International Journal of Multidisciplinary Academic Studies and Research (IJMASR)
Registered with MSME, Govt. of India: UDYAM-MH-20-0329275
Available at https://ijmasr.org Volume-1, Issue-4, April 2026, Page-207-213.

To Cite This Article
Mr. Namesh M. Sangode, Dr. Abhijit Nardey, & Er. Bajrang Ambhore. (2026). Quantification of Blast Loads and Response of Structure under Blast. International Journal of Multidisciplinary Academic Studies and Research (IJMASR), 1(4), 207–213. *https://doi.org/10.5281/zenodo.20223091*

Article Info
Received: 18th April 2026, Accepted: 20th April 2026, Published: 23rd April 2026.

Quantification of Blast Loads and Response of Structure under Blast

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Abstract- A bomb explosion within or immediately nearby a building can cause severe damage on the buildings external and internal structural frames, collapsing of walls, loss of life etc. In addition, major catastrophes resulting from explosion causes large dynamic loads, greater than the original design loads, of many structures. The analysis and design of structures subjected to blast loads require a detailed understanding of blast phenomena and its effects on various structural elements. Blast loads are in fact dynamic loads that need to be carefully calculated just like earthquake and wind loads. This mini project presents the study of effect of Blast loading on a two storey RCC building. Effect of variable blast source weight is calculated by considering at various standoff distances from point of explosion. The blast load was analytically determined as a pressure-time history and numerical model of a two story typical structure was created in SAP2000. The influence of the lateral load response due to blast in terms of peak over pressures and dynamic pressures is calculated at 16.40ft standoff distance from the point of explosion and the response of structure is studied under the calculated peak pressures occured due to blast.

Keywords: *Charge weight, Stand-off distances, Scaled Distance, Peak Pressure.*

I. INTRODUCTION

In the past few decades, danger of explosion damage to a structure is increased as a result of increase in number and intensity of terrorist activities all over the world. Generally, structures are not designed for blast loads due to the reason that the magnitude of load caused by a blast is huge and the cost of design and the construction is much higher. As a result, the structure is susceptible to damage from blast load. Recent cost blast incidents in the country trigger the minds of developers, architects and structural engineers to find solutions to protect the life of human being and structures from blast disasters i.e from sudden impact. Special importance has been given to blast loads on landmark structures, such as high-rise buildings in metropolitan cities; the explosion of explosives (bombs, trinitrotoluene TNT, etc.) Inside and around buildings can cause catastrophic impacts on structural integrity of the building, such as damage to the external and internal structural frames and collapse of walls. Moreover, loss of life can result from the collapse of the structure. The earthquake problem is rather old, but most of the knowledge on this subject has been accumulated during the past decades. The blast problem is rather new, information for the development in this field is mostly made available through the publications of the Indian Researches, Army Corps of engineers, Naval facilities engineering command, air force civil engineering support agency and the other government/public offices and institutes. The guide lines for the blast loading are published in Indian code IS 4991-1968. The study on Quantification of Blast Loads and Response of Structure under Blast is justified by the growing need to protect civilian, industrial, and strategic infrastructure against accidental or intentional explosions. Modern buildings, transportation hubs, defence facilities, and critical utilities face increased vulnerability due to urban densification, industrial hazards, and security threats.

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Despite this, many existing design approaches rely on simplified assumptions that do not fully capture the complex nature of blast pressures and their interaction with structural elements. Accurate quantification of blast loads is essential for understanding how overpressure, impulse, and duration vary with charge weight and stand-off distance, while response analysis is critical for predicting damage patterns, failure mechanisms, and structural resilience. This research provides a scientific basis for safer design, strengthening schemes, and performance-based evaluation by integrating empirical methods, analytical modelling, and numerical simulation. Ultimately, the study enhances structural safety, supports national standards on blast resistance, and contributes to developing reliable guidelines for modern protective engineering.

II. RESEARCH METHODOLOGY

Building description:

A two storey RCC frame building with 6.0 m height with two bays in both x&y directions situated in seismic zone III has been considered for the purpose of present mini project. And all below dimensions are assumptions.

1. Floor to floor height = 3.0 m
2. Size of Columns = 400 mm x 400 mm
3. Size of Beam = 230 mm x 230 mm
4. Thickness of slab = 150 mm

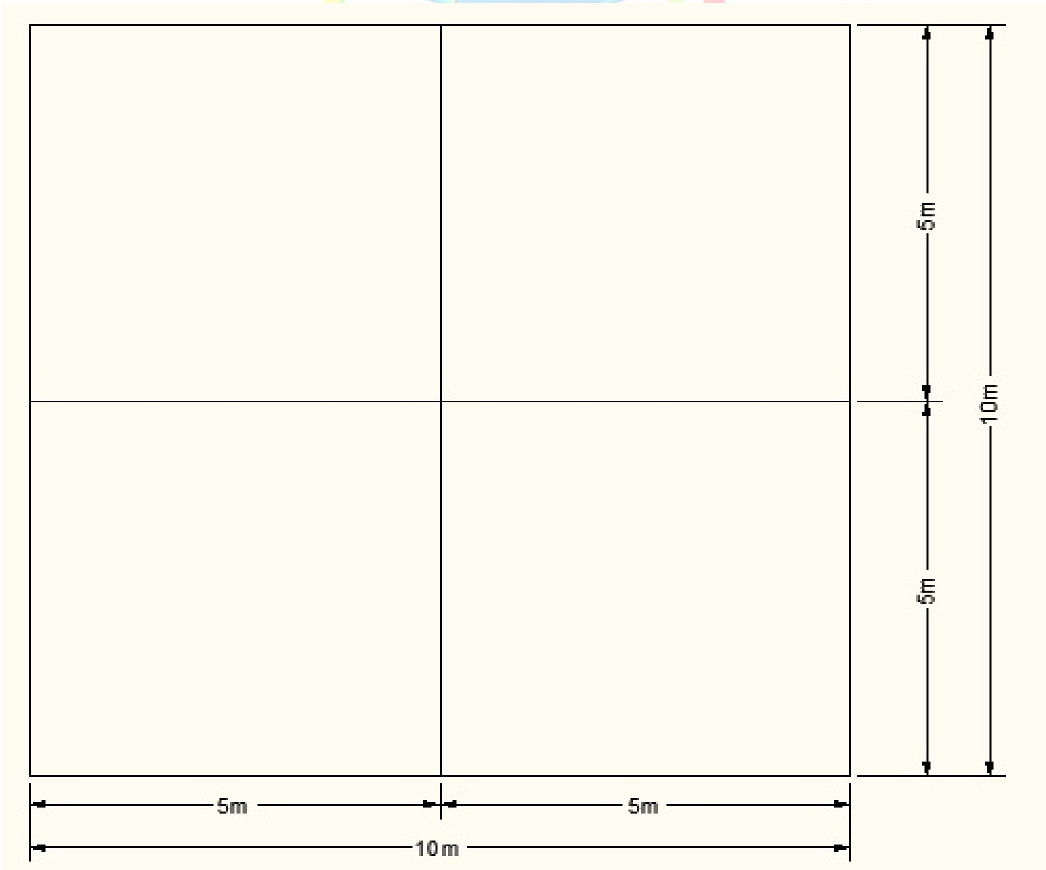

Figure 6.1: Plan view of the building

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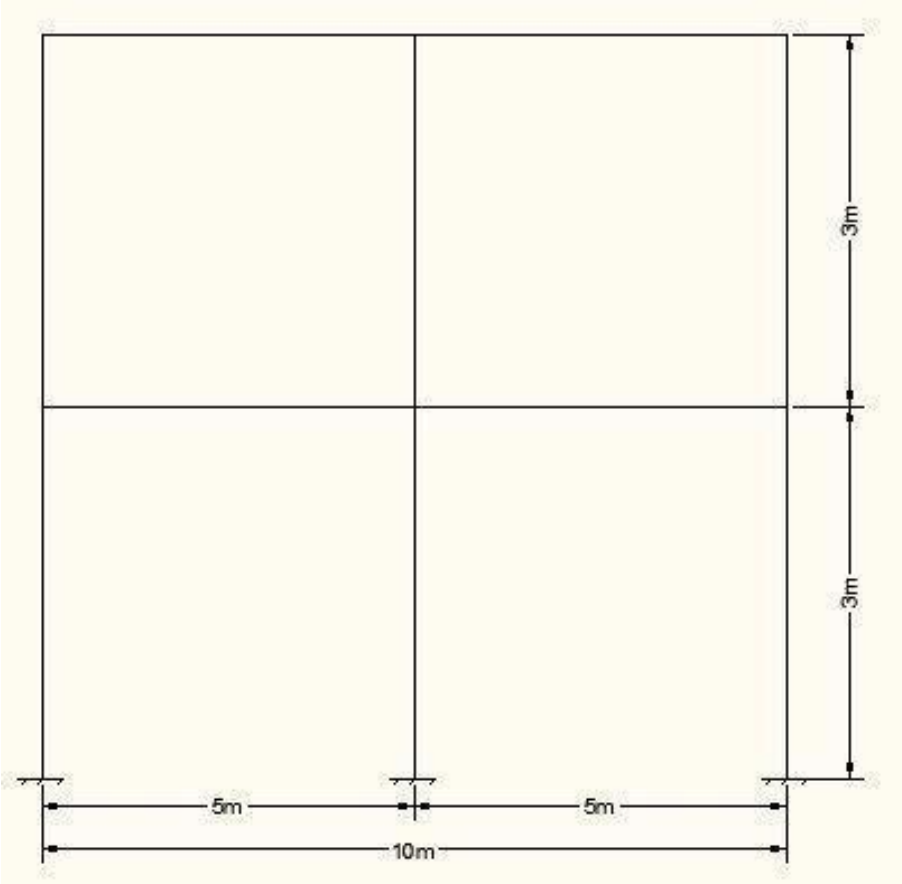

Figure 6.2: Elevation view of the building

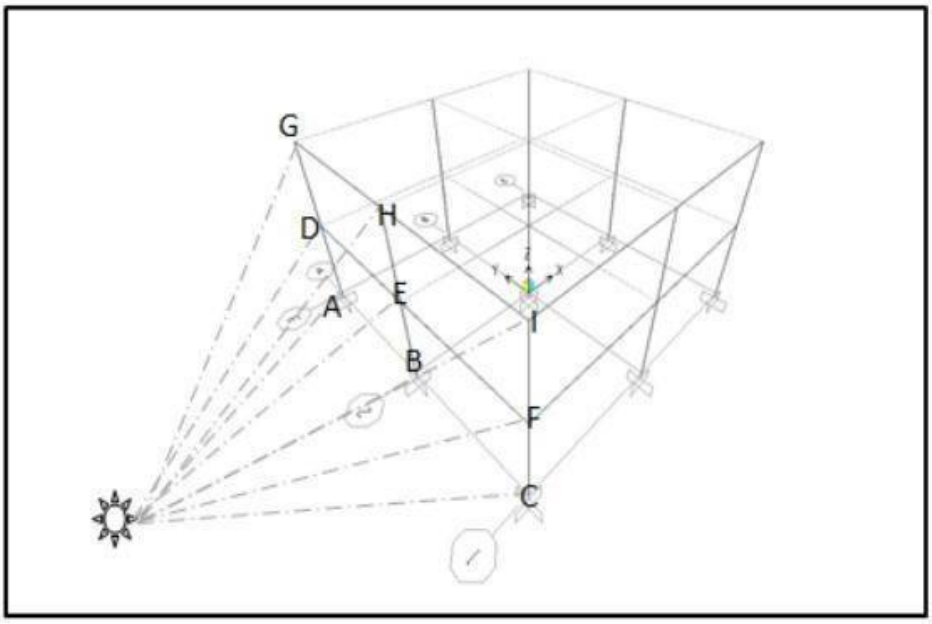

Figure 6.3: Isometric view and blast explosion to the building

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III. RESULTS

The response of explosion of 560lbs TNT at 16.40ft standoff distance is given below in terms of nodal displacements, shear force, moment and torsion.

Table 3.1: Shear Force & Bending moment values of the beams along in the front façade

Storey	Bays	Beams	Max Shear force	Max bending moment
1	Bay 1	AB & BC	118.01 KN @ 2.50m -28.068 KN @ 5.0m	383.69 KN-m @ 2.50m -343.54 KN-m @ 5.0m
	Bay2	AB & BC	231.78 KN @ 2.5m -60.92 KN @ 5.0m	139.87 KN-m @ 2.50m -148.21 KN-m @ 5.0m
	Bay3	AB & BC	124.615 KN @ 2.5m -37.37 KN @ 5.0m	334.40 KN-m @ 5.0m -374.54 KN-m @ 2.5m

Table 3.2: Shear Force & Bending moment values of the beams along in the beside the front facade

Storey	Bays	Beams	Max Shear force	Max bending moment
1	Bay 1	AB BC	150.80 KN @ 2.50m -45.84 KN @ 2.50m 108.11 KN @ 5.0m -77.47 KN @ 5.0m	338.69 KN-m @ 5.0m -378.88 KN-m @ 2.50m 379.36 KN-m @ 5.0m -339.26 KN-m @ 2.50m
	Bay2	AB BC	241.57 KN @ 2.50m -67.11 KN @ 2.50m 221.990 KN @ 5.0m -54.737 KN @ 5.0m	1.159E-04 KN-m @ 2.50m -3.038E-04 KN-m @ 5.0m 0.001 KN-m @ 2.50m -0.0010 KN-m @ 5.0m
	Bay3	AB BC	150.805 KN @ 2.50m -45.843 KN @ 2.50m 108.116 KN @ 5.0m -77.48 KN @ 5.0m	378.884 KN-m @ 2.50m -338.6945 KN-m @ 5.0m 339.25 KN-m @ 2.50m -379.35 KN-m @ 5.0m

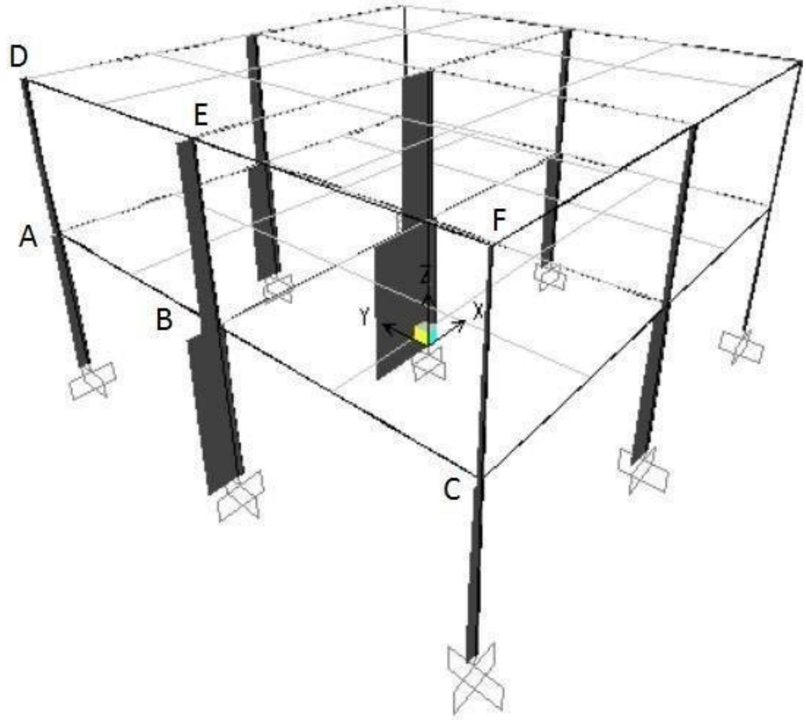

Figure 3.1: Shear force diagram due to blast

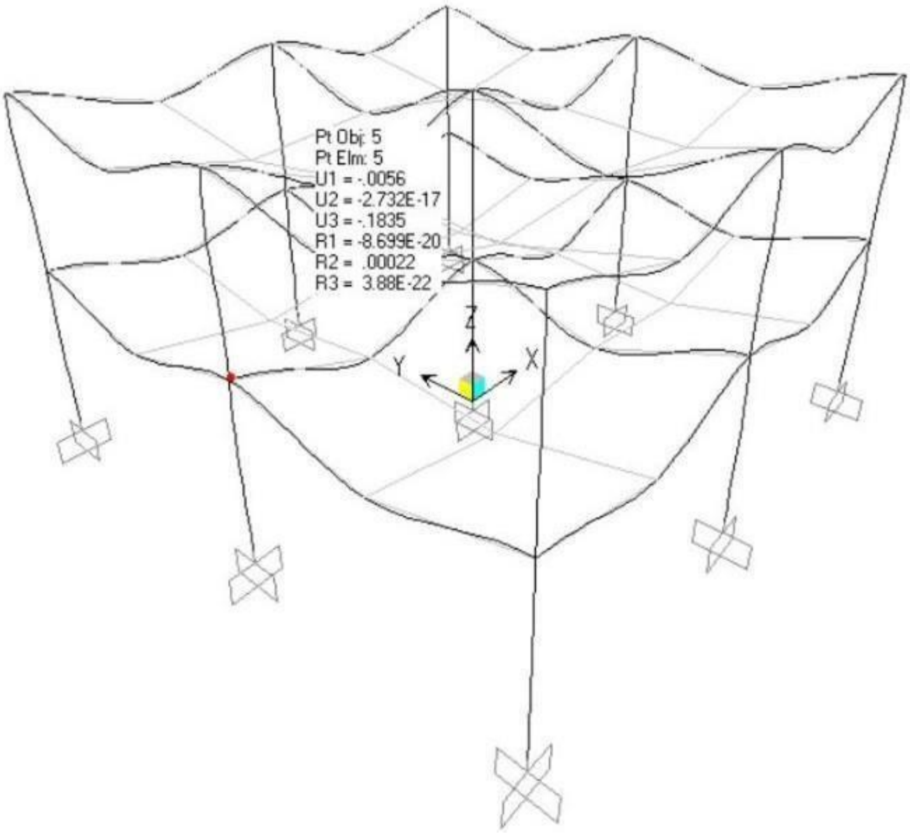

Figure 3.2: Displacement diagram due to dead load

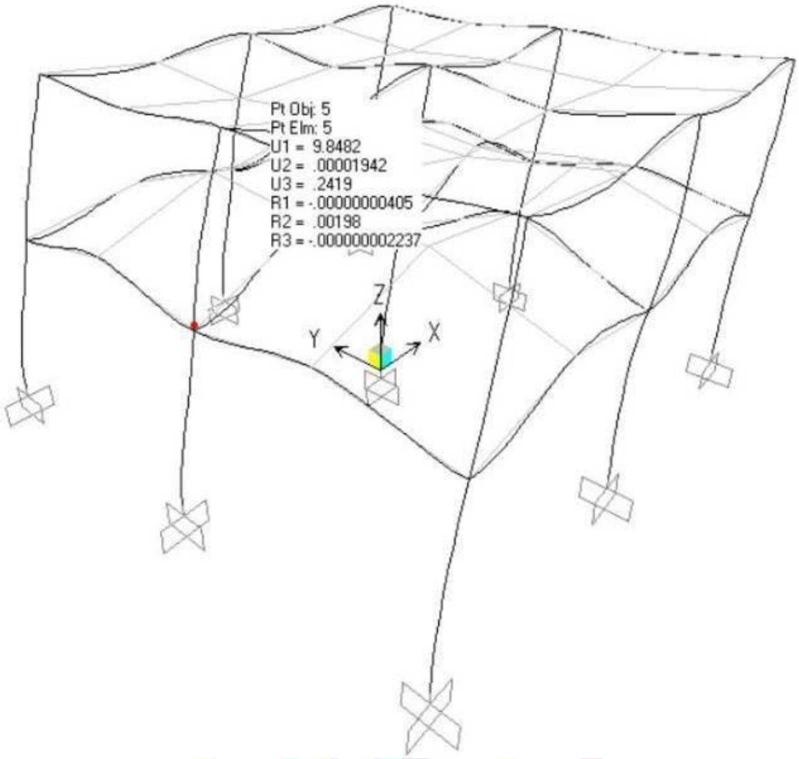

Figure 3.3: Displacement diagram due to blast loads

Table 3.3: Displacement values of the structure in front façade

Storey	Nodes	Max Displacement
1	D	9.84mm
	E	9.84mm
	F	9.84mm
2	G	24.01mm
	H	24.01mm
	I	24.01mm

Discussion:

The quantification of blast loads and the study of structural response under blast effects have become increasingly important in the field of structural engineering due to the rising risk of accidental and intentional explosions in industrial facilities, military zones, transportation systems, and public infrastructures. Blast-resistant design aims to ensure structural safety, minimize casualties, and prevent progressive collapse when subjected to extreme dynamic loading conditions.

A blast load is generated due to the rapid release of energy from an explosion, resulting in high-pressure shock waves propagating through the surrounding medium. The pressure-time history of a blast wave generally consists of a sharp rise in peak overpressure followed by a gradual decay phase. The intensity of the blast depends on several parameters such as explosive weight, standoff distance, confinement conditions, and atmospheric characteristics. Quantification of blast loads is commonly performed using empirical relationships based on scaled distance concepts developed from experimental investigations like the TNT equivalency method and Hopkinson-Cranz scaling law.

The response of structures under blast loading significantly differs from conventional static or seismic loading because blast loads act over a very short duration with extremely high intensity. Structural elements experience large deformation, high strain rates, localized damage, cracking, spalling, and sometimes total collapse. The behavior of structures under blast loading is influenced by material properties, geometry, support conditions, ductility, and energy absorption capacity.

Several analytical, numerical, and experimental methods have been developed to evaluate blast effects on structures. Empirical methods provide quick estimations of peak pressure and impulse, whereas numerical techniques such as Finite Element Analysis (FEA) using software like ANSYS, LS-DYNA, and ABAQUS enable detailed simulation of nonlinear structural behavior under dynamic loading. Single Degree of Freedom (SDOF) models are also widely used for simplified dynamic response analysis because they provide reasonable accuracy with reduced computational effort. Research studies indicate that reinforced concrete structures exhibit better blast resistance due to their mass and energy dissipation characteristics, while steel structures provide superior ductility and flexibility. However, inadequate detailing, poor reinforcement configuration, and insufficient confinement can lead to brittle failure modes. Various retrofitting techniques such as fiber-reinforced polymer (FRP) wrapping, steel jacketing, blast walls, and energy-absorbing materials have been proposed to enhance blast resistance.

CONCLUSION

The explosion in or near the structure can cause catastrophic damage to the structure, forma- tion of fragments, destruction of life-support systems (air conditioning, sprinklers). Injuries and deaths can be caused by exposure to explosion wave front, collapse of the structure, impact of parts, fire and smoke. Secondary effects of the explosion can hinder or even prevent the evacuation of people from the structure causing additional injuries and deaths.
Blast load for close explosion was determined and simulated on a model building using SAP2000, the conventional software for the static/dynamic analysis of structures. Loading was defined as a record of pressure over time (pressure-time history) with the parameters calculated by the available literature.
1)Though the pressures exerted are very high during explosions, the source of explosion, dura- tion of blast wave and arrival time plays important role in overall response of structure.
2)The maximum displacement occurs at the central node of the building. Also, the displacement is maximum at the top storey.
3)The axial forces in columns are maximum at the first storey whereas shear forces and mo- ments are maximum at the top storey in columns and beams as the distance from source of explosion increases.
4)The given structure can be analyzed for any standoff distance for varying charge weights by using this methodology and critical distance can be found out for the explosion for given structure.

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