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Analysis of Reinforced Concrete Structure Subjected to Blast Load

Deepthi Nambiar A[1], Lokesh J K[2]
[1, 2]Department of Civil Engineering, NMAM Institute of Technology, Nitte

Abstract: The objective of this study is to shed light on blast resistant building design theories, the improvement of building security from the effects of explosion in structural design process and the design methods that should be carried out. First of all, blast wave phenomenon and types of explosion have been explained in brief. Storey displacement and storey drift is calculated by applying blast load on a G+5 models created in Sap 2000. Comparison between building with shear wall and without shear wall has done. Comparison between x bracing and inverted v bracing has done for different charge weight and different stand-off distance. The result shows that blast load depends on the charge weight and stand-off distance. More the charge weight more will be the blast load and greater the distance of blast, the lesser will be the blast load. Providing shear wall and bracings gives better result in resisting the blast load.

Keywords: Blast load, Blast wave, Explosion, Storey displacement, Storey drift, Charge weight, Stand-off distance, Shear wall, Bracings.

I. INTRODUCTION

Blast resistance design is a subject of interest for structural engineers these days and becoming popular in the field of structural engineering. Since several terror attacks were faced in the society, it is very important of this subject to emerge. Many governments and some private building owners requires a new building which resist the effect of potential blast and other incident that could cause extreme local damages. A bomb explosion inside or outside the building or nearby areas can cause extreme local damages on the structural frame, falling down of walls, bursting of large expanses of windows and shutting down of critical life safety system. Loss of life and injuries to peoples can result from any causes containing blast effect or collapsing of the buildings, fire and smoke. Moreover, significant problems due to the gas chemical explosion results in large dynamic load when compared to the original design load in numerous structures. Strategies for blast security have turned into an important thought for structural engineers because of the increase in terror attacks. Blast load is a short duration load and it is also termed as impulsive loading. Numerically it is treated as triangular loading. Ductile element for example steel and reinforcement can take in some amount of strain energy more that the brittle elements such as timber, masonry, glass which fails due to the blast effect. The damaging of the building causing loss o life is a factor that has to be minimized if the terror attacks cannot be stopped. In this paper we have explored the available literature on blast load and explained the problems and possibility of the assessment and risk overcoming of structures with standard structural analysis software.

A. Blast Wave Phenomenon

At the point when a bomb is exploded, a huge measure of energy is discharged which causes the atmospheric air to pack as the discharged gas increases. This packed air is called the blast wave and it goes from the blast source. As the blast timing increases the blast pressure amplitude decreases. This mechanism is explained through the figure 1.

At first, the blast wave increments to a pressure value more than the surrounding pressure and this is termed as the peak over pressure. This peak over pressure decreases as the wave travels far from the origin. The wave requires time, “tA”, to reach its peak over pressure.

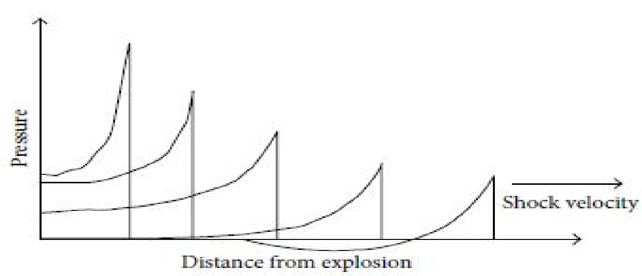

Figure 1: Blast wave propagation

Since the time period is very short, it is taken as negligible or equivalent to zero for the design purposes. The shock wave travels with a velocity U and the peak pressure "Pso" as shown in figure. Once the wave reaches the peak over pressure, it will reduce. This is called as positive period of the blast. The time taken by the pressure to reduce from the peak pressure to surrounding pressure is given as "to". Once the pressure reaches the surrounding pressure it will again reduces than the ambient pressure and it is termed as negative period of the blast. It remains for long time when contrasted to the positive blast phase and it is denoted as "Pso". The negative phase of the blast is typically not considered into design purpose but the positive phase is considered because the main structural damages are due to the positive phase. The effect due to the negative phase are very less when compared to the positive phase. Therefore there won't be large impact on the structures. However the overall pressure values have to be taken while considering the full performance of the building when subjected to blast loading.

The collapse of the structure or the damages in the structure depends on the standoff distance and also the amount of energy released during the explosion. [Fig 2]

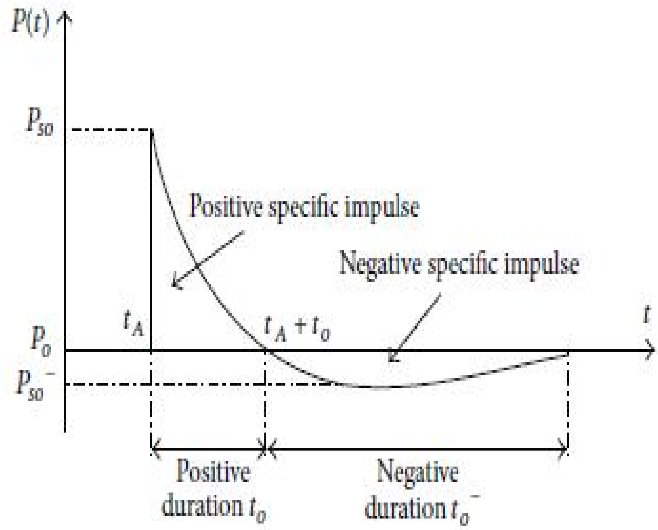

Figure 2: Blast wave pressure-time history

II. LITERATURE REVIEW

T Ngo, P. Mendis *et, al*.[1] illustrated that the terror attack inside or close-by building causes major damages to the building as well as the life of the people. Because of the danger from such extreme loading conditions, so many methods have been carried out to construct a blast safe structure. The examination and design of a blast proof structure needs a complete comprehension of the blast phenomenon and dynamic response of different structural members. In this paper a clarification of nature of explosion and system of blast wave in free air is given. This paper additionally introduces distinctive methods to estimate blast load and structural response. It is concluded that for high risk places for example public and commercial tall building, blast resistant structure should be constructed. Providing ductility also improve the building to resist the blast load.

Umesh Jamakhandi and Dr.S.B. Vanakudre [2] objective is to understand the blast proof building design theories, improvement of building safety against explosive and design techniques that should be accepted. Explosives and blast types have discussed in the beginning. The software ETABS is used to analyse the blast load and plotted a graph lateral displacement versus elevation of the building. It is concluded that when the explosive weight is increased, the storey drift increases and when the distance of the source of blast increases, the storey drift decreases. It is established that the finest model is rectangular frame which shows the lowest value of story drift.

Hrvoje Draganic and Vladimir Sigmund [3] presented a way towards deciding the blast load on the structure and give a numerical case of an invented structure presented to this load. The point was to get comfortable with the issue of blast load due to regularly developing terror attacks and absence of rules. The blast load for close blast was resolved and mimicked on a model building utilizing SAP2000 and loading was characterized as a record of weight after some time. It is found that the building which is exposed to far explosion requires only the sufficient ductility and for close explosion more reinforcement is required.

Zeynep Koccaz *et, al.* [4] the expansion in the quantity of terrorist attacks particularly over the most recent couple of years has demonstrated that the impact of blast load on structures is a genuine issue that ought to be mulled over in the outline procedure. In spite of the fact that these sorts of attacks are outstanding cases, man influenced calamities; to blast loads are in truth powerful loads should be painstakingly computed simply like seismic loads and wind loads.

The target of investigation is to reveal insight into blast safe building plan speculations, the upgrade of building safety against the impact of explosives in both compositional and auxiliary outline process and the design procedures that ought to be completed. In the beginning, explosives and blast composes have been clarified quickly. Also, the common parts of blast method have been introduced to clear up the impacts of explosives on structures. To have a superior comprehension of explosives and qualities of blast will lead us to make us blast safe building plan more proficiently. Basic strategies for expanding the ability of a building to provide security against terrorist effect is studied both in architectural and structural approach.

Christopher D. Eamon *et, al.* [5] presented that different qualities of a structure will influence its reaction when subjected to blast load. In this examination, the resistance of a reinforced concrete structure to the blast load was examined using an existing finite element approach. 14 different models were created to analyse, with 5 structure designed as moment resisting frame structures and 9 were designed as shear wall structures. Structures with 3,6,10 stories and 3, 4, 5 bay symmetric setups were considered. Charging weights were given depends on the building height in the range of 340-700 kg. The result shows that the parameters such as building size and shear wall placement has major role in design of blast resistant structure. The shear wall in structure and building larger in height and plan has more resistance to blast load and collapse.

Manmohan Dass Goel & Vasant A. Matsagar [6] proposed that due to the fanatic activities, the buildings are presented to dangers from blast load. Lots of incidents have taken place which caused risk to life and property. Therefore the aim of this study is to present different strategies for blast load to make it less severe and to protect the structure. Strategies to protect the structure from blast are divided in to two categories: strengthening the member and protection strategies. It is found that protection of the structure is less expensive when compared to the other and also it includes standoff distance from the threat so that the blast load pressure reduces due to the distance. And they also provide a solution for places like cities where standoff distance cannot be provided. In such situation a designed blast wall can be provided to resist the blast pressure. [Fig 3].

Assal T. Hussein [7] carried out the analytical method for a SDOF frame work investigation subjected to blast loading. Two sort of blast wave applied to understand the non-linear behaviour of the structure. Time history analysis is carried out which gives the basic study of the behaviour of SDOF system under detonation load. Two kinds of explosion wave simple and bilinear pulse is applied. Result showed the type of wave on time history analysis and computed energy. The outcome obtained from the computer program NON-SDOF clarified the impact of type of blast wave on the behaviour system.

Rupert G. Williams *et, al* [8] displayed an attempt to find out numerical reaction of a seismically designed SDOF structure to blast loading. A portal frame was designed in Northen Trinidad to resist the blast load. 500 kg of charge weight of TNT was used and different standoff distance of 45, 33, 20 meters were taken. By using empirical methods the blast load was determined. From this study it is showed that the designed SDOF model entered the plastic region due to the blast load in a critical standoff distance.

Edward Eskew & Shinae Jang [9] carried out a systematic approach determine the causes and results of terrorist attacks. The better way to understand the impact of terror is to understand the nature of the attack. Different type of explosions, including physical, chemical, electrical and nuclear was provided in this report. Impact from an explosion is obtained from analytical and experimental methods. Analysis technique for a damaged structure is also explained in depth. From this knowledge of an explosion the damage of the structure can be determined or detailed models could be developed to calculate the damage that has happened already.

Jon A. Schmidt [10] carried out the method accessible to characterize an external bomb threat and assess basic design loads and component reaction using simple dynamic models and principle. Due to the expansion of threats of terror attacks in the course of last decade has made consciousness of building owners and designers. A structure cannot resist any explosion but it can be improved by increasing the performance of the structure. It is found that by increasing the standoff distance and also strengthening the elements, designer can give a structure a reasonable chance of escaping death and reducing severe damages.

ABS Consulting Ltd. [11] developed a tool for the analysis of the response of the structure which is subjected to blast load. This tool is named as BLAST STAR, which is utilized to examine the basic structure under the blast type pulse of various types of geometries, durations and peak pressure. The tool uses the finite element analysis to obtain the result so as to discover the force displacement and equivalent mass characteristics of a system. The result of the analysis is analysed against the non-linear model FE analysis. The outcome discovered the maximum displacement gained for multiple loading set up for a series of the structures. The level of displacement is demonstrative of the level of damage emerging from a specific pulse load and can be utilized to anticipate levels o plastic strain in the structure. Computation of the response forces at the support as well as forces are additionally done and the outcome analysed.

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Ashish Kumar Tiwary *et, al* [12] explained the effects of bomb explosion or terror attack that causes major distructions on the building's external and internal structural elements containing collapse of the walls, windows. It also results in loss of life and injuries to resident. In some cases one or more columns of the building are destructed which leads to failure of beam slab system which results in dynamic fall of the pieces or a whole structure. Subsequently, columns inclined to blast are required to be researched for high strain loading impacts. This paper presents the modular investigation of a steel section taken from a vast building outline subjected to blast loading. Proper examination was done to evaluate the strength of numerical model prepared in explicit dynamic ANSYS.

Saeed Ahmad [13] carried out an experiment on four different reinforced concrete walls with different thickness. These walls are tested with various explosive loads and measured distance. Pressure sensor, accelerometer, dynamic strain amplifier, data acquisition board and strain gauges were used to measure air blast and ground shock parameters. It is concluded that air blast and ground shock is important for correct analysis of structural response of structure.

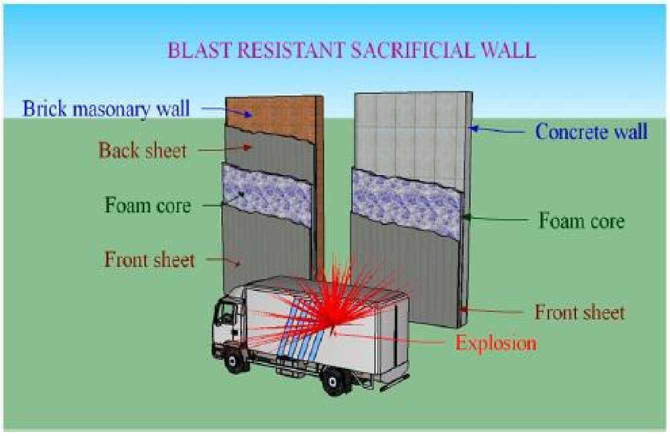

Fig 3 Typical layout of a Sacrificial Wall

A. *Effect Of Blast Load*

Blast effects on structures are classified in to two: Primary effect and Secondary effect. Primary effect includes

1) *Air Blast:* The increase in the air pressure surrounding the building due to the blast wave.
2) *Direct Ground Shock:* This type of shock is due to the blast that occurs when an unstable material is placed as fully covered or half covered on the surface. The vibration from this travels horizontally same as earthquake but with different frequency.
3) *Heat:* Some amount of unstable energy is transformed to heat. Building equipment gets damaged at expanded heat. Because of high temperature the heat can also cause fire.
4) *Primary* Fragments: Fragments from the volatile sources which are scattered out into the atmosphere at high velocity. Secondary effect is the fragments that hit the people or building close to the explosion. They damage the windows and glasses and also cause injuries to the people near the explosion.

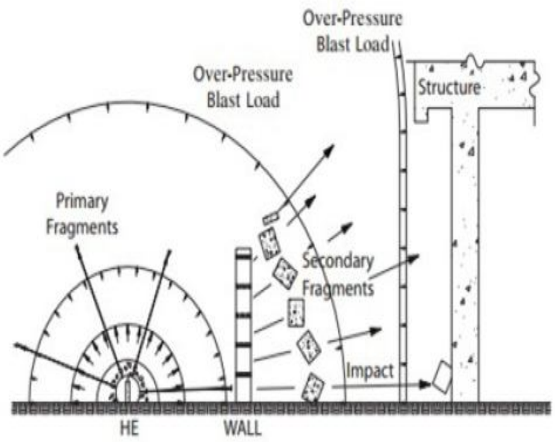

Figure 4: Debris and Broken Fragments

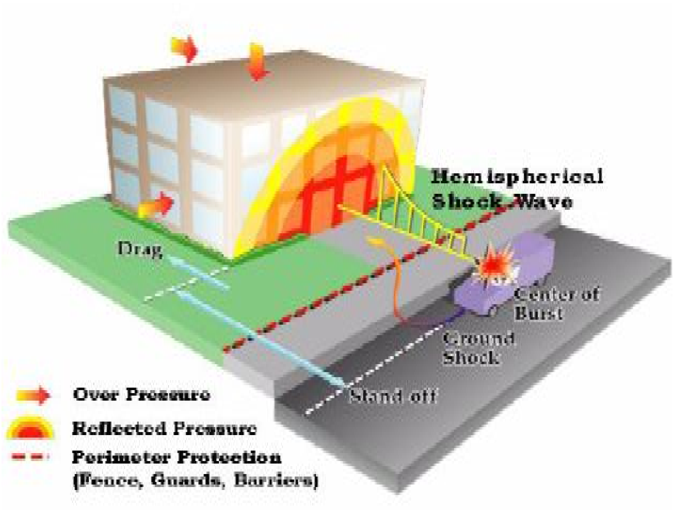

Fig 5: Blast wave impact on structure

B. Preventive Philosophy

It is impossible to design a building which is blast resistant but it can be designed by improving the performance of the structural members. The philosophy that can be followed during design is

1) The outside columns could removed from the frame and consider the interior columns as less capacity so the interior columns will be more than the usual. The load for the missing columns should be distributed by using suitable techniques.
2) After removing the exterior columns, the beams should be made stronger than usual. If the beams are weak after the blast load, the loads are distributed to the interior columns.
3) Provide shear walls at suitable intervals.

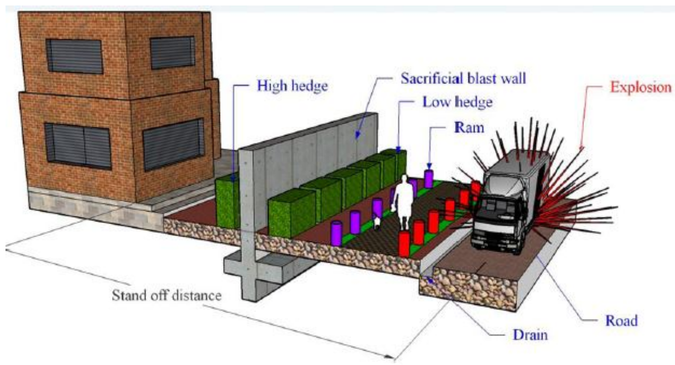

Fig 6: Different methods to improve the safety of building against blast loading

III. METHODOLOGY

A G+5 model is created in Sap 2000. Dead loads and live loads are taken from IS 875 part 1 and part 2. It is analysed as non-linear static (loads are applied as static joint load) in the modal. The height of the storey is 3m and the materials used are M20 grade of concrete for beams and slabs and M25 grade of concrete for columns and Fe500 steel.

Three models are created in sap 2000 i.e. building with shear wall, building without shear wall and building with bracings including shear wall. Shear walls of M25 grade of concrete and 200mm thickness is provided at three sides of the lift having a height of 3m. Building without shear wall is created by providing columns of 200x600mm size at four corners of the lift.

The UFC 3 340-02 code guidelines are used for the calculation of external surface blast load. The blast load values obtained from the procedure for a TNT weight of 100kg, 200kg, 300kg with 30m and 35m stand-off distance is shown in Table 1.

The obtained blast load value for 100kg, 200kg, 300kg at 30m and 35m stand –off distance are applied as joint load at the front side of the building for the given models (Fig 10, Fig11)

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Weight of Explosive (TNT)	Pressure on the front face in KN/m^2	Stand- off distance in m	Corner joint load in KN	Middle joint load in KN
100 Kg	38.58 KN/m^2	30 m	26.21 KN	52.42 KN
	22.39 KN/m^2	35 m	15.21 KN	30.42 KN
200 kg	56.49 KN/m^2	30 m	38.37 KN	76.75 KN
	46.85 KN/m^2	35 m	31.82 KN	63.65 KN
300 kg	75.101 KN/m^2	30 m	51.02 KN	102.04 KN
	65.45 KN/m^2	35 m	44.46 KN	88.93 KN

Table 1: The pressure and joint load acting on the front face

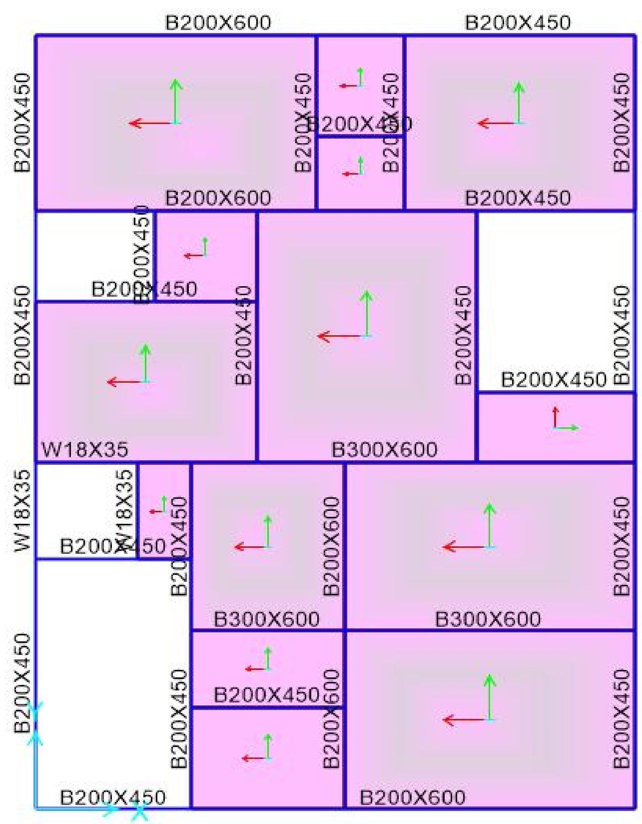

Fig 7: Plan of a building

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Structure is analyzed for different cases:
Case 1: G+ 5-storey building having blast with charge weight of 100kg TNT at 30m standoff distance.
Case 2: G+ 5-storey building having blast with charge weight of 100kg TNT at 35m standoff distance.
Case 3: G+ 5-storey building having blast with charge weight of 200kg TNT at 30m standoff distance.
Case 4: G+ 5-storey building having blast with charge weight of 200kg TNT at 35m standoff distance.
Case5: G+ 5-storey building having blast with charge weight of 300kg TNT at 30m standoff distance.
Case 6: G+ 5-storey building having blast with charge weight of 300kg TNT at 35m standoff distance.
Model 1: Building with shear wall
Model 2: Building without shear wall
Model 3: Building with bracings by using section ISMB 100.

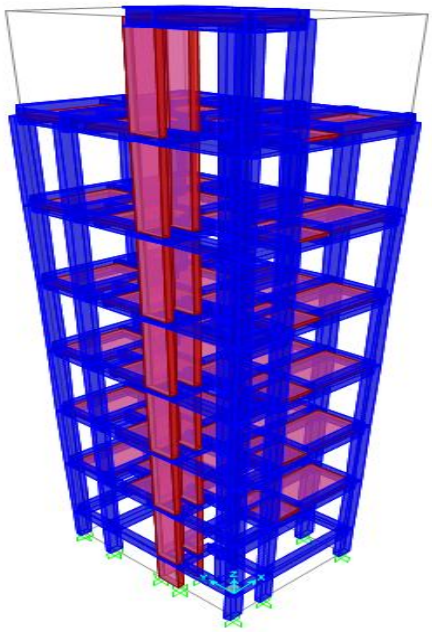

Fig 8: Rendered view of G+5 storey building with shear wall

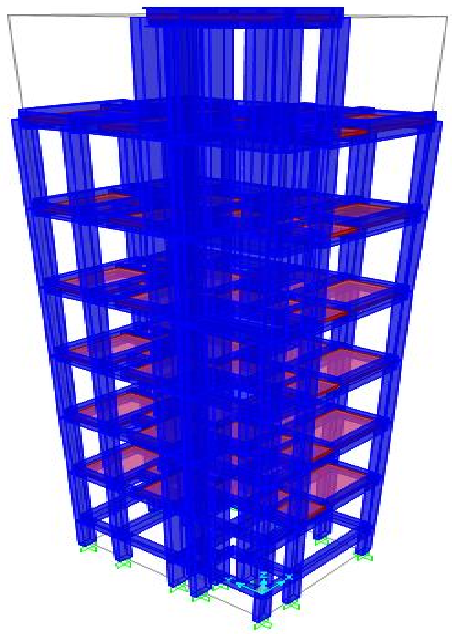

Fig 9: Rendered view of G+5 storey building without shear wall

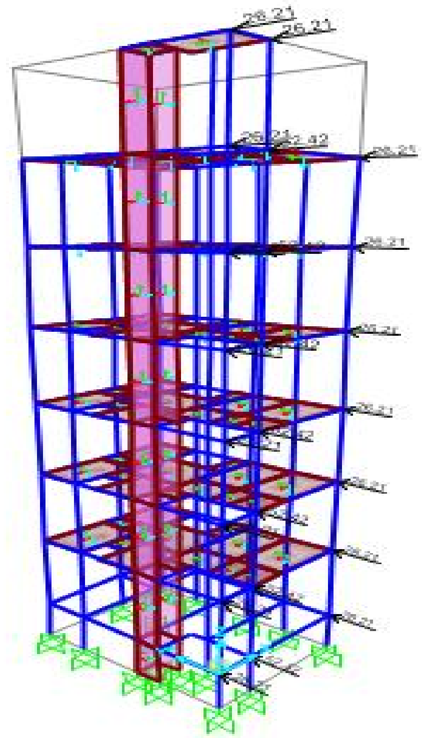

Figure 10: 100 kg TNT blast load applied at front face of building as joint load at 30m stand-off distance(With shear wall)

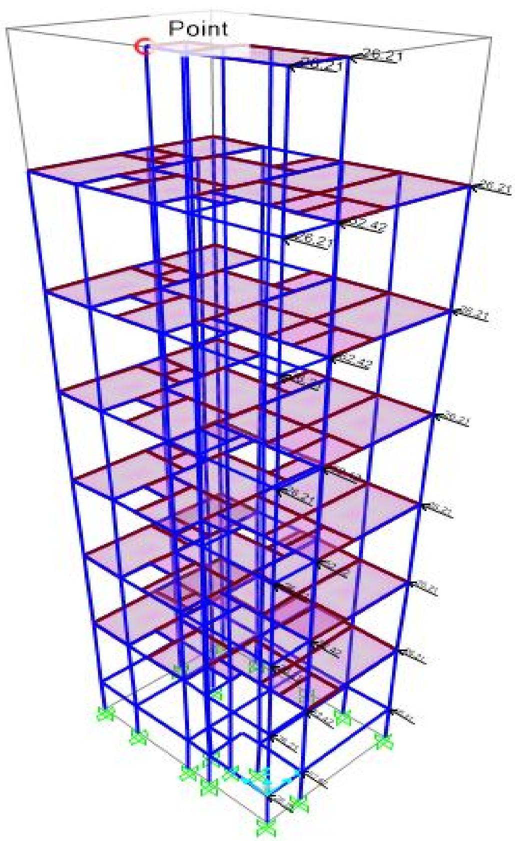

Figure 11:100 kg TNT blast load applied at front face of building as joint load at 30m stand-off distance (Without shear wall)

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Three types of comparison has shown in this paper

1) Comparing the building with and without shear wall for different charge weight and different stand-off distance.
2) Comparison between x bracing and Inverted-v bracing has done by analyzing the lateral displacement of the structure subjected to blast load for 100kg,200kg,300kg TNT at 30m and 35m distance.
3) Comparing building with shear wall and building with bracing (including shear wall) has done for different weight of explosives at different stand-off distance by analyzing horizontal displacement and storey drift of the structure.

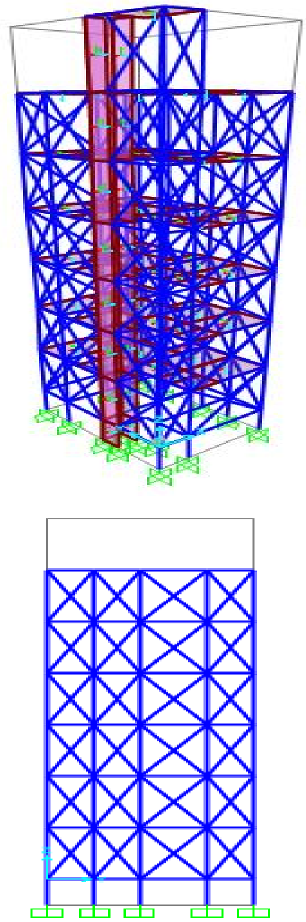
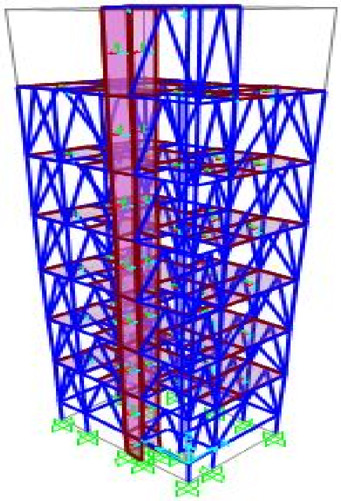


Fig 11: Building with X bracings of Section ISMB 100 provided at outer periphery



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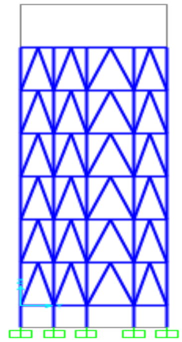
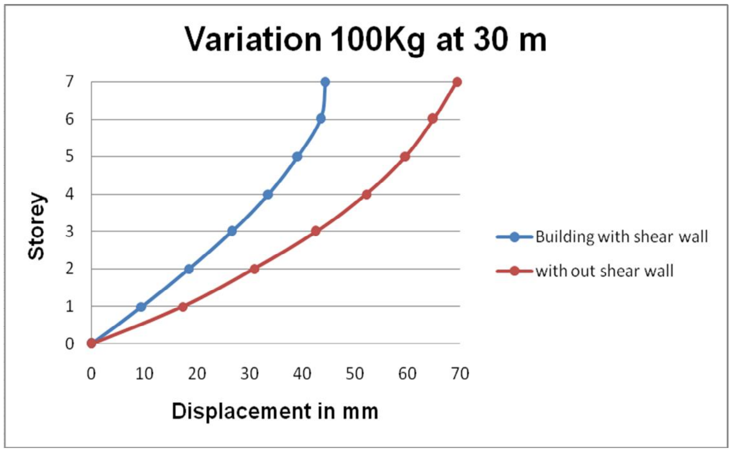


Fig 12: Building with inverted v bracings of Section ISMB 100 provided at outer periphery

IV. RESULTS AND DISCUSSIONS

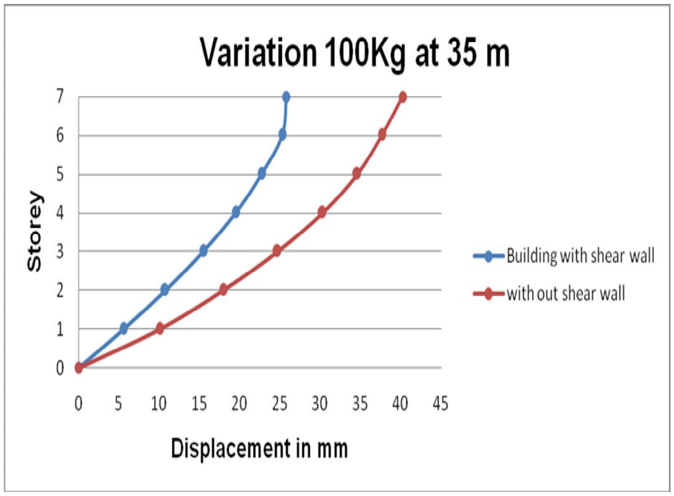
A. *Storey Displacement*

As building with shear wall provided for lift is compared to building without shear wall, the graph of storey displacement versus storey level of building shows that as stand-off distance increases, blast load decreases and as charge weight increases, blast load increases.



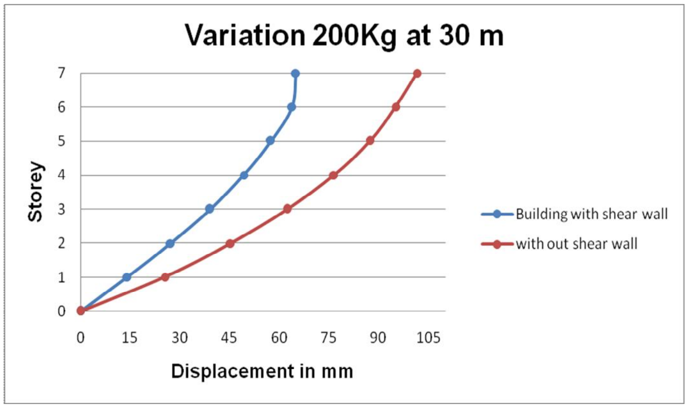
Graph 1: Lateral Displacement results of 100Kg TNT between building with shear wall and without at 30 m stand-off distances

The maximum storey displacement for 100kg TNT at 30m stand-off distance in building with shear wall is 44.39mm and building without shear wall gives 40.26mm storey displacement. (Graph 1)



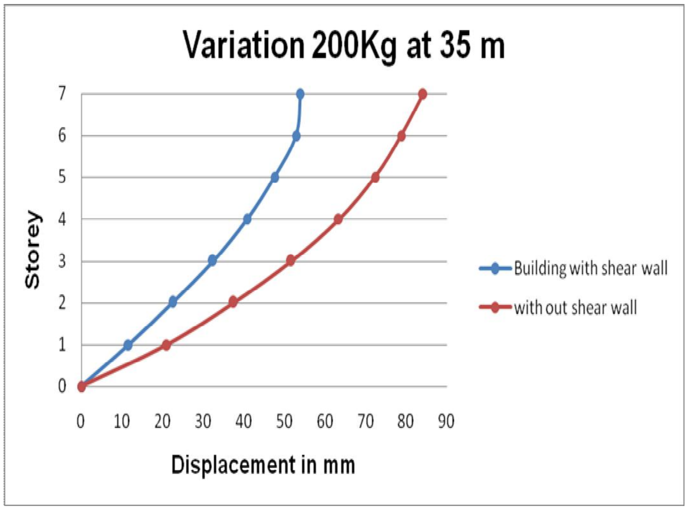
Graph 2: Lateral Displacement results of 100Kg TNT between building with shear wall and without at 35 m stand-off distances

Building with shear wall gives 25.76mm storey displacement at 35m stand-off distance and building without shear wall gives 40.26mm. (Graph 2)



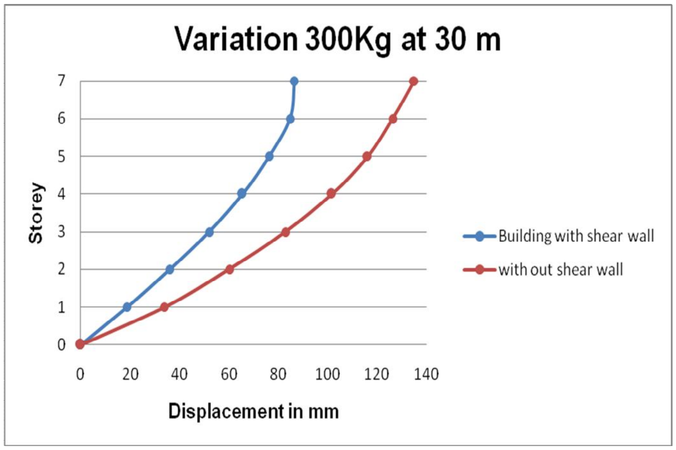
Graph 3: Lateral Displacement results of 200Kg TNT between building with shear wall and without at 30 m stand-off distances

The maximum storey displacement for 200kg TNT at 30m stand-off distance in building with shear wall is 64.98mm and building without shear wall gives 101.57mm storey displacement .(Graph 3)



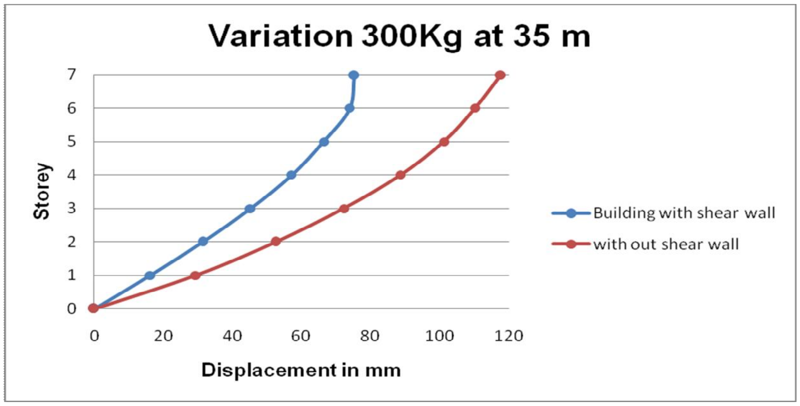
Graph 4: Lateral Displacement results of 200Kg TNT between building with shear wall and without at 35 m stand-off distances

Whereas building with shear wall gives 53.90mm storey displacement at 35m stand-off distance and building without shear wall gives 84.23mm. (Graph 4)



Graph 5: Lateral Displacement results of 300Kg TNT between building with shear wall and without at 30 m stand-off distances

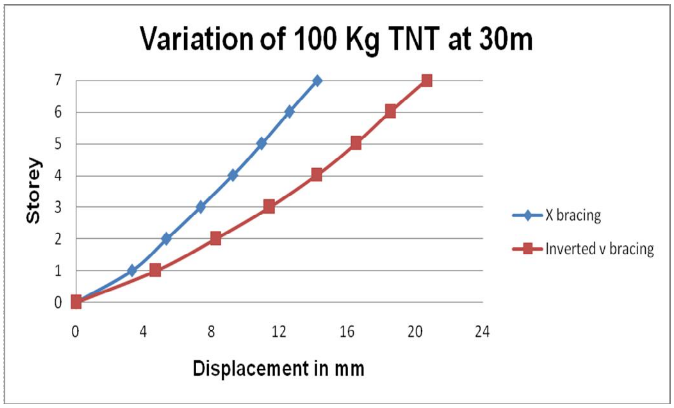
The maximum storey displacement for 300kg TNT at 30m stand-off distance in building with shear wall is 86.42mm and building without shear wall gives 135.05mm storey displacement. (Graph 5)



Graph 6: Lateral Displacement results of 300Kg TNT between building with shear wall and without at 35 m stand-off distances

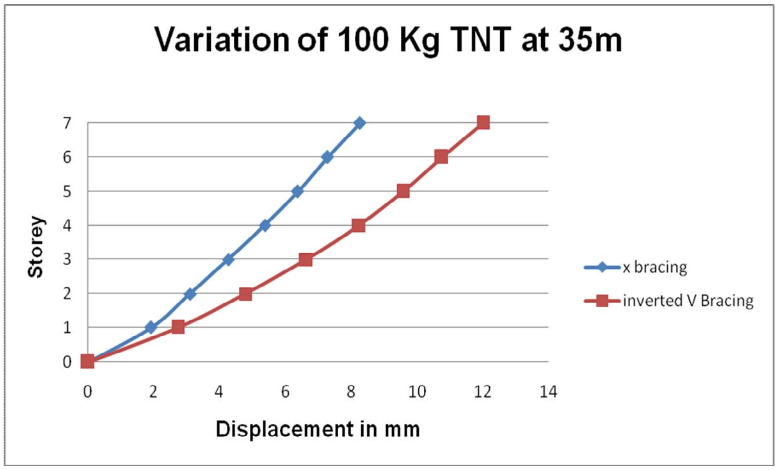
Whereas building with shear wall gives 75.30mm storey displacement at 35m stand-off distance and building without shear wall gives 117.69mm. (Graph 6)

As x bracing is compared with inverted v bracing, the graph of later displacement versus storey level of building shows that as distance of the source of blast increases, the storey displacement decrease and as weight of explosive increases, the storey drift increases.



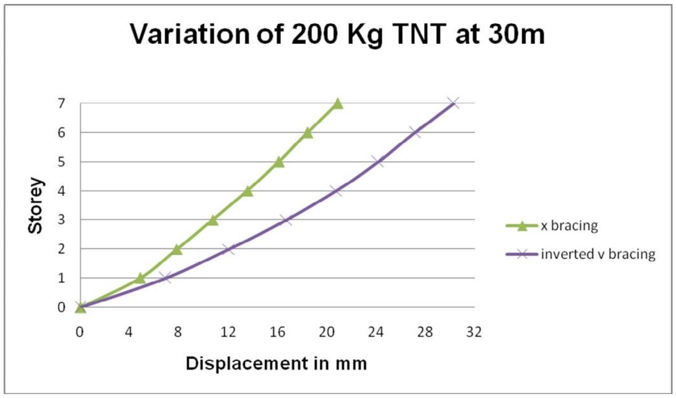
Graph 7: Lateral Displacement results of 100Kg TNT between X bracing and Inverted V bracing at 30 m stand-off distance

The maximum storey displacement for 100kg TNT at 30m stand-off distance is 14.26mm for X bracing structure and 20.70mm for inverted-v bracing structure. (Graph 7)



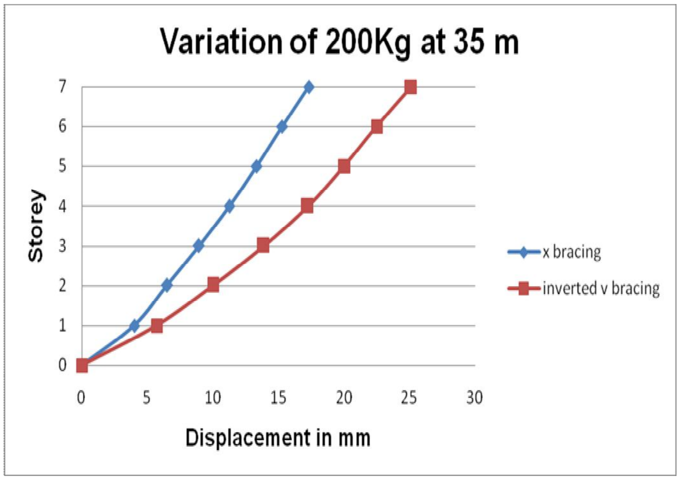
Graph 8: Lateral Displacement results of 100Kg TNT between X bracing and Inverted V bracing at 35m stand-off distance

At 35m stand-off distance, the highest storey displacement in X bracing structure is 8.27mm and in inverted-v bracing structure, it is about 12.014mm. (Graph 8)



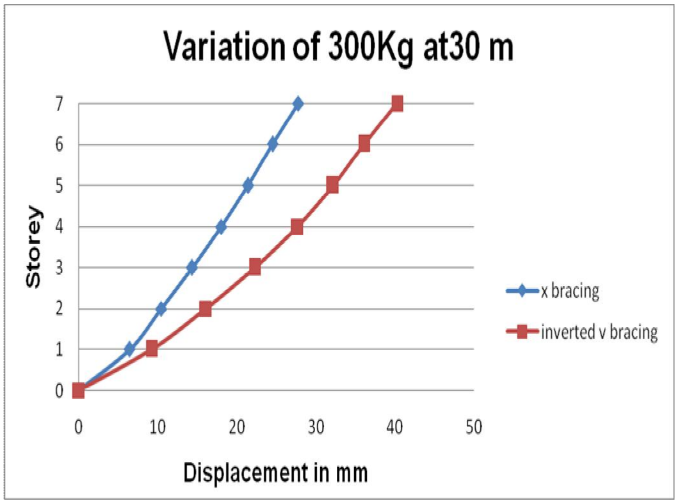
Graph 9: Lateral Displacement results of 200Kg TNT between X bracing and Inverted V bracing at 30 m stand-off distance

For 200kg TNT, the maximum lateral displacement at 30m stand-off distance is 20.88mm in X bracing structure and 30.30mm in inverted v bracing structure. (Graph 9)



Graph 10: Lateral Displacement results of 200Kg TNT between X bracing and Inverted V bracing at 35 m stand-off distance

At 35m stand-off distance, the highest storey displacement in X bracing structure is 17.32mm and in inverted-v bracing structure, it is about 25.13mm. (Graph 10)



Graph 11: Lateral Displacement results of 300Kg TNT between X bracing and Inverted V bracing at 30m stand-off distance

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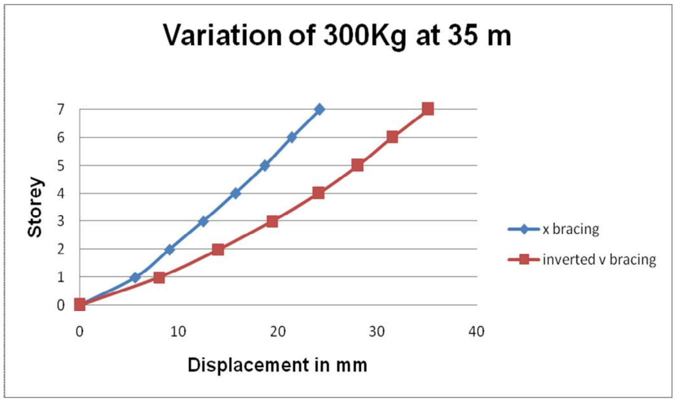
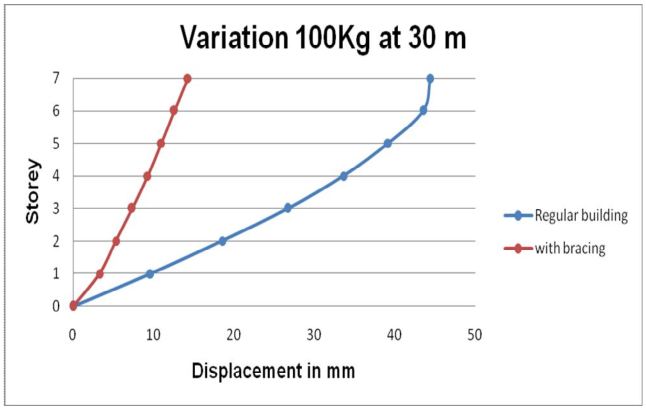
For 300kg TNT, the maximum lateral displacement at 30m stand-off distance is 27.75mm in X bracing structure and 40.29mm in inverted v bracing structure. (Graph 11)



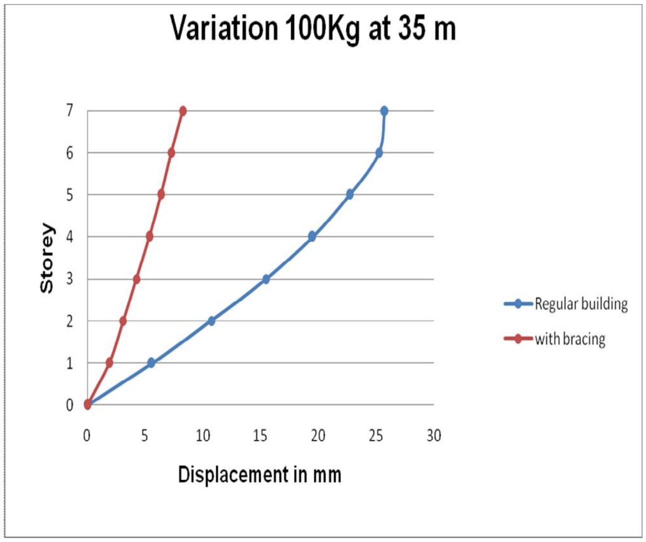
Graph 12: Lateral Displacement results of 300Kg TNT between X bracing and Inverted V bracing at 35m stand-off distance

At 35m stand-off distance, the maximum storey displacement in X bracing structure is 24.20mm and in inverted-v bracing structure, it is about 35.11mm. (Graph 12)

As building with shear wall is compared with building with bracing and shear wall, the graph of later displacement versus the storey level of building shows that as distance of the explosion increases, the storey displacement decrease and as weight of explosive increases, the storey drift increases.



Graph 13: Lateral Displacement for a charge weight 100 kg TNT at 30m standoff distance with and without bracings



Graph 14: Lateral Displacement for a charge weight 100kg TNT at 35 m Stand-off distance

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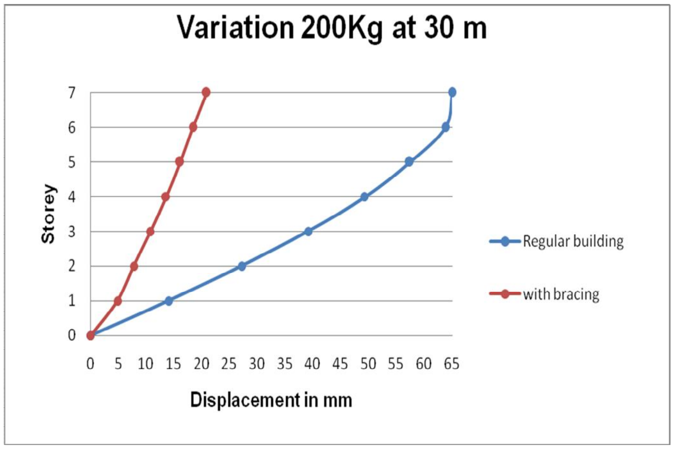
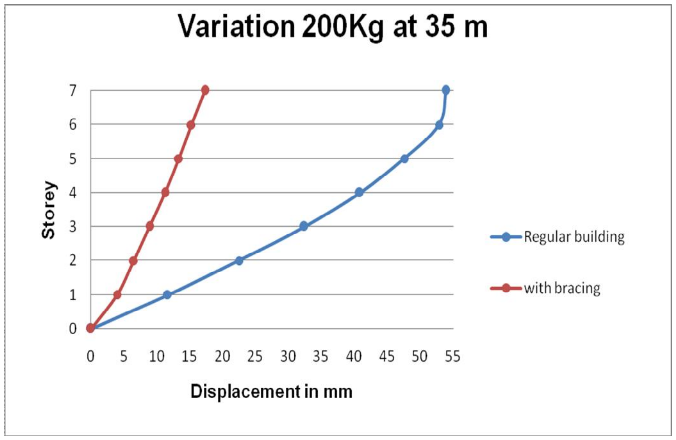
The maximum storey displacement for 100kg TNT is 44.39mm at 30m and 25.76 at 35m stand-off distance. Whereas for building with x bracing the maximum storey displacement is 14.26mm at 30m and 8.27mm at 35m.(Graph 13 and 14)

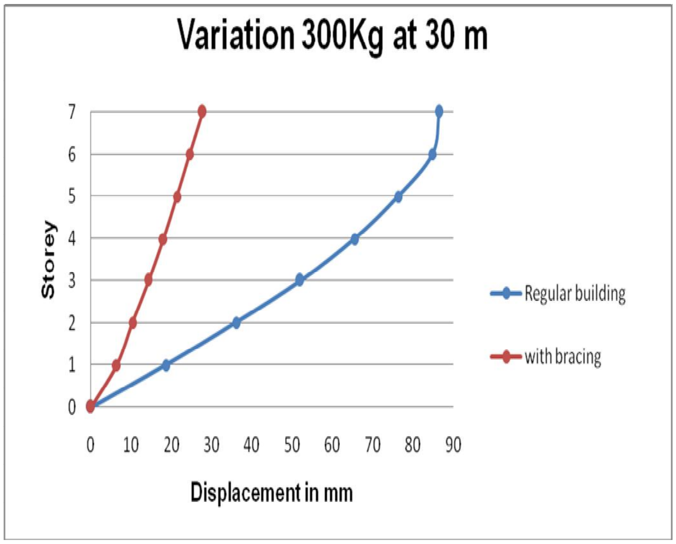


Graph 15: Lateral Displacement for a charge weight 200kg TNT at 30m stand-off distance



Graph 16: Lateral Displacement for a charge weight 200kg TNT at 35m stand-off distance

For 200kg TNT, the maximum lateral displacement in regular building is 64.98mm at 30m and 53.90mm at 35m and for building with bracing 20.88mm at 30m and 17.32mm at 35m (Graph 15 and 16)



Graph 17: Lateral Displacement for a charge weight 300kg TNT at 30m stand-off distances

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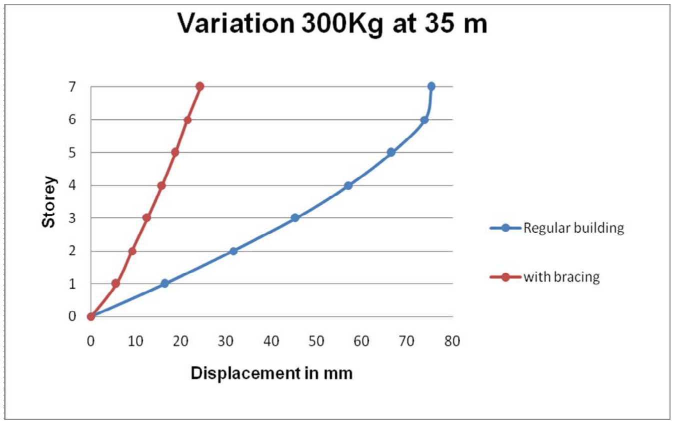
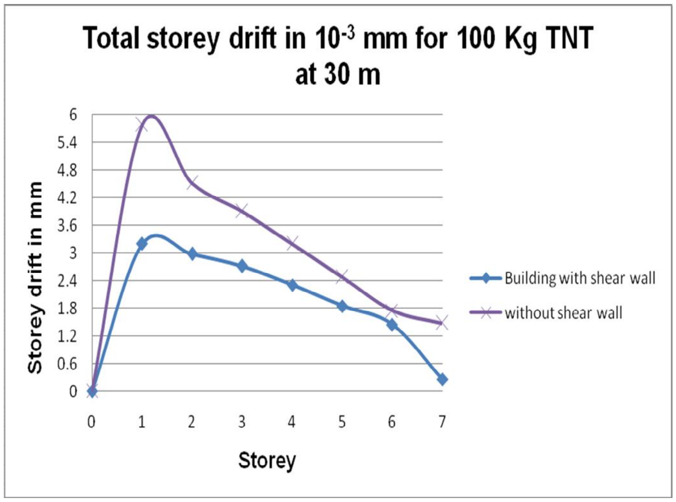


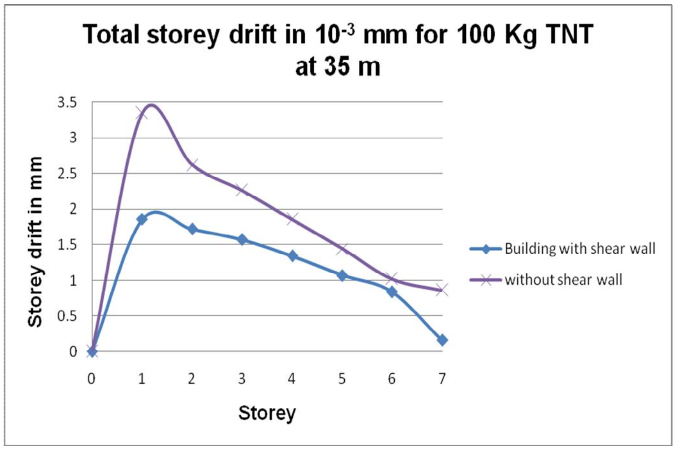
Graph 18: Lateral Displacement for a charge weight 300kg TNT35m stand-off distance

For 300kg TNT, the maximum lateral displacement in regular building is 86.42mm at 30m and 75.30mm at 35m and for building with bracing 27.75mm at 30m and 24.20mm at 35m (Graph 17 and 18).

B. Storey Drift

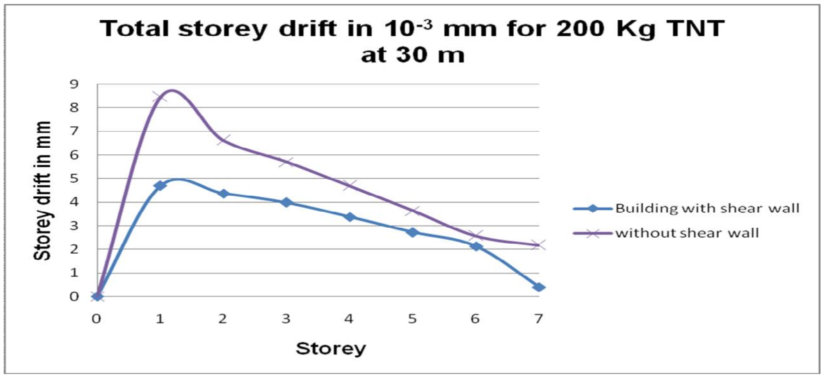


Graph 19: Inter storey drift for an explosive weight 100kg at 30m stand-off distance between building with shear wall and without shear wall

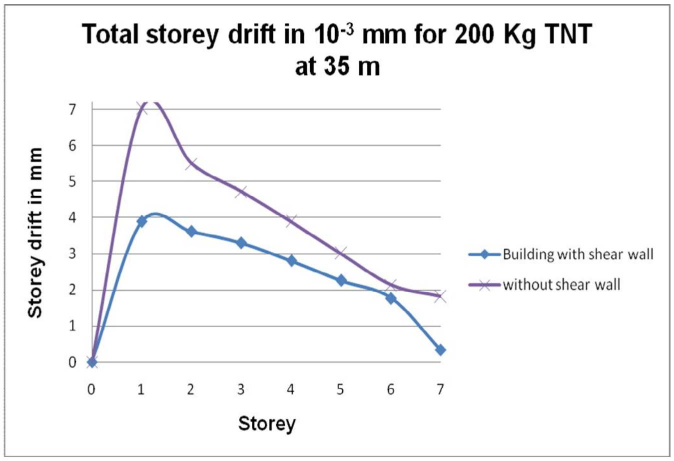


Graph 20: Inter storey drift for a charge weight 100kg TNT at 35m stand-off distance between building with shear wall and without shear wall

From the comparison between building with shear wall and building without shear wall, it is found that for 100kg TNT, the highest storey drift in building with shear wall is 3.20mm at 30m and 1.86 at 35m stand-off distance. Whereas for building without shear wall the highest storey drift is 5.78 mm at 30m and 3.35mm at 35m. (Graph 19 and 20).

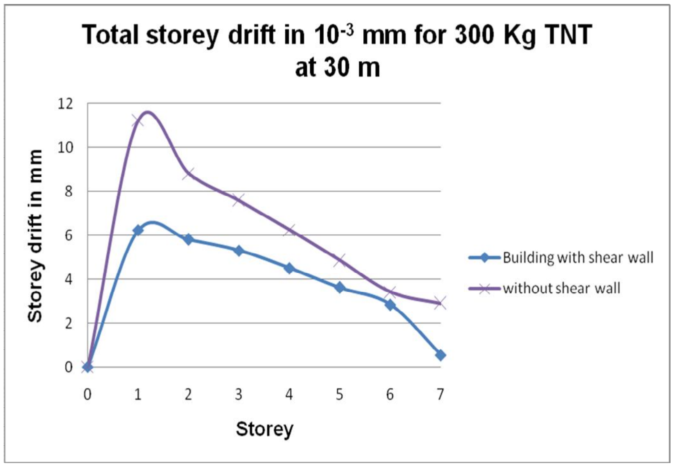


Graph 21: Inter storey drift for a charge weight 200kg TNT at 30m stand-off distance between building with shear wall and without shear wall



Graph 22: Inter storey drift for a charge weight 200kg TNT at 35m stand-off distance between building with shear wall and without shear wall

For 200kg TNT, the maximum storey drift in building with shear wall is 4.686mm at 30m and 3.886mm at 35m and for building without shear wall, the maximum storey drift is 8.46mm at 30m and 7.016mm at 35m. (Graph 21 and 22)



Graph 23: Inter storey drift for a charge weight 300kg TNT at 30m stand-off distance between building with shear wall and without shear wall

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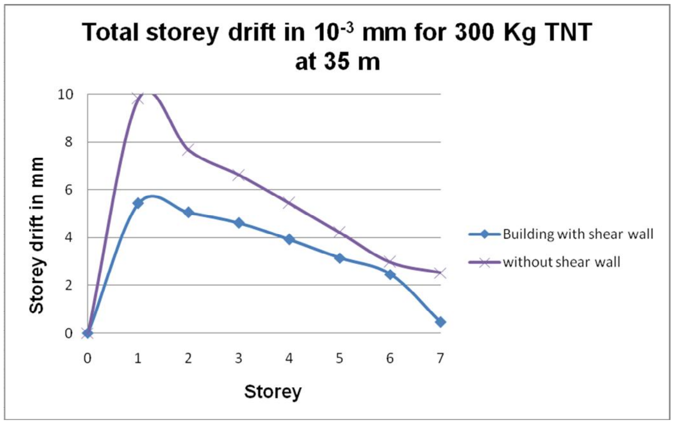
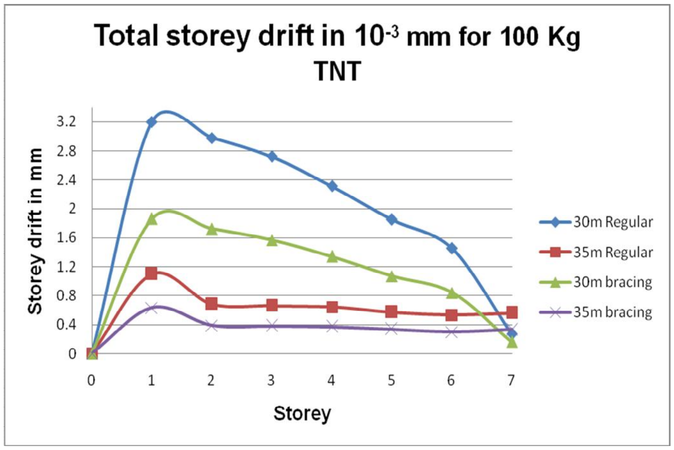


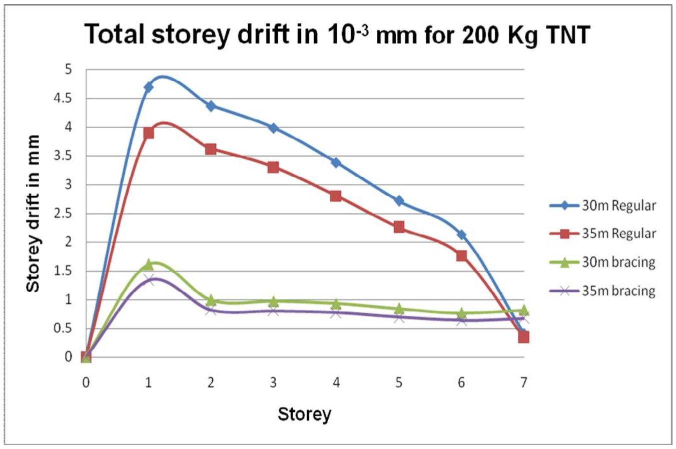
Graph 24: Inter storey drift for a charge weight 300kg TNT at 35m stand-off distance between building with shear wall and without shear wall

For 300kg TNT, the maximum storey drift in building with shear wall is 6.230mm at 30m and 5.43mm at 35m and for building without shear wall, the maximum storey drift is 11.25mm at 30m and 9.80mm at 35m. (Graph 23 and 24)



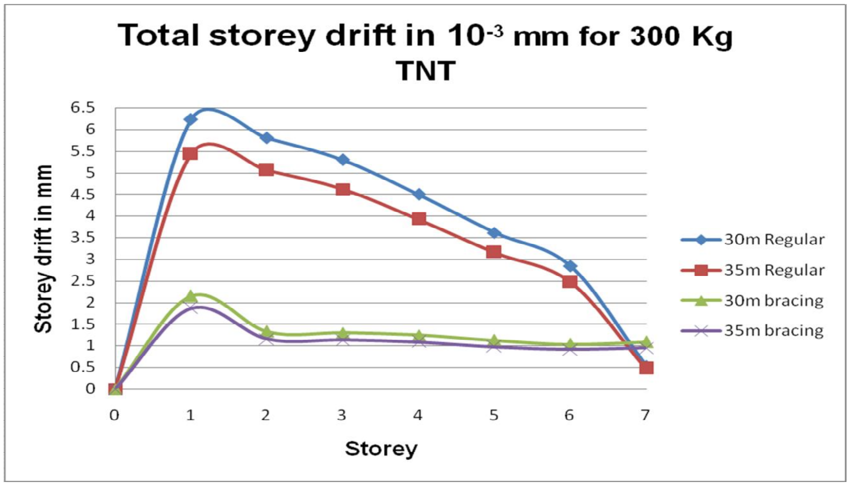
Graph 25: Inter storey drift for a charge weight 100kg TNT at varying stand-off distance

Similarly, from the comparison between building with shear wall and building with bracing and shear wall, it is found that the maximum storey drift for 100kg TNT is 3.20mm at 30m and 1.86 at 35m stand-off distance. Whereas for building with x bracing the maximum storey drift is 1.10mm at 30m and 0.63mm at 35m. (Graph 25)



Graph 26: Inter storey drift for a charge weight 200kg TNT at varying Stand-off distance

For 200kg TNT, the maximum storey drift in regular building is 4.686mm at 30m and 3.886mm at 35m and for building with bracing 1.613mm at 30m and 1.336mm at 35m.
(Graph 26).



Graph 27: Inter storey drift for a charge weight 300kg TNT at varying Stand-off distances

For 300kg TNT, the maximum storey drift in regular building is 6.230mm at 30m and 5.43mm at 35m and for building with bracing 2.143mm at 30m and 1.866mm at 35m. (Graph 27)

From the comparison between building with shear wall and building without shear wall, the latter shows more horizontal displacement when compared to building with shear wall. Shear walls are used to oppose the horizontal forces. Shear wall has high plane stiffness and strength which can oppose large horizontal loads and support gravity loads. It also reduces lateral sway of the building and reduces damages to the building. Therefore, providing shear wall to the building will reduce lateral displacement and storey drift when subjected to blast load when compared to building without shear wall.

From the comparison between building with x bracing and building with inverted-v bracing it is clear that Inverted V bracings gives more lateral displacement and storey drift than X bracing because X bracing covers more area than inverted v bracing. Therefore, providing X bracing to the building will reduce the lateral displacement and storey drift when subjected to blast load.

The result obtained from the comparison between building with shear wall and building with x bracing and shear wall shows that building with bracings shows better result in resisting the blast load.

Storey drifts were high at lower storey compared to the higher storey that describes that the effect of blast load is more in lower level due to nearer detonation point and travelling of shock waves at ground.

V. CONCLUSION

1) According to the outcome, the structure affects appreciably when the weight of explosive increases and distance of the blast source decreases respectively.
2) The storey displacement and storey drift values should be within the permissible limits.
3) *Model -1:* Building with shear wall According to the Indian Standard code 1893, the permissible highest lateral displacement is 42mm (i.e. H/500). Therefore the horizontal displacement of building with weight of explosives 100kg, 200kg and 300kg TNT at 30m and 35m distances are not fulfilling the codal provision. Except for 100 Kg at 35m stand-off distance, lateral displacement satisfies the conditions.
4) *Model -1:* Building with shear wall According to the Indian Standard code 1893, the permissible highest inter storey drift is 12mm (i.e. 0.004x h). Therefore the inter storey drift of building with weight of explosives 100kg, 200kg,300kg TNT at 30m and 35m standoff distance are fulfilling the condition of the code.
5) *Model-2:* Building without shear wall The permissible highest lateral displacement is 42mm. Therefore the horizontal displacement of building with different weight of explosives 100kg, 200kg and 300kg TNT at 30m and 35m stand-off distances are not fulfilling the code terms.
6) *Model-2:* Building without shear wall The acceptable highest inter storey drift is 12mm. Hence the inter storey drift of building with weight of explosives such as 100kg, 200kg,300kg TNT at 30m and 35m stand of distances are agreeing the codal terms.

7) *Model-3:* Building with bracing and shear wall According to the IS 1893 code, the permissible maximum lateral displacement is 42mm. The lateral displacement of building with weight of explosives 100kg, 200kg and 300kg TNT at 30m and 35m stand-off distances are fulfilling the code conditions.
8) *Model -3:* Building with bracing and shear wall According to IS 1893 code provision, the permissible maximum inter storey drift is 12mm. Hence the inter storey drift of building with weight of explosives 100kg, 200kg,300kg TNT at 30m and 35m stand of distances are satisfying the code conditions.
9) Comparison between building with shear wall and building without shear wall shows that the latter shows more lateral displacement. Shear wall plays important role in with standing gravity loads other properties of shear walls is also to withstand compressive loads due to large dimensions along length it is able to endure large lateral displacements.
10) As X bracing is compared with Inverted V bracing, it shows that more lateral displacement and storey drift occurs in the building with Inverted V bracing than X bracing. Because x bracings covers large cross sectional area than v bracing. Therefore providing X bracings gives better result in lateral displacement when compared to inverted v bracing.
11) It is observed that the structure with bracing resist maximum lateral load from the comparison between building without bracing and building with bracing. This is may be due to the increase in moment of inertia of the structure.

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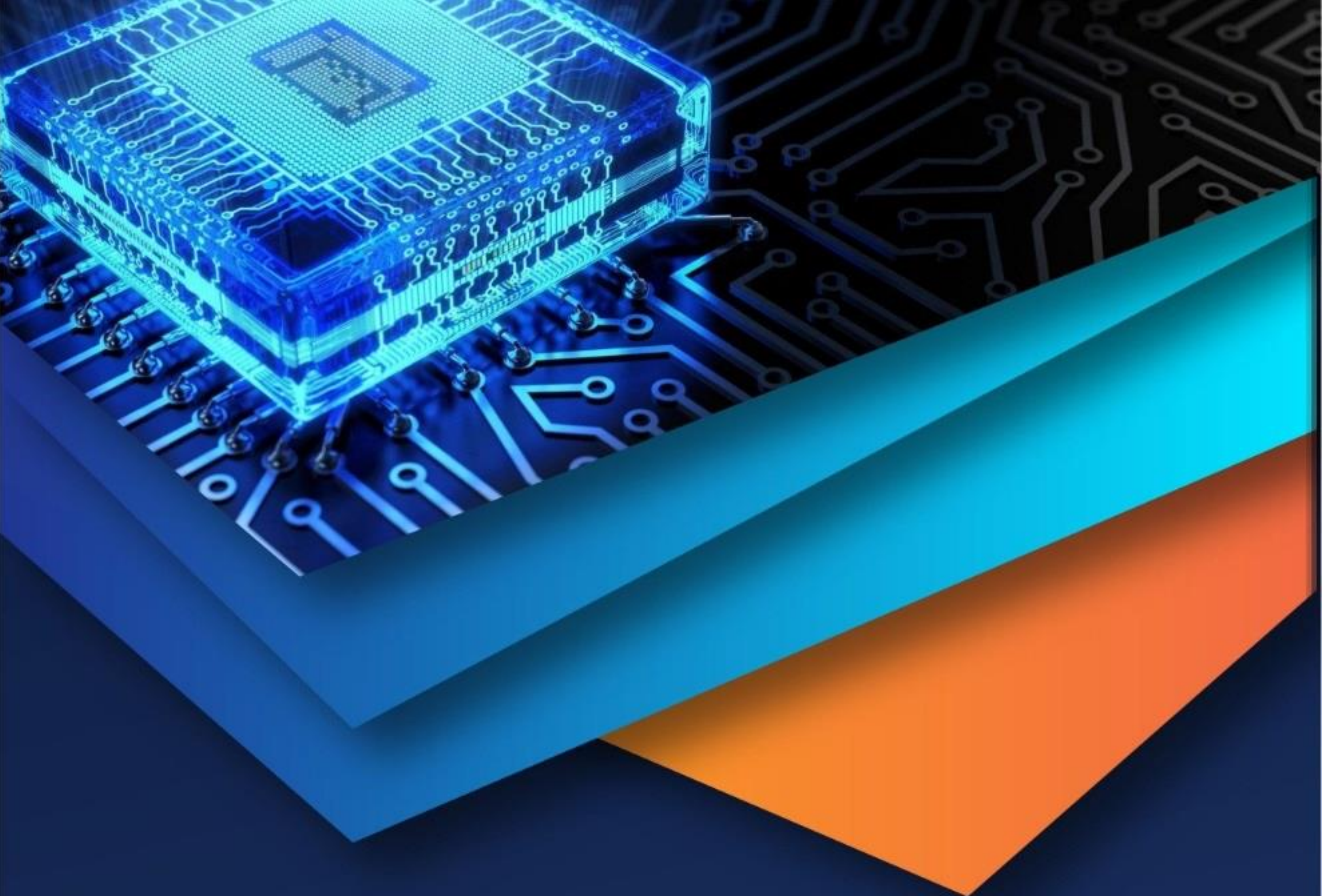

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