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PREDICTING SAFETY OF THE BUILDING SUBJECTED TO BLAST LOADING USING PERFORMANCE BASED SEISMIC FRAME WORK

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ABSTRACT

In order to kill as many people as possible and seriously harm public property, terrorists frequently use vehicle-borne incendiary bombs to attack popular landmarks and public buildings with high occupancy. While the explosion's immediate shock is what causes the majority of victims, the collapse of structural pieces may significantly raise the overall number. Most of these structures were or are being constructed without taking into account their susceptibility to such catastrophes. Performance targets are declarations the appropriate level of having casualties, direct economic loss (repair expenses), and downtime due to occupied space linked to replacement or repair of a damaged building parts in the next generation of performance-based design methods. Developing performance based standards for building blast engineering could benefit from some aspects of the performance-based seismic engineering framework. The low rise to high rise model was examined for the effects of extreme blast loads brought on by deploying TNT charges weighing 1000 kg and 500 kg at standoff distances of 20 m, 25 m, and 30 m, respectively. The Nonlinear Blast Time History Analysis (NLBTHA) was used to investigate the building's multiple performance tiers.

Keywords: Blast loading, Charge weight, Standoff distance, Blast Time History Analysis, Parametric study.

1. Introduction

Explosive loads have drawn gaining a lot of attention recently as a result of numerous unintended or deliberate incidents involving significant structures all around the world. The most prominent recent example includes tragedies similar to the American embassy bombings in Kenya, Dar es Salaam and Nairobi, Tanzania in 1998, Khobar Towers military barracks in Dhahran, Saudi Arabia, Murrah Federal Building in Oklahoma City and World Trade Centre in New York in 1996. Figure (Fig. 1) also includes a quantification of the number of fatalities and injuries related to each individual terrorist incidence.

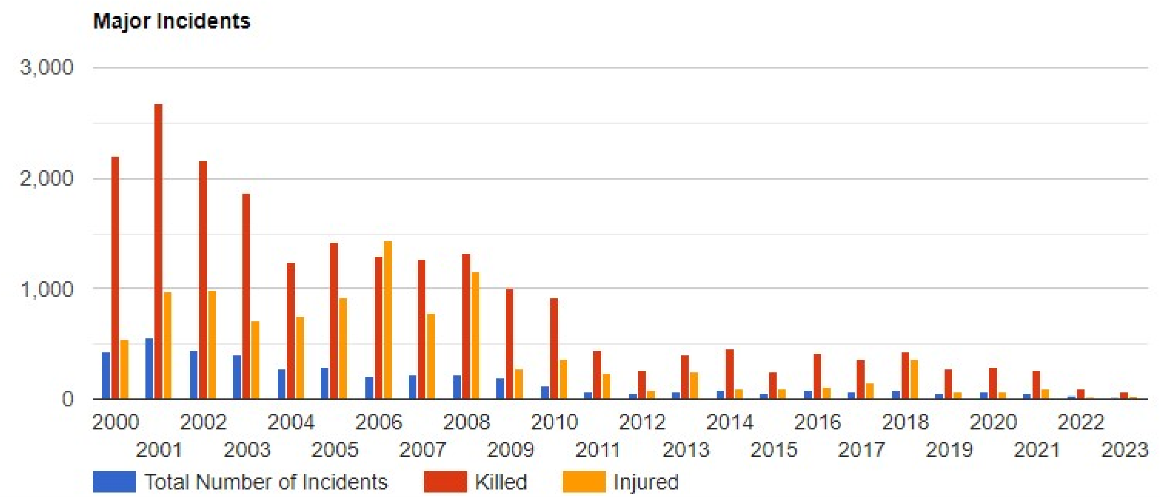


Fig. 1: **Deaths and injuries record from terrorism 2006 to 2023**.(South Acia Terorism Portal)

1.1 Blast Phenomena

An explosion primarily causes a considerable and sudden rise in localized pressure. Such overpressure is characterized by its speed, severity, and length, and it spreads as a wave known as the "blast wave." These are essential factors to consider when assessing the effects of an explosion close to structural elements. Numerous variables, such as the Sort and Amount of the bursting Mass, Interest target's dist. from the Explosion, the target's geometry, and the kind of reflecting surfaces, affect the numerical values of these parameters. The past few decades have seen a number of study on these topics, and they have produced trustworthy numerical approaches for the quantification of overpressure Time Histories. (2013) Gholamreza A. and Marzieh The first phase entails specifying the input dynamic load (time-pressure wave), for a type of explosion and explosive that is being taken into consideration. The procedure of assessing the structure's real dynamic reaction to the applied dynamic loads comes next. This intricate method involves analyzing the structure while taking into account greater strain rates, non-linear behavior of inelastic materials, blast load calculation uncertainty, and time-dependable deformations.

The establishment of a relationship is essential between different engineering demand characteristics and the dynamic reaction of structures in order to streamline the analysis process. A brief load known as a blast load is also known as an impulsive load. Blast loading is modelled mathematically as a triangle loading, as seen in figure 2.

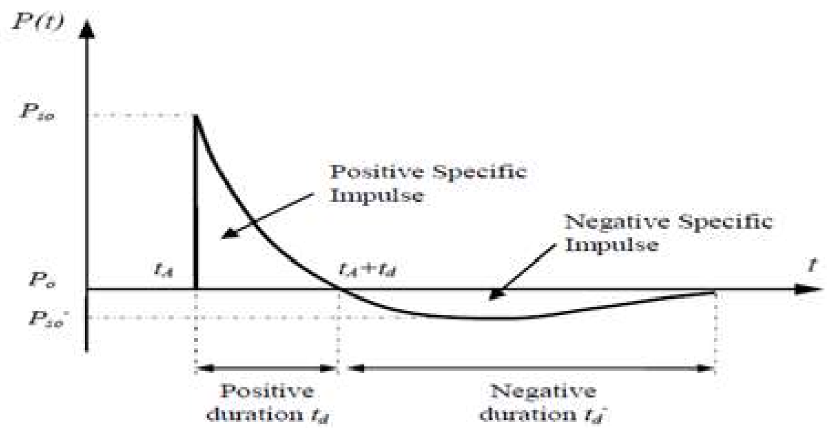


Fig.2: Blast wave pressure-time history

1.2 Performance Based Analysis Procedures

Extreme circumstances, such as blast loads and violent earthquake shaking, can cause serious structural damage to building frames and nonlinear behavior. The current standardized procedures for planning for explosive and earthquake loads may result in structures with an acceptable level of safety, but they are indirect, have a high degree of unreliability, and may lead to a labor-intensive and expensive building process. having a reliable and accurate understanding of the potential for loss (physical, direct economic, and indirect economic) as a result of future bombings, performance based engineering could makes it easier to design and build structures. [Ronald Hamburger and Andrew Whittaker]

Performance of the structure when it is subjected to ground motion beyond the elastic limits, and this performance assessment involves the measurement of the structure's reaction parameters including member forces, deformation, drift, and inter-story drift. Engineering demand parameters (EDPs) are the name given to these metrics, which are thought to be a predictor of damages to the structure. These EDPs, which show a structure's deformation capabilities, are based on the development of plastic hinges during the collapse mechanism and are used to define different levels of damage and associated losses that resulted from specific ground motion in terms of various performance levels (Md. Zameeruddin and Sangle, 2016, Ghobarah, 2001). FEMA 356 (FEMA 356) established these performance levels, such as immediate occupancy (IO), life safety (LS), and collapse prevention (CP).

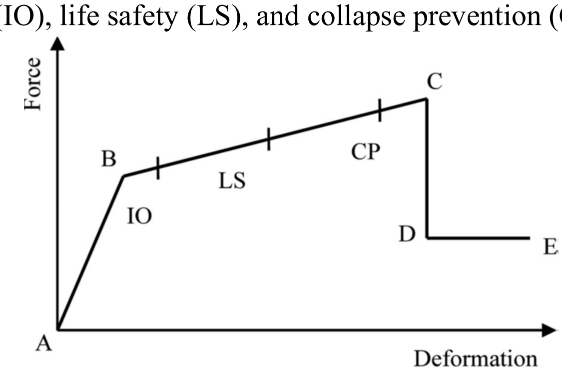


Fig.3 : Force- Deformation relationship of a Typical Plastic Hinges

Performance levels are reached at a specific drift attainment under inertia loads or seismic loads and represent the allowable risk of structural damage. In their current condition, they can only detect a damage state; they cannot scale the damage numerically.

In the current study, different performance levels for varying building height, detonation (TNT), and standoff distance are identified as per Table 2 by evaluating different Engineering demand parameters, such as Story displacement, Interstory Drift, which is the result of nonlinear blast time history analysis. An analysis of 18 models was conducted, and performance levels were used to assess damage. In NLBTHA, the development of plastic hinges in columns and beams serves as a representation of the collapse mechanism.

Table 2: Permissible drift limits at various performance levels and associated damage states (FEMA 356, 2000; ATC 40, 1996)

Performance level	Description	Drift limits
Operational Level (OP)	Structure is not damaged in any way	< 0.7%
Immediate occupancy Level (IO)	Damage to structural components is partial.	1%
Life safety Level (LS)	Astonishing structural and non-structural damage	2%
Collapse prevention Level (CP)	Structure is about to collapse	3%
Collapse Level (C)	Collapse	4%

1.3 METHODOLOGY

In the current work, the time period of a single tale RCMRF frame idealized into a single degree of freedom system was calculated in order to validate the program .The time period was determined using rough analysis techniques and was verified using SAAP 2000 analysis. According to IS 4991-1968, a blast pressure triangle time history is calculated for different standoff distances and detonations. Each frame's front face has a blast pressure triangle time history calculated for it.

Table 1 lists the 18 models for whom NLBTHA performed. Predictions of structural reaction quantities, such as member forces, deformations, and interstory drifts, were looked at during the performance assessment process.

1.4 Modelling Details

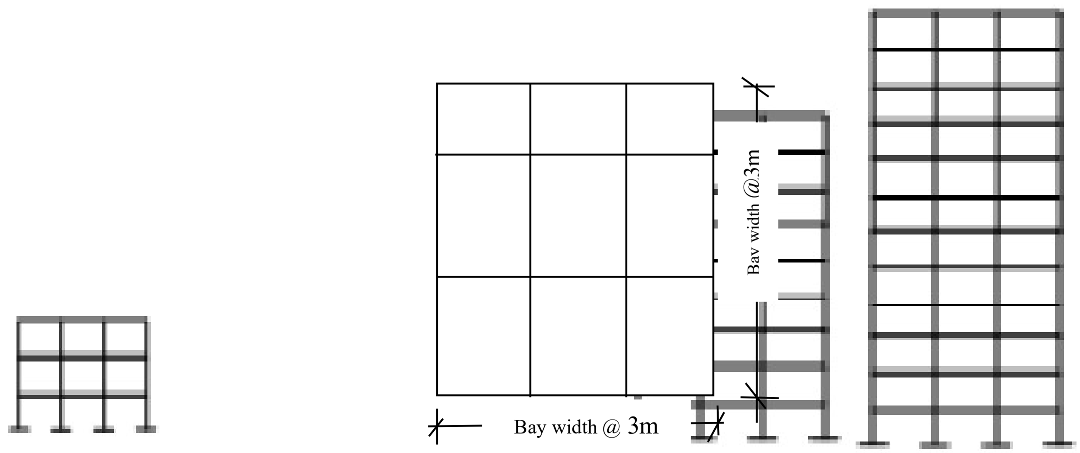
In this study, evaluated the capabilities of reinforced concrete moment resistant frames (RCMRFs), which serve as a good representation of the fundamental architectural design prevalent in India. 18 two-dimensional RCMRFs with various story and bay counts were used for this investigation. SAP 2000V 17.0 was used to perform the analytical modelling of the example structures (Wilson and Habibullah, 2000). The number of stories from low rise to high rise is taken into account, and the number of bays is the same for all models. Taking into account the number of story’s, standoff distance, and detonation, all 18 frames were separated into three groups., as indicated in Table 2.

Table 2 Modelling Details

Model No.	MRFs	Standoff Distance (m)	Detonation (TNT) kg	Model Name	Group
1	**S3B3**	20	500	**S3B3_20_0.5**	Group 1
2		25	500	**S3B3_25_0.5**	
3		30	500	**S3B3_30_0.5**	
4	**S3B3**	20	1000	**S3B3_20_1**	
5		25	1000	**S3B3_25_1**	
6		30	1000	**S3B3_30_1**	
7	**S9B3**	20	500	**S9B3_20_0.5**	Group 2
8		25	500	**S9B3_25_0.5**	
9		30	500	**S9B3_30_0.5**	
10	**S9B3**	20	1000	**S9B3_20_1**	
11		25	1000	**S9B3_25_1**	
12		30	1000	**S9B3_30_1**	
13	**S12B3**	20	500	**S12B3_20_0.5**	Group 3
14		25	500	**S12B3_25_0.5**	
15		30	500	**S12B3_30_0.5**	
16	**S12B3**	20	1000	**S12B3_20_1**	
17		25	1000	**S12B3_25_1**	
18		30	1000	**S12B3_30_1**	

Table 3: RC section details for example MRF’s

Group	**MRF’s**	**Storey's**	**Column**		**Beam**	
			Width (mm)	**Depth (mm)**	**Width (mm)**	**Depth (mm)**
ALL	S3B3	1-3	550	550	300	380
	S6B3	4-6	500	500	300	380
	S9B3	7-9	450	450	300	350
	S12B3	10-12	300	300	300	300



S3B3 **S9B3** **S12B3**

Figure 4: Geometry and typical layout of studied RCMRFs.

For the RCMRFs used in this example, blast loads were computed using IS 4991:1968 while dead and live loads were computed using IS 875 - 1987 (Parts 1 and 2). For each floor of the example RCMRFs, a mean Dead Load of 18 KN/mtr (including finish) and a mean Live Load of 4.5 KN/m were assigned. The Fe415 grade reinforcing steel used in the RCMRFs has a characteristic yield strength of 500 MPa, while the M25 grade concrete utilized in the RCMRFs has a 28-day characteristic cube strength of 25 MPa. The material properties that were taken into consideration during Design are listed in Table 4.

Table 4: Material Properties of MRFs consider for Design [IS 456 and IS 1786]

Material Properties of MRFs	**Concrete Grade, M 25**	**Steel Grade, Fe 415**
Weight per unit volume (KN/m^3)	25	76.97
Mass per unit volume (Kg/m^3)	2.548	7.849
Modulus of elasticity (KN/m^2)	25E+ 06	2E + 08
Characteristic strength (KN/m^2)	25000	45000 (yield)
Minimum tensile strength (KN/m^2)	-	4,85,800
Expected yield strength (KN/m^2)	-	4,65,500
Expected tensile strength(KN/m^2)	-	5,33,500

1.4 Determination of Blast load Parameters

Blast parameters due to the detonation of a 0.1 ton explosive are evaluated on an above ground rectangular structure, for all story height, standoff distance and detonation are calculated to generate pressure time history are given in table 5.All the calculation is done as per IS 4991-1968

The pressure diagrams are as shown in figure 5

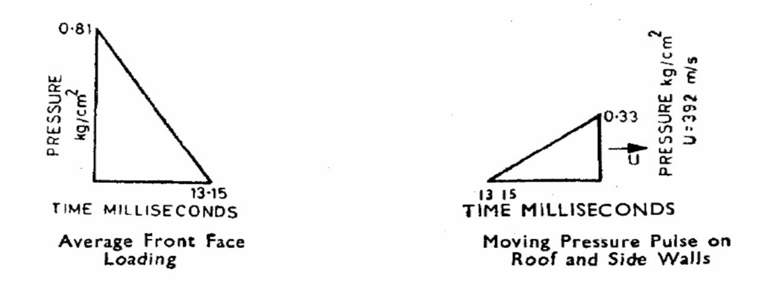


Figure 6:Blast Pressure Variation for front face and side walls

Table 5: Blast Load Parameters for varying detonation and standoff distance

Sr.No.	Detonation(TNT) Tonne	Standoff Dist. m	Scale Dist. Cm	to sec	td sec	Pso kg/cm2	Pso KN/M2	Pro kg/cm2	Pro KN/M2
1	0.5	20	25.20	0.01956	0.01205	2.16	211.896	7.41	726.92
2	0.5	25	31.50	0.02394	0.01585	1.30	127.53	3.83	375.72
3	0.5	30	37.80	0.02762	0.0187	0.92	90.252	2.47	242.31
4	1	20	20.00	0.01459	0.00861	3.87	379.647	16.13	1582.4
5	1	25	25.00	0.01941	0.01191	2.20	215.82	7.59	744.58
6	1	30	30.00	0.02293	0.01539	1.40	137.34	4.20	412.02

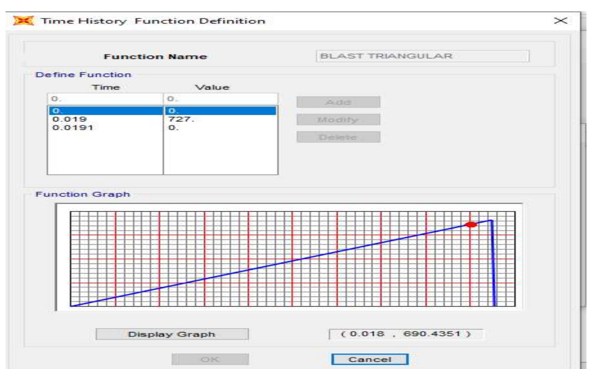


Figure 6: Blast Pressure Time History for S12B3 of standoff distance 20 m and detonation 0.5 TNT in SAP2000 v17

1.6 Result and Discussion.

In this study, story displacement for each floor was calculated after analysis of 18 models. Additionally, all types have different standoff distances and detonations. The diversity in height-related tale drift is shown in Figures 7 to 13.

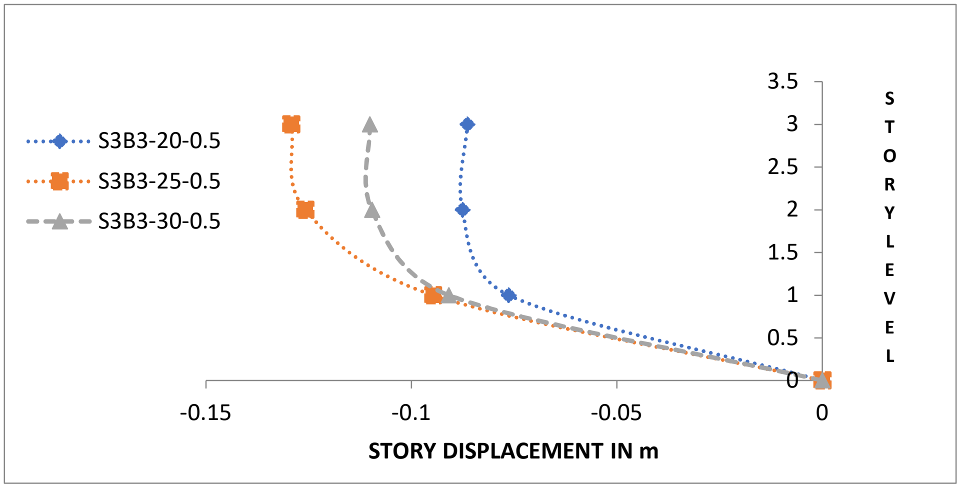


Figure 7: Story Displacement of S3B3 frame for 500 TNT.

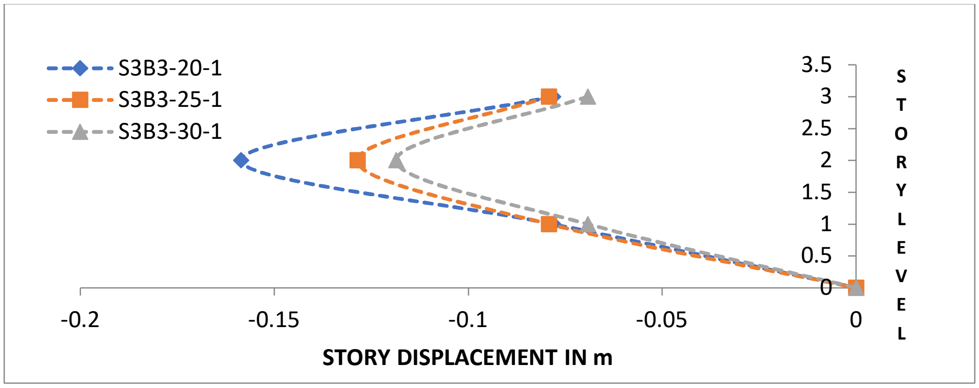


Figure 8: Story Displacement of S3B3 frame for 1000TNT.

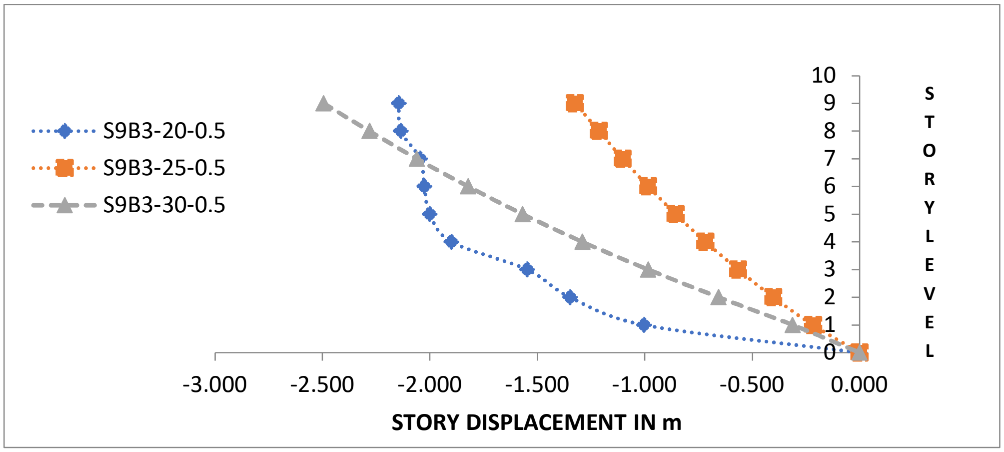


Figure 9: Story Displacement of S9B3 frame for 500 TNT.

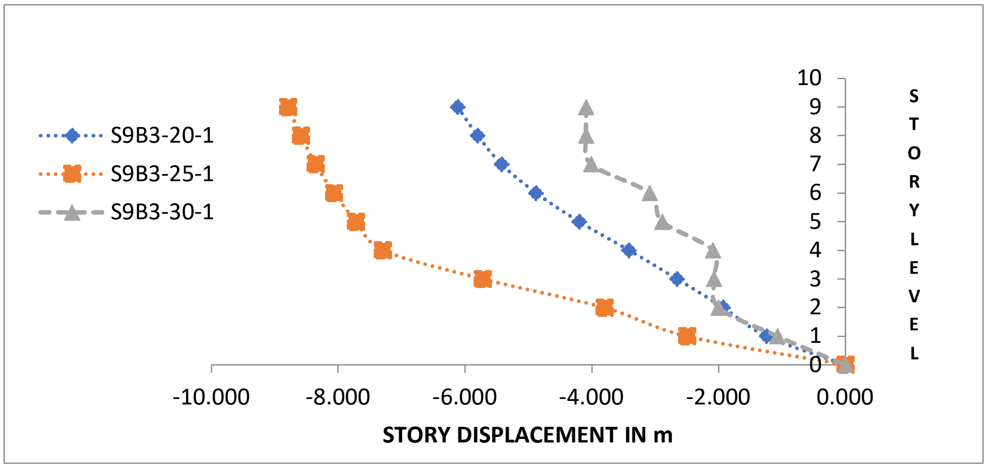


Figure 10: Story Displacement of S9B3 frame for 1000 TNT

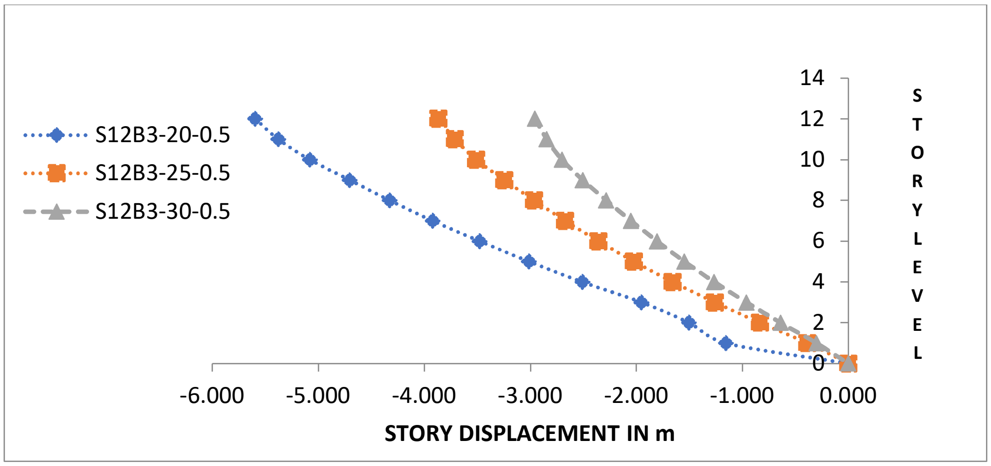


Figure 11: Story Displacement of S3B3 frame for 500 TNT.

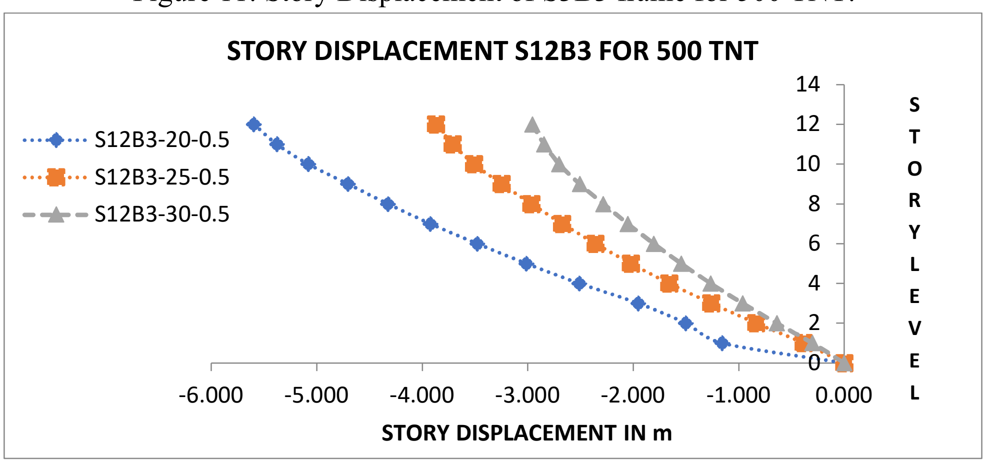


Figure 12: Story Displacement of S12B3 frame for 500 TNT.

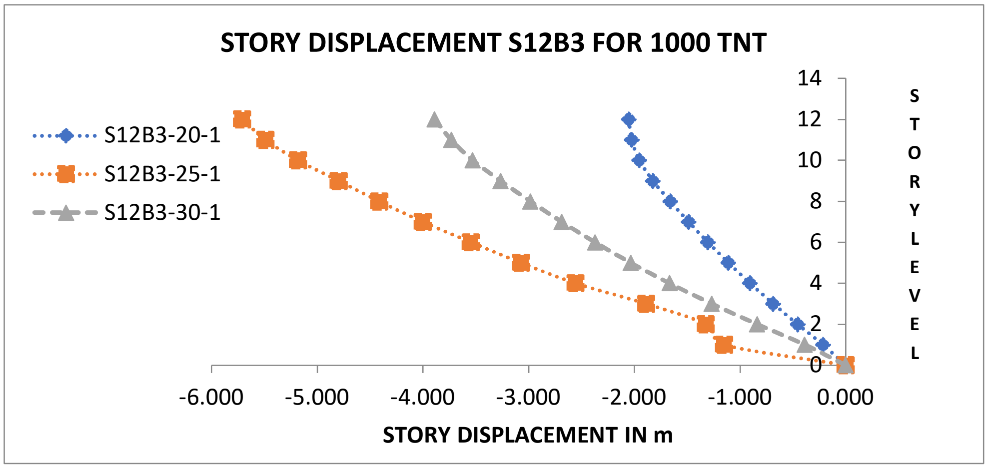


Figure 13: Story Displacement of S12B3 frame for 1000 TNT

1.7 Observations

1. According to the study, story displacement rises as tale level rises.

2.Story displacement of the model S3B3 reaches its maximum value when the detonation is changed from 500TNT to 1000 TNT for 20 m standoff distance.

3. When detonation is changed to 1000 TNT, the story displacement of the model S9B3 reaches its maximum value at a standoff distance of 25 m.

4. The story displacement of the type S12B3 is minimal at 20 m standoff distance for 500 TNT detonation, but it reaches its maximum value at 1000 TNT detonation.

1.8 Performance based blast engineering.

Having a solid understanding of the potential losses (physical, direct economic, and indirect economic) that could arise as a result of a bombing in the future, performance-based engineering should make it easier to design and construct buildings. Table 6 by [Andrew Whittaker and Ronald Hamburger] presents the suggested Performance levels, descriptions of damage, and projected downtime, all of which are provisional and subject to change. Using the procedures for seismic performance assessment described in Table 2 based on the performance of the building shown in Figure 14 performance. The performance of the building with varied height v drift for varying standoff distance and the detonation is identified using a ready-to-use graphic.

Table 6. Levels of potential building performance for blast-type loadings. [Andrew Whittaker and Ronald Hamburger]

Performance level	Damage description	Downtime
Immediate occupancy	little damage to structures and non-structures	24 hours
Life safety	Damage to the glazing and non-structural components; possible structural damage to the	Several months to a year

	beams and columns over a small region; absence of collapse; sufficient emergency exit; absence of fatalities from structural damage	
Collapse prevention	Significant structural and nonstructural damage, widespread structural damage, an impending collapse, potential egress restrictions, and low loss of life from structural damage	Possible total loss

Figure 14 of the study illustrates how the structure performs at various building heights and corresponding story displacements. Buildings with a minimum story height of up to 2 m for all standoff distances have been seen to operate at a high level. Building operations will switch from OP to IO level as height increases by up to 4 m. As the height increases, the behavior changes from IO to CP. By referring to the chart in figure 14, it is possible to directly interpret the performance of a structure.

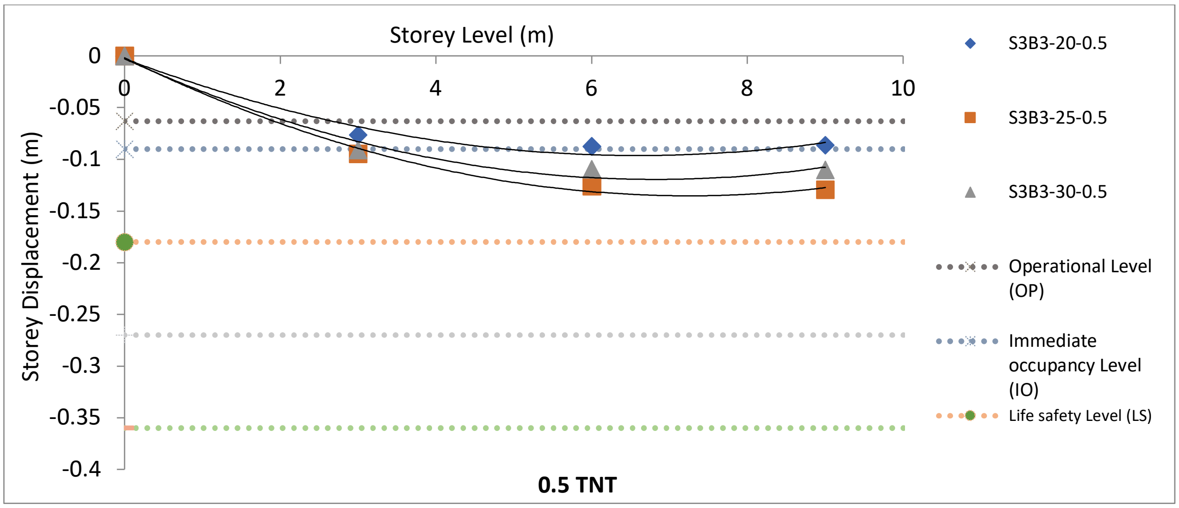


Figure 14: Various Performance level identified for S3B3 frame.

1.9 Conclusion

1.The temporal history of blast pressure depends on the standoff distance and the detonation (Table 5)

2. Story displacement rises as stories get taller.

3. Story displacement goes up when detonation goes down and down when it goes up.

4. Building performance improves as story height is reduced.

5.Building performance can be evaluated directly by using chart shown in figure 14.

6.The duration of the building's standoff distance will shorten and vice versa as it increases.

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