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Blast Loading and Its Effects on Building

Mohini Chaurasiya[1], Ganesh Jaiswal[2]
[1]*Student (M. Tech), Civil Engineering Department, IET, Lucknow*
[2]*Assistant Professor, Civil Engineering Department, IET, Lucknow*

Abstract: ***Terrorist assaults have become more common in recent years. Their main purpose is to destroy important structures such as areas of defense, hospitals, schools, buildings. Due to the explosion, high pressure is generated and the blast time is also very short, but it can damage the structure from outside and inside. Which can cause a lot of damage to human life. There has an influence on the nation's economy. Like the earthquake and wind load, the blast load should also be designed, keeping in mind the important structures that have to be avoided from the explosion. In this research paper, six story R.C.C. Structures exposed to explosion loads are analyzed. We study the effect on the building by changing the weight of the explosive and the distance between the explosion source and the building. The IS 4991-1968 code has been used to calculate the parameters of the explosion pressure waves. The program ETabs 2019 has been used to analyze the effect of blast load. The structure has been modified by providing shear walls to reduce excessive displacement due to blast loading on the building. The results of the analysis are compared after adding the shear wall with the general building model. The result was that after the addition of the shear wall, the effect of blast loading is greatly reduced.***

Keywords: Blast phenomena, Standoff distance, detonation charge weight (TNT), Front face pressure, Side face pressure, ETABS, RCC, Blast waves, explosive effects, Story Displacement, Storey Drift, Overturning Moment, Shear wall.

I. INTRODUCTION

Buildings have been threatened by blast-induced impulsive pressures in recent years because of enhanced international terrorism. Various cases of this form have occurred across the world, posing a significant risk to national security and property. Structural engineers are involved in this field to reduce losses and analyze the structure of the phenomena as well as its impact on structures where citizens collect and are the focus of such assaults. Its consequences for structures where people congregate and are the focus of such assaults. Terrorists are also adopting stronger explosives and technological developments, which have enhanced the intensity of explosive events. As a consequence, in addition to heavily defended and historical places, also significant high-rise buildings and complexes must be constructed to endure blasts. Assessment of the reinforced concrete frame structure is challenging because the impulsive load created by a detonation is inherently unpredictable and causes pressure in a small duration. The pressure exerted on the building by the blast is affected by the charge weight and standoff distance. The significant purpose of this study is to compare the responses of normal buildings and buildings with shear walls. As a response, evaluating whose building is more blast resistant. Both models are exposed to blast loads of detonators weighing 0.1 tons at distances of 20m, 40m, and 60m. Both models' analysis responses are compared.

M. Meghanadh et al [1]They have investigated the impact of blast loads on a five-story RCC structure. The impact of a 100 kg trinitrotoluene (TNT) explosion source located 40 meters distant from the building has been observed. IS: 4991 has been used to calculate blast loading and side-on overpressure. STAAD Pro has been used to study the force-time history of a building and the variation in maximum displacement, velocity and velocity. Gautham T N et al. [2]They have studied the impact of the standoff distance for explosion loading; That is essential for building analysis. In this paper, G+5 buildings have been analyzed and loading is calculated as per IS 4991-1968. ETABS has been used to investigate and analyze 16 different cases. The respective front face pressure and lateral face pressure on the building has been calculated for multiple charge loads and distances between explosive source and building. Pressure on the front and sides of the face, as well as the maximum joint displacement and the number of beams or columns that failed to achieve the required capacity V/s standoff distance are all derived from the graph analysis results. Jayashree S. M. et. Al. [3]The G3 story frame of RCC and SIFCON is compared during detonation loading to determine whether SIFCON should be used rather than RCC. The characteristics of Reinforced cement concrete and SIFCON have impacted, and variables that change time such as displacement and frequency range are compared to each other as well. To create and analyze space frames, SAP 2000 has been utilized. SIFCON, according to analysis, consumes 25-30% less frames than RCC. Although its strength and stiffness are comparable to RCC, SIFCON's frequency is 30 percent greater than RCC. As a result of study, SIFCON has a higher capacity of energy consumption than RCC, as well as increased strength, and flexibility.

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A. Objective of Work

1) This project's major goal is to examine how buildings work when they are subjected to detonation loads and how to diminish the effects of detonator loads by adding a shear wall into the structure.
2) To understand how a building reacts when confronted to blast loads of varied standoff lengths and charge weights.
3) To examine and analyze the behavior of several building models in order to provide analysis outcomes.
4) The IS code 4991 and ETABS software are used to determine the building's reaction due to explosive loading.

II. BLAST LOAD CIRCUMSTANCE

When an explosion occurs, a large amount of hot gases is produced, compressing the surrounding gases and moving them away from the explosion center at a faster rate. The standoff distance, the length between the place of origin of the explosion and the structure. The pressure or strength of the blast wave decreases as it moves away from the blast source, and as a result, the impact on the structure will be less with a greater standoff distance. A shock front or wave is generated when the blast wave released by an explosion spreads into the surrounding air. The blast wave engulfs the entire structure, which is exposed to the pressure of the explosion. The detonation load is influenced by the type of material, the mass of the detonation charges, the energies that are expelled after the detonation, a standoff distance, and the severity of the pressure released.

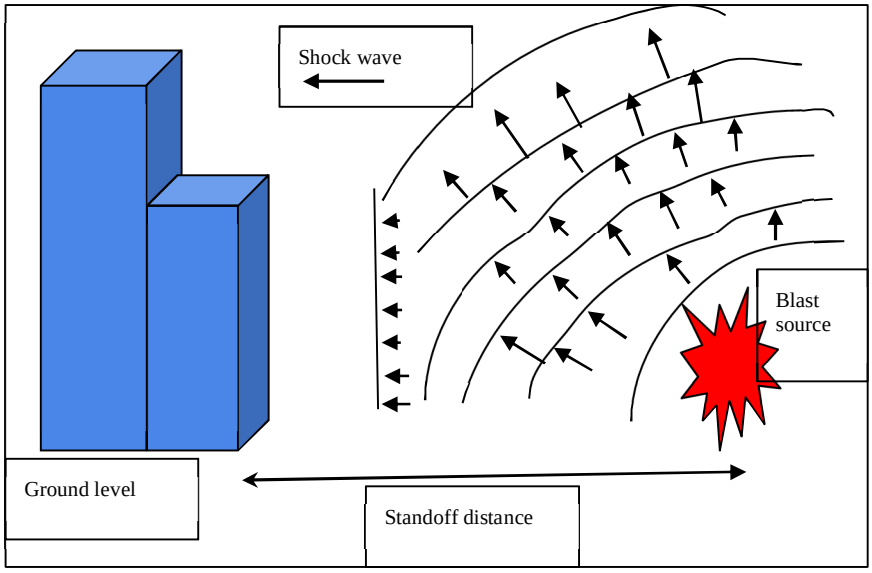

Fig. 1 Blast loading on structure

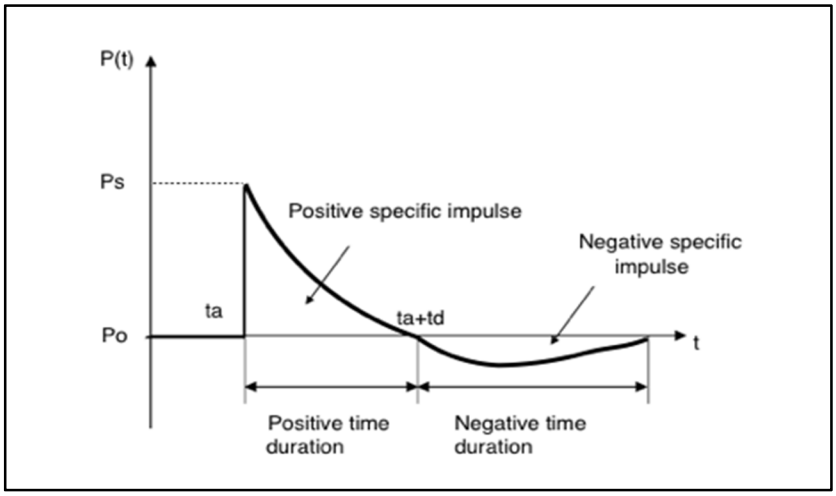

Fig. 2 Shock wave produced by Blast

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III. METHODOLOGY

The study evaluated a burst of 100 kg of TNT at 20m, 30m, and 40 meters away from the building. IS: 4991code has been used to calculate the peak pressure value. In addition to the direct blast pressure, this response from the supporting wall serves as a uniformly distributed load on the column and beam with varying time periods. The pressure is then transmitted to the building structure, such as columns and beams on the building's front and flanks that are facing the explosion.

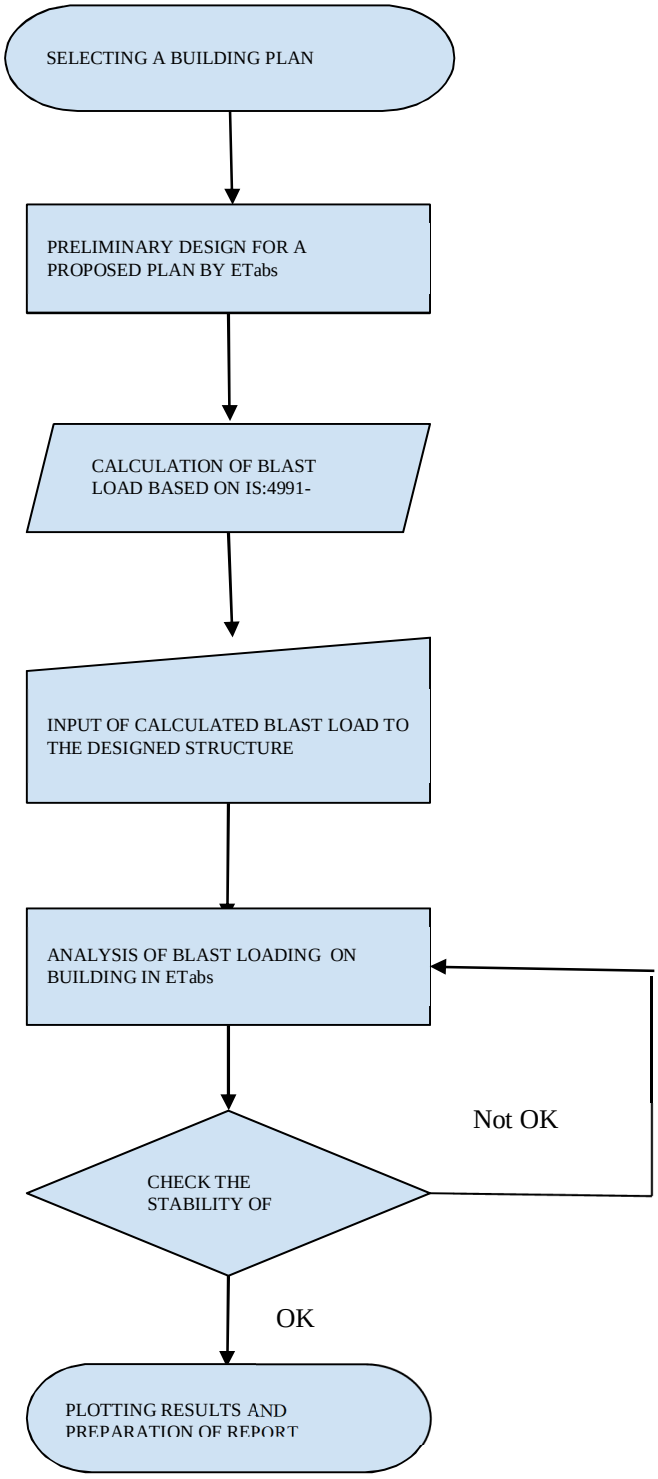

Fig. 3 Flow chart

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Two types of models have been taken for the analysis of the building: -

1) *Model 1*: Blast loading on Normal Building.
2) *Model 2*: Blast loading on Normal Building with shear wall

A. Structural Details

Table 1
Material Properties Considered

Steel reinforcing grade	Fe 500
Concrete grade	M30
Concrete Density	25kN/m^3
Steel density	78.5 kN/m^3

Table 2
Structural Description

Building type	RCC
Building Dimension	12x12m
Height of story	18m
Each floor height	3m
Size of Beam	300x450mm
Size of Column	450x450mm
Thickness of Slab	120mm
Thickness of Wall	230mm

Table 3
Loading Details of 6 Storied Rcc Buildings

Detonation load	According to IS: 4991
Live load	3 kN/m^2
Dead load	All member's self-weight
Wall load	13.8 kN/m (on Beam)
Floor finish load	1 kN/m^2

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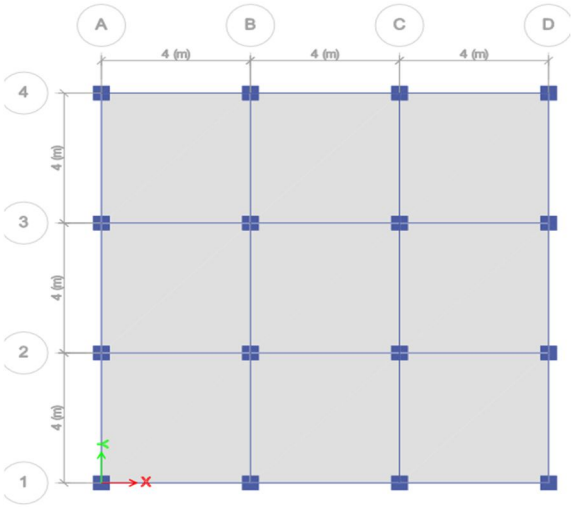

Fig. 4 Plan of the Building

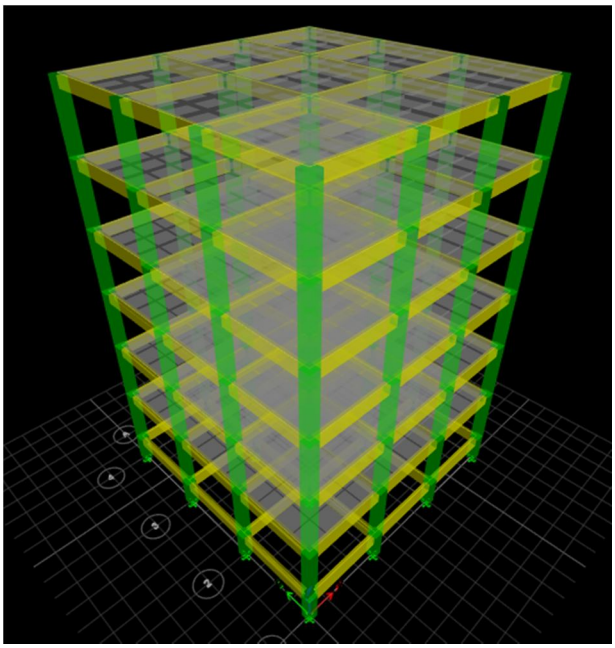

Fig. 5 3D view of Model 1

B. Blast Load Calculation

The blast parameters from the explosion of a 100 kilograms' charge (Trinitrotoluene) at a 20m,30m and 40m standoff distance from the building's front faces are computed using IS 4991: 1968. (reaffirmed 2013).

1) Front Face Loading [4]

The net pressure acting on the front face at any time t is the reflected overpressure p_r or ($p_s + C_d q$), whichever is greater:
where Cd = drag coefficient,
p_r = the reflected overpressure which drops from the peak value p_{ro} to overpressure ($p_s + C_d q$) in clearance time t_c given by:
$t_c = 3S/U$ or t_d whichever is less
S = H or B/2 whichever is less
U = shock front velocity = M.a
where a = velocity of sound in air which may be taken as 344 m/s at mean sea level at 20^0C, and M = Mach number of the incident pulse

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2) Side Wall Loading [4]

= Side wall loading is the peak value of overpressure (p_{so}+ $C_d q_0$) and time t_d [4]

The calculated blast parameters are given in table 4 -

Table 4
Blast Load Parameters Obtained From Is 4991: 1968 FOR 0.1 tons TNT

Parameters	For standoff distances		
	20m	30m	40m
Scaled distance(z)	43	64.65	86.17
Peak side overpressure (Pso) (kg/cm^2)	0.73	0.35	0.233
Dynamic pressure (q_{so}) (kg/cm^2)	0.171	0.042	0.0185
Peak reflected overpressure(Pro) (kg/cm^2)	1.87	0.806	0.51
Positive phase duration (t_o) (millisecond)	14.0	17.5	19.82
Duration of equivalent triangular pulse(t_d) (millisecond)	9.6	13.15	14.94

IV. MODIFICATION OF STRUCTURE

The building is analyzed to check the members that have failed or not failed due to the blast loading. On analysis of charge weight 0.1tonne and Standoff distance 20m,30m,40m, it is found that the structure of Standoff distance of 30m and 40m is safe for this condition, but the beam and column of the building located at 20m distance are failing. Hence, Shear walls are added to the building to enhance the stability of the structure building. After the modifications are made, the model is re-analyzed to see if it can withstand the load placed on it.

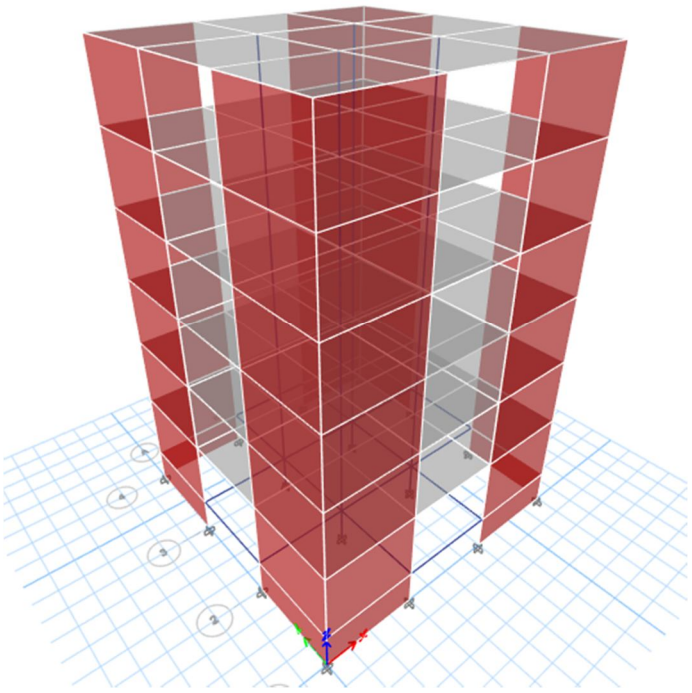

Fig. 6 Buildings with Shear Wall (3D view of Model 2)

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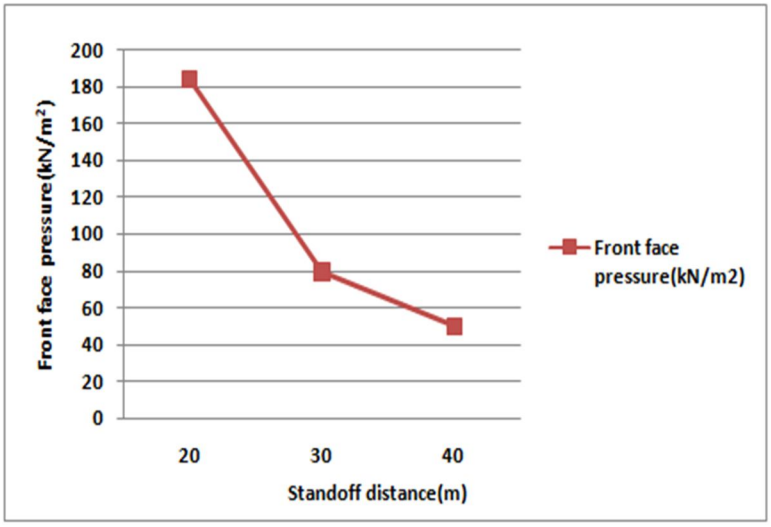
V. RESULT AND DISCUSSION

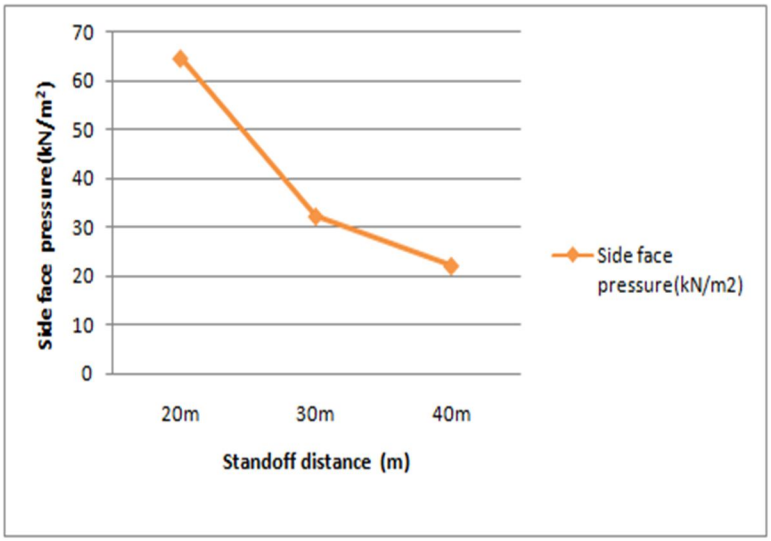
The following charts should be drawn based on the above mentioned results.

Case no.	Charge weight In TNT (Kg)	Standoff distance	Pressure On the Front face (KN/m^2)	Pressure On Side face (KN/m^2)	Normal Building		Normal Building with Shear Walls	
					the structure's greatest displacement	the structure's greatest Storey Drift	the structure's greatest displacement	the structure's greatest Storey Drift
1	100	20m	183.45	64.75	164.574	0.013	11.175	0.000666
2	100	30m	79.46	32.37	71.27	0.00563	6.806	0.000412
3	100	40m	50	22.20	44.857	0.003543	4.28	0.000259

Graph 1: The graph between the distance of the building from the blast source and the blast pressure on the front wall.



Graph 2: The graph between the distance of the building from the blast source and the blast pressure on the side wall.



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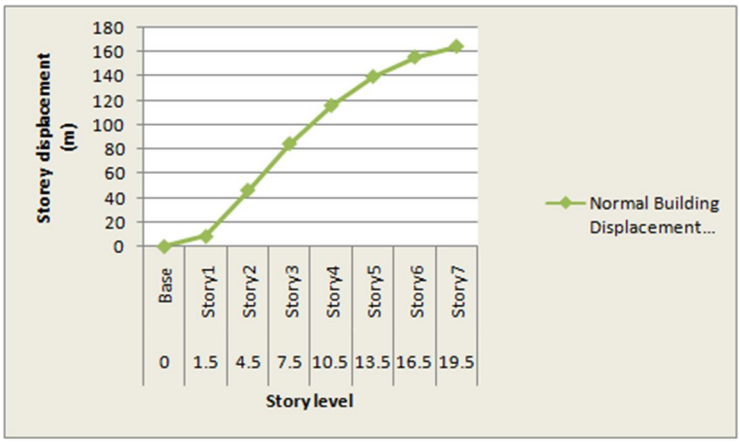
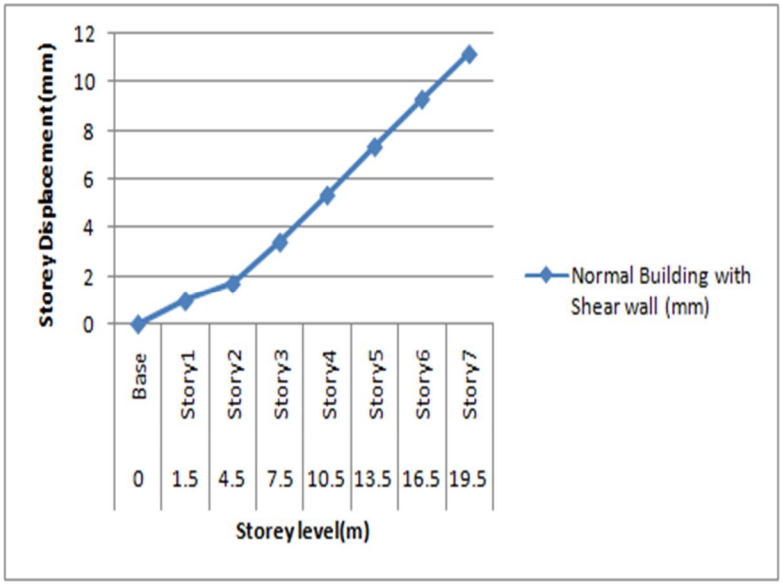
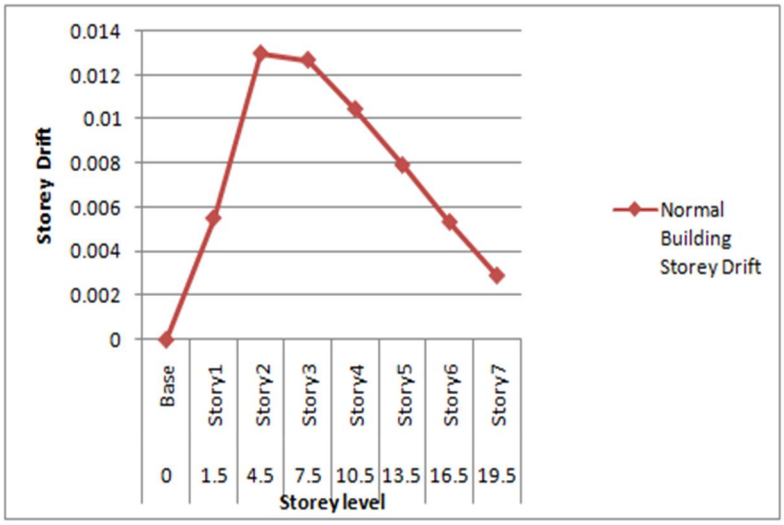
Graph 3: Graph between displacement and story level at 20 m standoff distance for the model 1



Graph 4: Graph between displacement and story level at 20 m standoff distance for the Model 2



Graph 5: Graph between Storey Drift and story level at 20 m standoff distance for the Model 1



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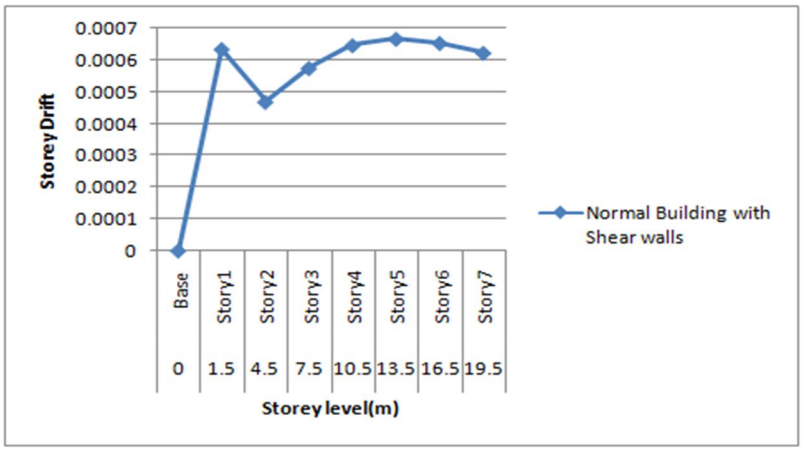
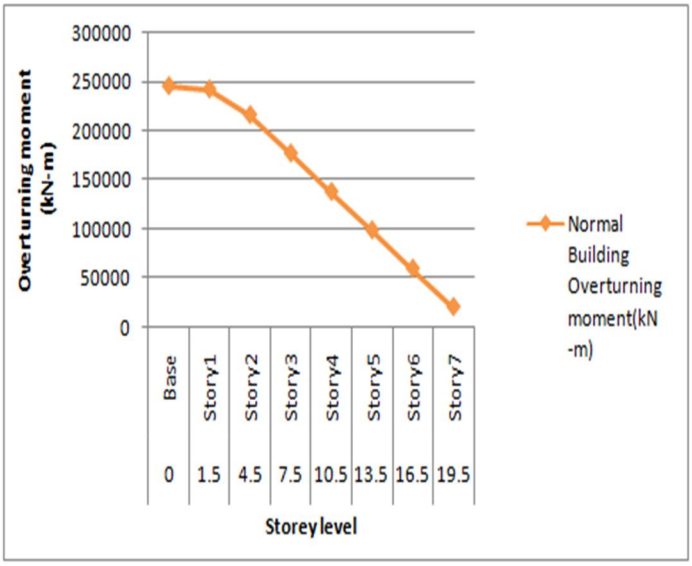
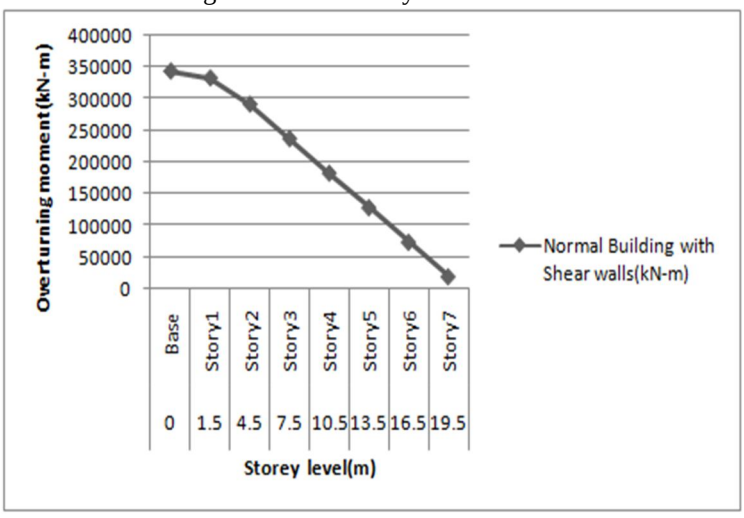
Graph 6: Graph between Storey Drift and story level at 20 m standoff distance for the Model 2



Graph 7: Graph between Overturning moment and story level at 20 m standoff distance for the Model 1



Graph 8: Graph between Overturning moment and story level at 20 m standoff distance for the Model 2



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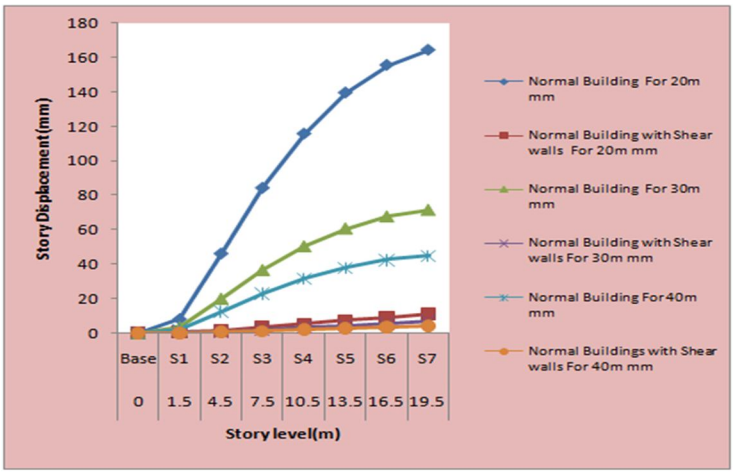
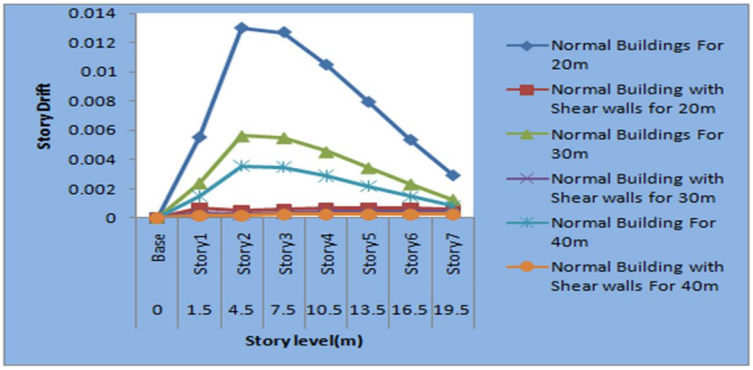
Graph 9: Analyses of Displacement Using Models 1 and 2 for 20,30, and 40m standoff distance



Graph 10**:** Analyses of Storey drift Using Models 1 and 2 for 20,30, and 40m standoff distance



The analysis of the detonation load on the building has given the following results -

At a Standoff distance of twenty meters, there is more pressure on the building than at Standoff distance thirty meters, forty meters, and at a Standoff distance of thirty meters, more pressure is being exerted than at forty meters. From this result, it follows that the pressure is increasing as the Standoff distance is decreasing. It provides greater building displacement and story drift due to the greater force exerted at a standoff distance of twenty meters than at a standoff distance of thirty meters and forty meters. Beam and column of the building at standoff distance of thirty meters and forty meters are safe, but the beam and column of the building at a standoff distance of twenty meters are failing. By modifying the building and installing shear walls, it has been found that the displacement and drift of the building have also been reduced and the beams and columns of the building failing at twenty meters' Standoff distance have also been protected.

VI. CONCLUSIONS

A. The detonation pressure increases as the distance of the structure from the explosion source decreases. The blast pressure is greater at a standoff distance of twenty meters compared to thirty and forty meters.

B. Compared to normal buildings, installation of shear walls at the corners of buildings has reduced the maximum displacement of the buildings by 93.2%, 90.0% and 90% at twenty meters, thirty and forty meters respectively.

C. Compared to normal buildings, installation of shear walls at the corners of buildings has reduced maximum storey drift of buildings by 94.87%, 92.68% and 92.68% at twenty meters, thirty and forty meters respectively.

D. When blast loading is applied at thirty and forty meters' standoff distance, displacement occurs on a normal building, but beam and column are safe, but beam and column are failing at standoff distance of 20m. Therefore, a shear wall is required to be provided only at a 20m standoff distance, due to which the beam and column are protected.

E. As a result, when a shear wall is joined with a Normal building, the structure is more resistant to explosive force.

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VII. ACKNOWLEDGMENT

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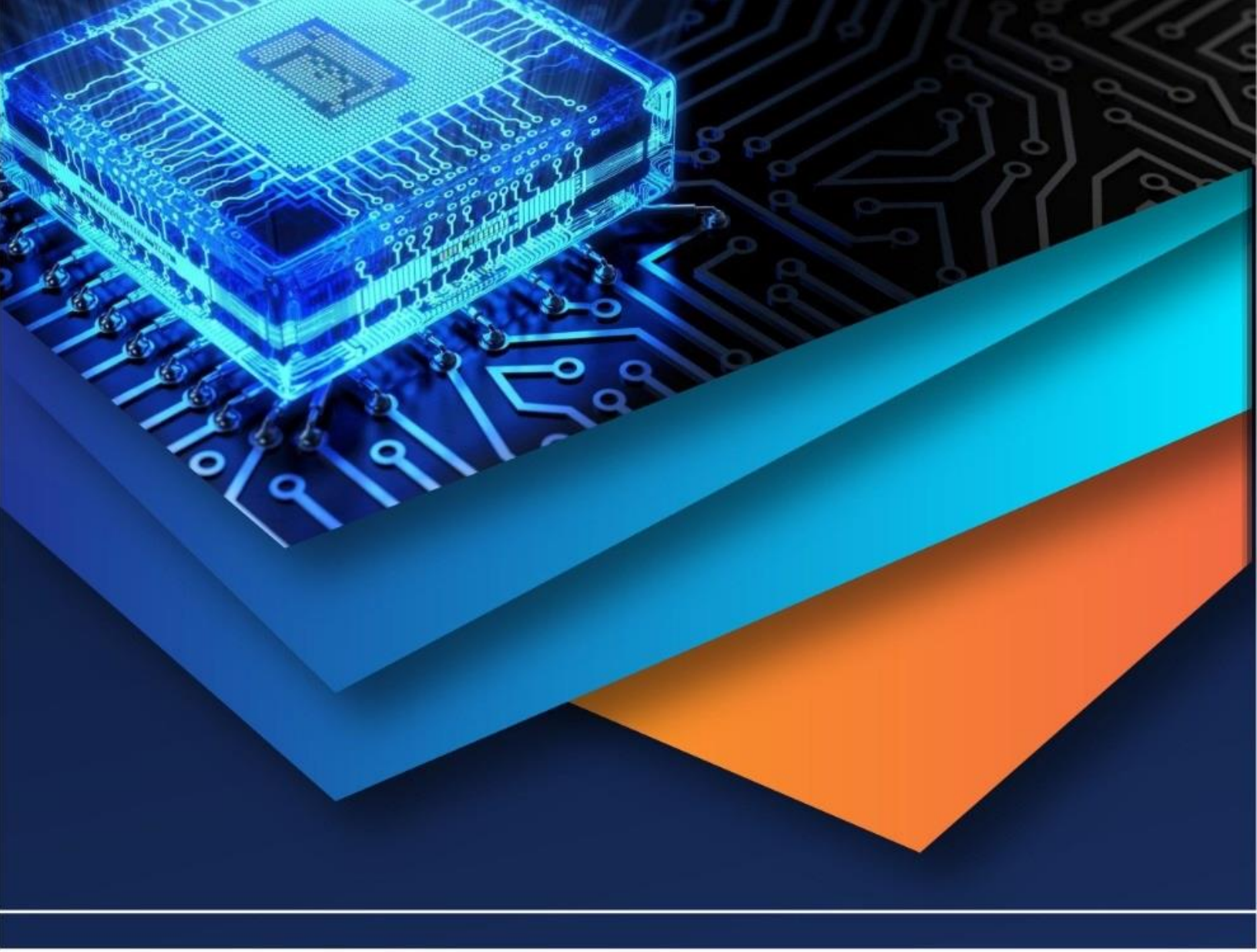

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