling laws involve assessing the over-pressure effects resulting from the detonation of various TNT or TNT equivalent charge weights at different standoff distances, all within identical ambient conditions. The underlying principle of these scaling laws suggests that the blast effect generated by the detonation of smaller charge weights at a closer standoff distance will be equivalent to the effect produced by larger explosive charge weights at a greater standoff distance. In essence, the scaling laws establish a proportional relationship, indicating that certain combinations of charge weight and standoff distance will yield comparable blast effects despite variations in these parameters.

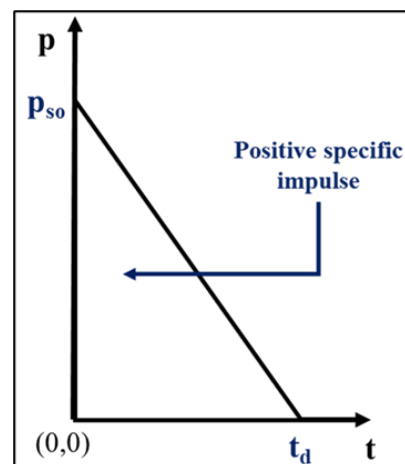


Figure 2. Idealized blast wave profile

Blast Structure Interaction

When a blast wave encounters a structure or any obstacle, it undergoes several phases of interaction, including reflection, rarefaction, and diffraction. Each of these phases contributes to the complex behaviour of the blast wave as it interacts with the surrounding environment and structures:

Reflection

It is a crucial phenomenon as it contributes to an increase in blast pressure intensity. This increase occurs due to the interaction between the reflected wave and the incident wave. Reflection can be classified into two types: regular reflection and Mach reflection, based on the angle of incidence. In regular reflection, the angle of incidence is zero. In this scenario, both waves reflected and incident are distinct and separate. The reflected wave travels away from the surface at the same angle as the incident wave. Regular reflection is a common occurrence when the blast wave encounters a surface. Mach reflection is a specific type of reflection that occurs at higher blast pressures and velocities. It is characterized by a distinctive “Mach stem” pattern. Unlike regular reflection, in Mach reflection, the angle of incidence is not zero. The reflected wave interacts with the incident wave to form a complex pattern that includes a Mach stem a region of increased pressure and intensity. Mach reflection is a more complex phenomenon and is typically observed under certain conditions, especially when the blast wave encounters obstacles or structures with specific geometries.

Understanding these reflection patterns is essential in predicting the behaviour of blast waves and designing structures to withstand or redirect their effects. Engineers use this knowledge to enhance blast-resistant design strategies and improve the safety of structures in blast-prone environments.

Diffraction

In certain scenarios, rapid changes in boundary conditions and the geometry of a structure can lead to a phenomenon where the incident blast wave passes over the object. As a result, the wave energy spreads around the structure through a process known as diffraction. Diffraction involves the bending or spreading of the blast wave around obstacles or through openings, and it occurs in a direction perpendicular to the propagation of the incident wave.

During diffraction, the blast wave encounters edges, corners, or openings in the structure, causing

the wave to change direction and spread. This process can lead to a reduction in the blast overpressure intensity in the immediate vicinity of the structure. Essentially, diffraction contributes to the redistribution of blast energy, mitigating the impact on the structure itself and the surrounding area.

Understanding the effects of diffraction is important in blast-resistant design, as engineers seek to optimize the structure's geometry and features to effectively utilize diffraction as a protective mechanism. By strategically designing structures to facilitate diffraction, it becomes possible to reduce the intensity of blast effects in specific areas, enhancing the overall safety and resilience of the built environment in blast-prone settings.

Rarefaction

At the free edges of a reflecting surface, where a blast wave encounters an obstacle or structure, the discontinuity between the forward-moving incident wave and the backward-moving reflected wave can lead to a phenomenon known as rarefaction. Rarefaction refers to the reduction in pressure below atmospheric levels, resulting in a decrease in the density of the medium through which the blast wave is propagating.

In the context of a blast event, rarefaction occurs as a consequence of the interaction between the incident and reflected waves. The positive pressure of the reflected wave is relieved at the free edges due to the discontinuity in wave patterns. The time taken for this relief process is referred to as the clearance time.

The significance of rarefaction and its impact on blast loads depend on the relationship between the clearance time and the duration of the positive phase of the blast wave. If the clearance time is longer than the duration of the positive phase, the rarefaction process can effectively relieve the positive pressure, and it may not significantly affect the blast loads. However, if the clearance time is shorter than the positive phase duration, rarefaction could contribute to the overall blast wave characteristics, influencing the pressure distribution and dynamic response of structures.

Understanding rarefaction is essential in blast-resistant design, as engineers consider these factors when designing structures to withstand blast events and optimize safety measures in blast-prone environments.

Materials and Methods

The primary aim of this study is to assess the response of a standard 21-storey building (G+20)

to blast-induced forces, considering the dynamic effects of the blast at varying magnitudes. The study specifically investigates the impact on structural performance, noting improvements when structural enhancements are implemented. These enhancements include the addition of a structural wall at the core, as well as infill walls at the periphery.

Furthermore, the study incorporates an analysis of the structure's response with a flexible base, incorporating the influence of soil-structure interaction. The objective is to gain insights into how these structural modifications and dynamic considerations contribute to the building's ability to withstand and respond to blast forces.

Structural Specifications of the Building

The subject of investigation in this study is a 21-storey reinforced concrete commercial building, each storey having a height of 3.6 m and a floor plan dimension of 30 m by 30 m, as illustrated in Figure 3. The structural elements are designed with specific dimensions: beams have a cross-section of 300 mm by 600 mm, columns have a cross-section of 600 mm by 600 mm, and slabs are 150 mm thick. Shear walls and infill walls have a thickness of 300 mm. Following the exposure conditions outlined in IS:456 (2000), different concrete grades (M40, M35, and M30) are assigned to various structural members, corresponding to compressive strengths of 40, 35, and 30 MPa, respectively. The Young's modulus of elasticity adheres to IS:456 (2000) standards, while the unit weight and Poisson's ratios for concrete are set at 25 kN/m³ and 0.2, respectively.

Reinforcement steel is utilized in accordance with IS:1786 (2008), with the selection of HYSD bars (Fe500 and Fe415). Concrete grade M40 is employed for shear walls and columns up to the 11th storey, while columns from the 12th to the 21st storey use M35 grade concrete. All beams and slabs are constructed with M30 grade concrete. Infill walls are presumed to be made of brick masonry, characterized by a unit weight of 20 kN/m³, Young's modulus of 3,600 MPa, and a Poisson's ratio of 0.2. For the explosive material in this particular study, Trinitrotoluene (TNT) is chosen, possessing a specific gravity of 1.64. The comprehensive detailing of the building's material properties and structural specifications serves as the foundation for analyzing its response to blast-induced forces in the subsequent research.

Preliminary Building Design

Before initiating the blast load analysis, a thorough design process for the building with structural walls was undertaken using the computational package ETABS (CSI, 2018 release).

The primary emphasis during this design phase was placed on addressing regular loads, namely dead and live loads, in accordance with IS:875 (1987a; 1987b; 1987c) Part 1, 2, and 5, respectively. The design optimization included the incorporation of live load reduction factors. Lateral loads, including wind and seismic forces, were meticulously considered following the guidelines specified in IS:875 (2015) (Part 3) and IS:1893 (2016) (Part 1). This comprehensive design approach ensured that the structure was appropriately configured to withstand the various loads it might encounter, setting the stage for subsequent blast load analysis.

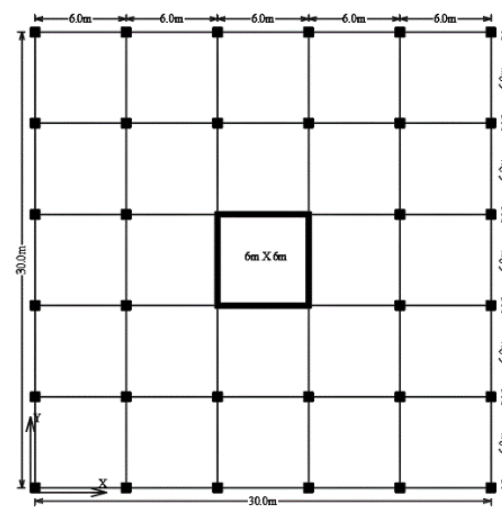


Figure 3. Typical floor plan of the building

Modal analysis was performed using Eigen's method with 15 modes. All 15 modes exhibited a mass participation factor exceeding 90% (ranging from 94% to 98%) in each principal direction (UX, UY, and RZ). These results met the criteria specified by IS:1893 (2016) (Part 1), wherein the first three modes contributed more than 65% to the mass participation factor. For the preliminary analysis, Response Spectrum (RS) analysis was employed, and the building successfully met all specified checks and criteria outlined in IS:1893 (2016) (Part 1). The design process, entirely conducted through computational methods, aimed to assess the adequacy of section and geometric properties assigned to structural members. All components underwent rigorous checks and successfully passed the design criteria, confirming their structural integrity and compliance with the specified standards.

Blast Load Analysis

The computational modelling of the building structure was carried out using a straightforward

approach, utilizing the features provided by the SAP2000 computational package (Figure 4). In this model, frame or line components were employed to represent beams and columns, while slabs and walls were modelled as shell or area elements. To establish a fixed base, fixed restraints were assigned to the joints of columns and shear walls located at the base of the structure. These restraints effectively restrained all six degrees of freedom at these joints. This fixed base condition was instrumental in capturing the structural response accurately.

The finite element model was created by meshing the structural elements using an appropriate meshing technique, ensuring a refined and detailed representation of the building's geometry and structural components in the computational analysis. This modelling approach provides a solid foundation for conducting subsequent analyses, including blast load analysis and structural assessments.

Blast loads were assessed for different quantities of TNT explosive charge weights, specifically 100, 300, and 500 kg, at varying standoff distances of 10, 20, and 30 m. The blast load direction was consistently considered along the X-axis of the structure's plan, and the calculations were carried out in accordance with the guidelines outlined in IS:4991 (1968). This methodology allowed for a systematic evaluation of the structure's response to explosive forces under different scenarios, considering both the magnitude of the explosive charge and the distance from the source.

The structural response to the blast is considered through a straightforward approach, where the blast load is defined at each beam-column joint located on the front face of the structure. This method takes into account the variable time taken by blast waves to reach each joint, considering differences in the angle of incidence due to varying distances from ground zero (the point of detonation). The variation in travel time results in a non-uniform distribution of blast pressure across the front face, with higher intensity at the bottom storeys and lower intensity at the top storeys. This approach reflects the dynamic and non-uniform nature of the blast impact on the structure, capturing the spatial and temporal aspects of the blast loading conditions. The blastwave pressure is converted into loads (measured in kN) by multiplying it with the tributary area around each joint. For each storey, separate load patterns and time-history functions are defined, with each blast load pattern associated with corresponding time-dependent functions. In each load pattern, the unit load is applied to each intermediate beam-column joint, while half the unit

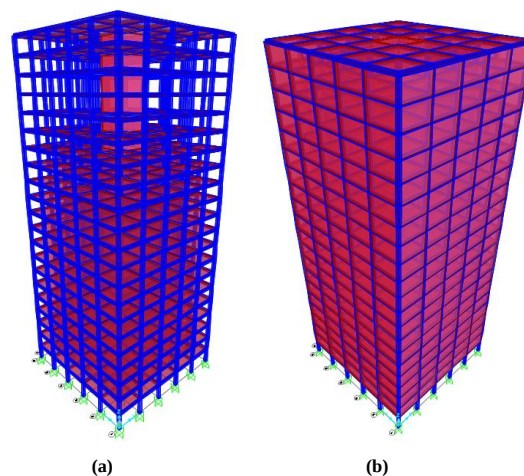


Figure 4. 3D view of the building with (a) shear wall (b) infill wall

load is applied to extreme beam-column joints. To address time dependency and the decay of blast loads, a total of 21 time-history functions are specified, each representing a triangular impulse with corresponding blast load values and durations. All blast load patterns and time history functions are grouped under a single load case to collectively represent the overall effect of blast loads on the entire structure.

It's noted that regular load patterns, such as live loads and dead loads, will remain consistent with those defined in the preliminary design, except for loads on the roof, which are omitted from consideration. This comprehensive approach allows for a detailed and dynamic analysis of the structural response to blast loads, considering both spatial and temporal variations. As per the specifications given in the IS:4991 (1968), a lateral load such as wind and earthquake loads should not be considered in blast load analysis.

Following the generation of a 3D geometric model, a nonlinear time-history analysis is conducted using the direct integration method to evaluate the structural response. The output time is set to one second, allowing for a detailed study of the structure's behaviour over this time period. A total of 12 models are analyzed, with the initial 9 models featuring a shear wall at the core and being studied under three different charge weights (100, 300, and 500 kg) at three distinct standoff distances (10, 20, and 30 m). Each individual model is considered under different structural configurations, including structures with shear and infill walls, with only infill walls, and without shear walls (Models 10, 11, and 12, respectively). These models are analyzed under a consistent blast effect, specifically the blast effect

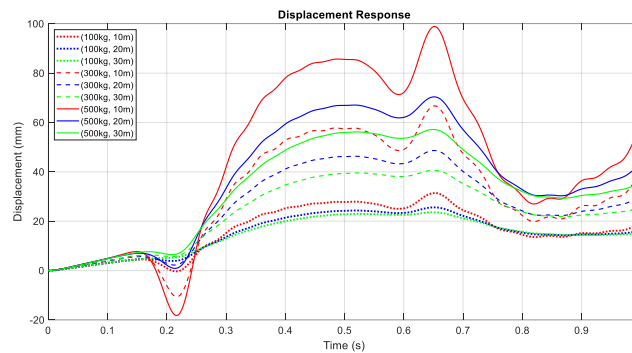


Figure 5. Displacement time-histories for group 1 models

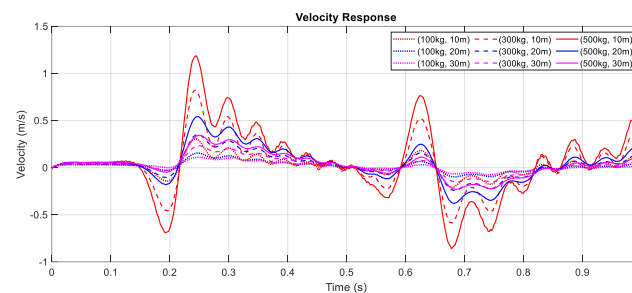


Figure 6. Velocity time-histories for group 1 models

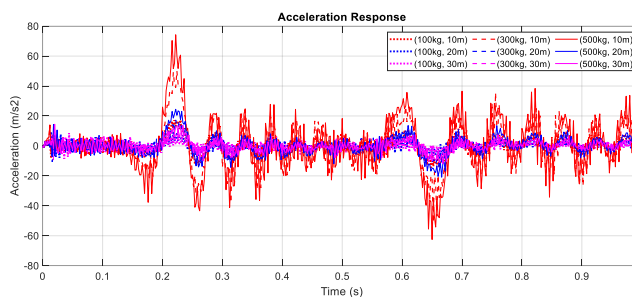


Figure 7. Acceleration time-histories for group 1 models

due to a 500 kg TNT charge at a 10 m standoff distance. This extensive analysis covers a range of configurations to comprehensively understand the structural response to varying blast conditions and wall configurations.

Results and Discussion

The response of structures to blast loads and its variations, specifically in terms of displacement, velocity, and acceleration for the top storey beam-column joints on the front face over time, are illustrated through graphs. The analysis is organized into two groups for a more systematic examination.

The first group focuses on variations in blast loads, considering different charge weights and standoff distances. The second group examines variations in structural configuration, encompassing different combinations of shear and infill walls.

For a clearer representation of the variation in structural response under the diverse effects of blast loads, a single plot is employed for each parameter (displacement, velocity, and acceleration). This approach aids in efficiently comparing the influence of blast loads and structural configurations on the dynamic response of the top storey beam-column joints

Figures 5, 6, and 7 illustrate the variation in displacement, velocity, and acceleration of the top

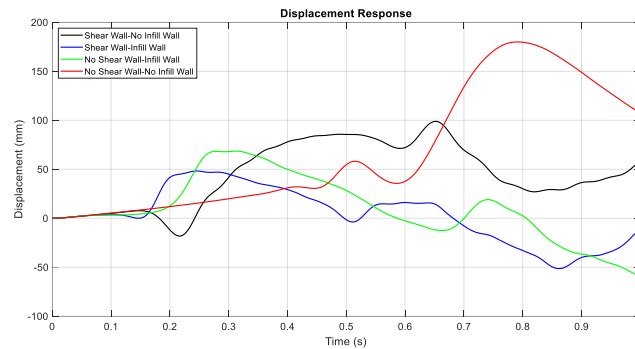


Figure 8. Displacement time-histories for group 2 models

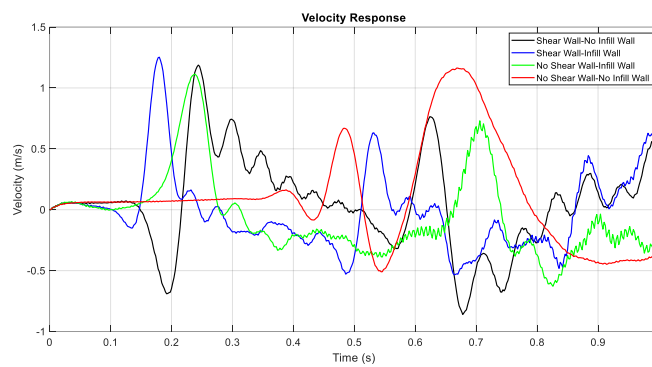


Figure 9. Velocity time-histories for group 2 models

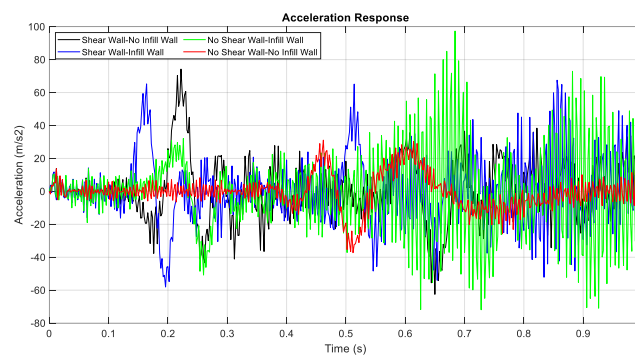


Figure 10. Acceleration time-histories for group 2 models

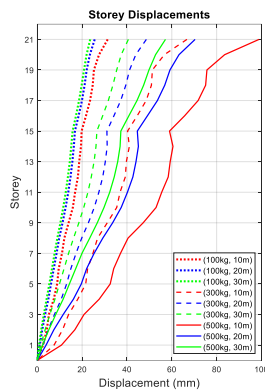
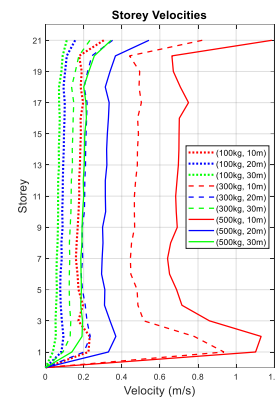
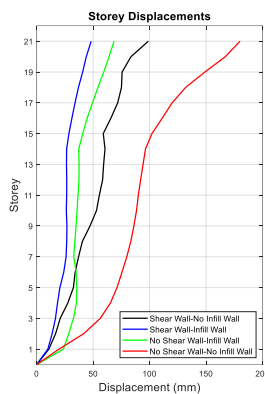
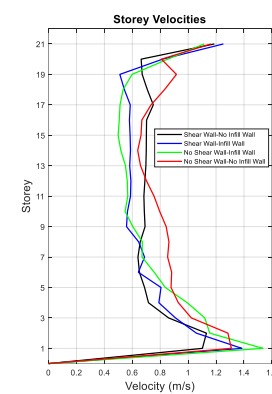
storey joint, respectively. These figures reflect the principles of the blast scaling law theory. Specifically, the results indicate that the structure subjected to a 300 kg TNT charge at a 10 m distance exhibits slightly higher displacements than those caused by a 500 kg TNT charge at a 30 m distance. Similarly, concerning velocity and acceleration, values are higher for the structure exposed to a 300 kg TNT charge at a 10 m distance compared to those resulting from a 500 kg TNT charge at a 20 m distance.

These observations align with the expected trends in blast scaling law, where the impact of blast load is influenced not only by the charge weight but also by the standoff distance from the source. The figures provide a visual representation of how these factors contribute to the structural response, supporting the theoretical framework of blast scaling law.

The response of the structure is significantly improved by the various structural systems investigated. Figures 8, 9, and 10 depict the variation

Table 1. Top storey peak responses

Structure configuration	D (mm)	Difference (% decrease)	Drift (mm)	IDR (%)	Difference (% decrease)
No shear wall-No infill wall	180.005	--	12.884	0.358	--
Shear wall-No infill wall	98.892	45.062	15.330	0.426	18.985
No shear wall-Infill wall	68.529	61.929	4.465	0.124	65.345
Shear wall-Infill wall	48.244	73.199	4.289	0.119	66.711

**Figure 11. Displacement over storey height for group 1 models****Figure 13. Velocity over storey height for group 1 models****Figure 12. Displacement over storey height for group 2 models****Figure 14. Velocity over storey height for group 2 models**

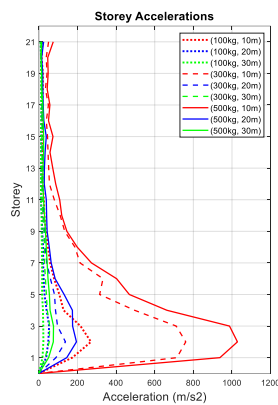
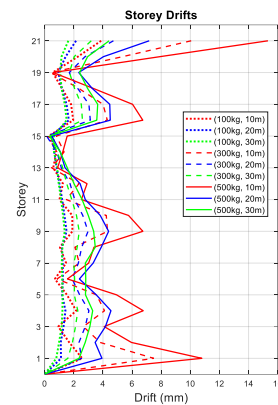
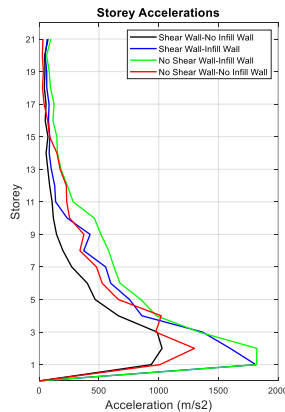
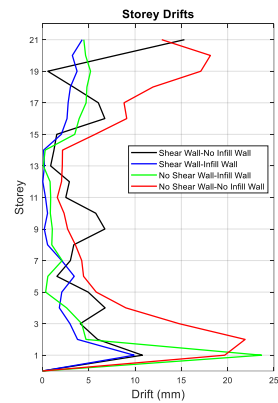
in displacement, velocity, and acceleration, respectively, of the top storey joint. The inclusion of a shear wall at the center of the structural plan enhances the lateral stability of the entire structure, resulting in reduced displacements when compared to a framed structure without a shear wall. Further reductions in displacements are observed with the addition of infill walls along the periphery of the structure, introducing additional stiffness to the beam-column joints on the front face. The most effective configuration is observed in structures with both shear walls and infill walls. Interestingly, irrespective of the presence of a shear wall, the provision of peripheral infill walls exhibits a similar

resistance with only minor differences. A detailed comparison of structures with combinations of shear walls and infill walls for top storey displacement and drift is provided in Table 1, highlighting the effectiveness of each structural configuration in mitigating the structural response to blast loads.

The analysis extends to the variation of displacement, velocity, acceleration, and storey drifts along the height of the structure. The corresponding displacement profiles are illustrated in Figures 11 and 12, revealing a deflection pattern similar to that observed in earthquake responses. Velocity profile, as depicted in Figures 13 and 14, show the first peak value at the top storey and

Table 2. Top storey peak responses

Model	Blast load	T_n (s)	D (m)	V (m/s)	A (m/s ²)	Drift (mm)
1	100 kg @ 10 m	2.579	31.411	0.3056	17.3601	3.873
2	100 kg @ 20 m	2.579	25.608	0.1555	9.6180	2.148
3	100 kg @ 30 m	2.579	23.614	0.1113	8.5948	1.620
4	300 kg @ 10 m	2.579	66.734	0.8222	50.0519	10.058
5	300 kg @ 20 m	2.579	48.646	0.3519	17.3547	4.716
6	300 kg @ 30 m	2.579	40.635	0.2329	10.5404	3.193
7	500 kg @ 10 m	2.579	98.892	1.1876	74.2360	15.330
8	500 kg @ 20 m	2.579	70.38	0.5426	24.4757	7.173
9	500 kg @ 30 m	2.579	57.174	0.3439	14.4920	4.4230
10	500 kg @ 10 m	1.241	48.244	1.2525	67.4898	4.2890
11	500 kg @ 10 m	1.369	68.529	1.1143	97.3457	4.4650
12	500 kg @ 10 m	3.475	180.005	1.1629	31.1077	12.8840

**Figure 15. Acceleration over storey height for group 1 models****Figure 17. Storey drift over storey height for group 1 models****Figure 16. Acceleration over storey height for group 2 models****Figure 18. Storey drift over storey height for group 2 models**

a second peak in the bottom two storeys, excluding the ground floor. Acceleration profiles, represented in Figures 15 and 16, indicate that peak accelerations are observed near the bottom storeys. The storey drift variation along the structure's height is shown in Figures 17 and 18, with peak values occurring at locations similar to those observed in velocity

profiles. To summarize the peak responses of all 12 models, Table 2 is provided, offering a consolidated view of the structural performance under varying blast loads and configurations. This comprehensive analysis provides valuable insights into the dynamic behaviour of the structure under blast-induced forces across different storeys.

Conclusions

The analysis reveals that acceleration and velocity reach their peak values at an early stage compared to displacement. Peak displacements and accelerations are observed in the top and bottom storeys, respectively. In terms of velocity and inter-storey drifts, there are two peak points corresponding to the top and bottom storeys. Notably, the structure subjected to a 300 kg TNT charge at a 10 m standoff distance exhibits more deformation compared to the 500 kg TNT charges at 20 m and 30 m standoff distances. This observed variation in charge weight and standoff distance aligns with the blast scaling law. Structures equipped with a core shear wall and structures with peripheral infill walls demonstrate substantial resistance compared to framed structures, reducing displacements by 45% and 61%, respectively. The structure with both shear and infill walls achieves an even greater reduction, up to 73%. Interestingly, the provision of peripheral infill walls remains the most effective in enhancing blast load resistance, even in the absence of shear walls, as it reduces storey drifts by 65%. In structure with shear walls and no infill walls, an 18% reduction in storey drifts is observed. This detailed analysis provides valuable insights into the effectiveness of different structural configurations in enhancing blast load resistance and demonstrates the impact of varying charge weights and standoff distances, supporting the observed trends in blast scaling law.

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