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Performance Evaluation Of Rcc Structures With And Without Base Isolation Under Blast Loading

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Abstract: Blast loading caused by accidental or intentional explosions is a major concern in modern structural design. RCC buildings designed mainly for gravity, wind, and seismic loads may experience severe damage under blast effects. This study evaluates the performance of RCC buildings with and without base isolation under blast loading using ETABS. Linear and the nonlinear dynamic analyses are carried out by applying blast pressure-time histories with varying charge weights and stand-off distances. Structural responses such as displacement, acceleration, base shear, and storey drift are compared to assess the effectiveness of base isolation in improving blast resistance and structural safety
Keywords: Blast performance, RCC Structure, Blast Load, Time history Analysis, ETABS, Base Isolation, Base Shear, Displacement.

I. INTRODUCTION

In recent decades, the danger of terrorist attacks involving bombs has become much greater, posing serious risks to civil infrastructure and human life. Buildings, especially public and high-occupancy structures, are potential targets due to their symbolic and functional importance. Explosions from these attacks make strong pressure waves, which are often referred to as blast waves. These blast waves move fast through the air around them and affect the structure of buildings.

A blast load is when the pressure jumps up high and then goes back down really fast. This can put a lot of stress on the parts of a building, which can cause damage like cracks, pieces breaking off columns failing and even the whole building falling down. Blast loads are different from regular loads because they are very strong, hard to predict, and only occur in a small area, making them difficult to plan for when building structures.

We need to understand how buildings behave when there is a blast to be able to design them to be safer. With computer tools and simulation techniques engineers can model what might happen in a blast and look at how the building would respond, including how much it would move, how the pressure would spread and how much energy it could absorb. This information helps make buildings stronger and reduces the damage they might suffer from a blast.

A. Blast Loading

Blast loading is a type of dynamic loading produced by an explosion due to accidental or intentional detonation of explosive materials. During an explosion, a large amount of energy is released within a very short duration, creating a high-pressure shock wave known as a blast wave. This wave travels rapidly through the air and exerts extremely high pressure on nearby structures.

When the blast wave strikes a building, the structure experiences:

- Sudden increase in pressure (positive phase)
- Rapid decay of pressure with time
- Negative pressure or suction phase after the shock wave passes

Blast loads are characterized by:

- High intensity
- Short duration
- Dynamic and impulsive nature
- Large energy release

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The severity of blast loading depends on:

- Explosive charge weight
- Stand-off distance
- Type of explosive
- Location of explosion
- Structural configuration

Blast loading can cause:

- Excessive displacement
- Storey drift
- Failure of columns and beams
- Glass breakage
- Progressive collapse of structures

In structural engineering, blast analysis is commonly performed using SAP2000 and ETABS to evaluate the safety and performance of buildings under explosion effects.

Pressure-Time History of Blast Load

The blast pressure varies with time and is represented by a pressure-time curve consisting of:

- Positive phase
- Negative phase
- Peak overpressure
- Blast duration

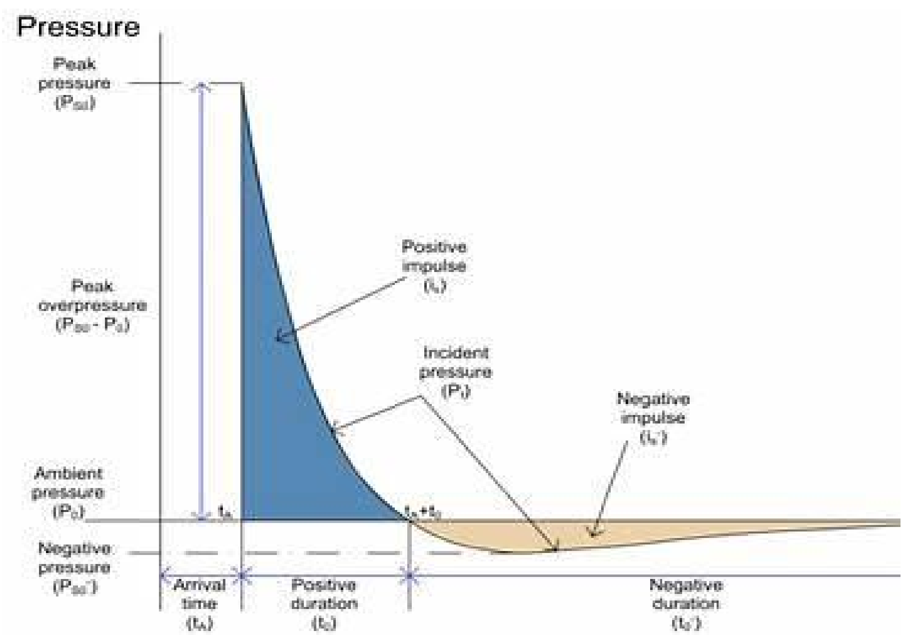

Fig.1 Pressure-Time History of Blast Load

Explanation of Blast Pressure Curve

- The pressure suddenly rises to a peak value immediately after the explosion.
- This stage is called the positive phase and causes major structural damage.
- After the positive phase, pressure decreases below atmospheric pressure, forming the negative phase or suction phase.
- The entire loading occurs within milliseconds but produces severe structural effect

B. Rubber base isolation

Rubber base isolation is a widely used structural protection technique designed to reduce the effects of dynamic loads such as earthquakes and blast forces on buildings. The system works by separating the building from the ground or forces that can cause it to shake. This is done by putting parts between the foundation and the building.

The common devices used for this are called laminated rubber bearings. These bearings are made of layers of rubber and thin steel plates that are put on top of each other. The rubber layers make the bearing flexible so it can move from side to side. The steel plates make sure the bearing can hold the weight of the building and keep it stable. This way the bearing can support the building while reducing the force of the shaking.

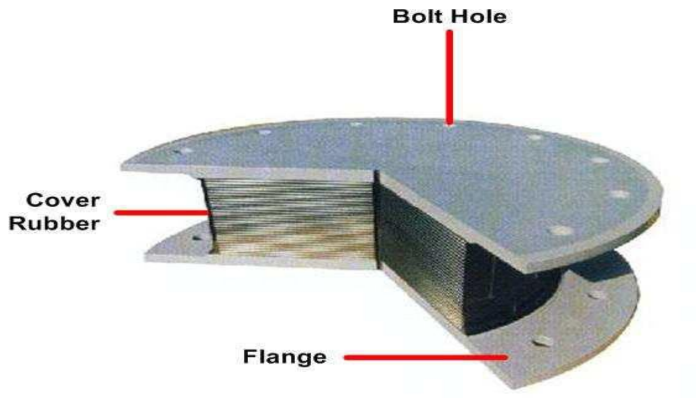

Fig.2 Rubber Base Isolation

II. LITERATURE REVIEW

"Comparative Analysis of the Performance of Reinforce Concrete Structures Under Blast and Seismic Load: A Review" (2025): This article gives an in-depth look at how reinforced concrete structures perform when they face blast and earthquake forces, and it points out the key differences and shared features between these two kinds of dynamic loads. The study focuses on how buildings behave under 2 types of loads: blast and seismic. These loads are different with respect to of how they last and how intense they are. Seismic loads are lasting movements that affect the whole building while blast loads are short but very intense shock waves this cause damage in specific areas.

The compare how reinforced concrete (RC) structures behave under these loads and find design considerations to improve their performance. The review shows that seismic design focuses on flexibility, energy absorption and overall deformation capacity. This allows buildings to absorb and redistribute energy over time. On the hand blast-resistant design prioritizes stiffness, localized reinforcement and high energy absorption to resist sudden and intense loads. In conclusion the analysis reveals RC structures behave under blast and seismic loading. It underscores the need for integrated design strategies and the use of software tools like ETABS, ABAQUS and ANSYS. These tools play a role, in predicting structural response and enhancing safety and reliability.

"Assessment of Structural Response of RC Building Under Blast Load" (2024): Focuses on assessing the structural response of reinforced concrete (RC) buildings subjected to blast loading, highlighting the increasing importance of considering explosive effects in modern structural design. The threat of explosions and terrorist activities is getting bigger and bigger. The authors think that blast loads are extremely important it comes to designing buildings. They are just as important as wind loads for the reason that can be very destructive.

The main goal of such study to see how a six-storey building made of reinforced behaves when it is hit by a blast. The researchers used computer programs to simulate the blast and see how the building reacts. They used a program called ABAQUS to model the building and the blast. This program is very good at showing how materials and structures react when they hit by a blast. In the end the research gives significance about how reinforced concrete buildings react when they are hit by a blast. It shows that making changes to the buildings structure such, as using columns can reduce the damage and make the building perform better. The researchers think that it is essential to take blast loads into account when designing buildings to create sure that they are safe and strong.

"Analysis of Reinforced Concrete Structure Subjected to Blast Load" (2024): Focuses on the analysis of reinforced concrete (RC) structures subjected to blast loading, emphasizing the need to evaluate structural performance under extreme dynamic conditions.
Blast loading happens when several energies is released suddenly. This makes shock waves that last for a very short time. These waves can cause damage to buildings especially if the explosion happens close by. The authors say it is crucial to understand how buildings made of reinforced concrete (RC) behave under conditions. This learning will help create more resilient buildings.
The main goal of this research is to see how a multi-storey RC building reacts to blast scenarios. The study looks at TNT charge weights, specifically 100 kg and 150 kg. It also considers distances from the explosion, such as 15 m and 20 m.
In conclusion the research observed insights into how RC buildings behave under blast loading. It highlights the importance of considering blast effects in building design. The research shows that component like charge weight and distance, from the explosion significantly influence the buildings response. Appropriate design measures are necessary to enhance safety and resilience.

"Elif Toplu and Osman Kırtel, "Performance of Base-Isolated RC School Building under Blast Loading" (2023): This study investigated the effectiveness of base isolation systems in improving the blast resistance of reinforced concrete (RC) school buildings. A three-storey RC school building was analysed using both fixed-base and base-isolated configurations incorporating lead rubber bearings designed in accordance with the Turkish Building Earthquake Code (2018). Numerical simulations were performed using SAP2000 through linear and nonlinear dynamic analyses under blast loading conditions. Blast loads were evaluated using the Hopkinson–Cranz scaling law and represented by the Friedlander pressure–time equation, while FEMA guidelines were adopted for estimating blast parameters and stand-off distances. The results demonstrated that the base-isolated structure exhibited lower base shear, reduced storey displacement, and smaller inter-storey drift compared with the conventional fixed-base structure, particularly at moderate and large stand-off distances. However, the effectiveness of the isolation system decreased under close-range explosions because of the highly impulsive nature of blast loading. The study concluded that base isolation significantly enhances the blast resistance and overall structural resilience of RC buildings and can be considered an effective protective measure against explosion-induced loading.

III. OBJECTIVES

The objective of the current research study is
1) Analysis of blast load characteristics on RCC buildings using ETABS.
2) Modeling and comparison of buildings with and without base isolation systems.
3) Conducting linear and nonlinear analyses under different blast loading conditions.
4) Evaluation of structural responses such as base shear & displacement.

IV. STRUCTURAL MODELING AND ANALYSIS

In the present study, a detailed analysis was carried out to assess the seismic performance building models using ETABS software. Initially, various research journals were reviewed to finalize the study's objectives. Three structural configurations were modeled:
Computation of blast loading for a G+5 storeyed framed building has been carried out for the three cases of blast loading. Three categories of buildings are considered as per IS code 4991:1968 for blast resistant designing purposes. In the first case the equivalent TNT charge weight W has been taken as 100 Kg and the actual effective distance from explosion i.e. R is taken as 5 m, & 10 m. The structural design was performed in accordance with Indian standards, considering various load combinations including dead load, live load, and blast loads. For both linear static and time history analysis methods were employed. The analytical results for all models were carefully extracted and compared to study their behavior under blast forces. Based on the observed data, significant insights were drawn, and conclusions were made regarding the influence of different infill materials on structural performance.
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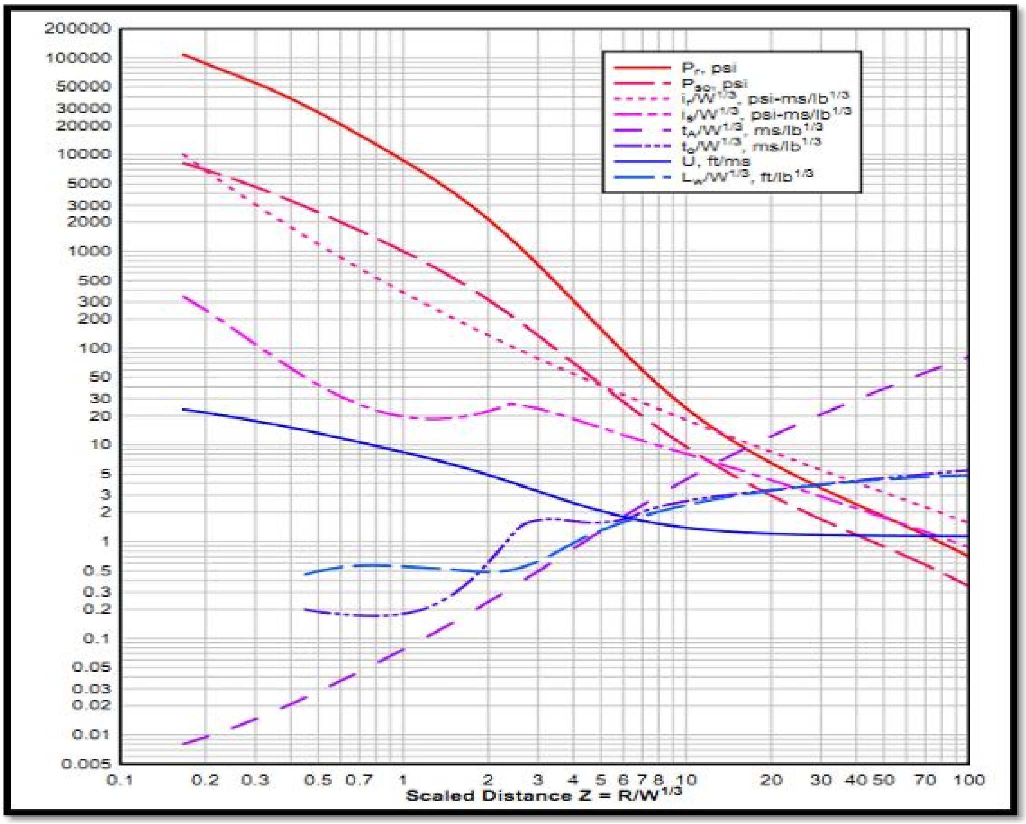

Fig.3: Positive phase shock wave parameters for a hemispherical TNT explosion on the surface at sea level

Friedlander Equation (Pressure – Time History)

$$P(t) = P_s\left(1 - \frac{t}{t_d}\right)e^{-bt/t_d}$$

Where:

- $P(t)$ = Pressure at time t
- P_s = Peak overpressure
- t_d = Positive phase duration
- b = Decay coefficient (typically 1 to 2)
- t = Time

Scaled Distance Formula

$$Z = \frac{R}{W^{1/3}}$$

Where:

- Z = Scaled distance (m/kg$^{1/3}$)
- R = Stand-off distance (m)
- W = TNT charge weight (kg)

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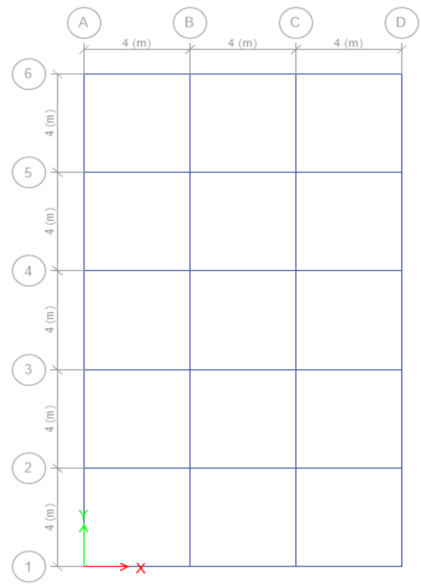

Fig.4: Plan of RCC structure

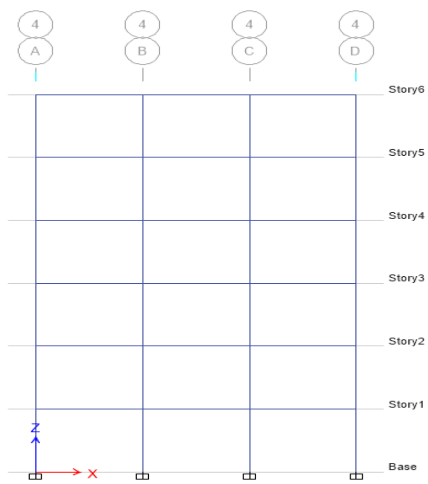

Fig.5: Elevation of RCC structure

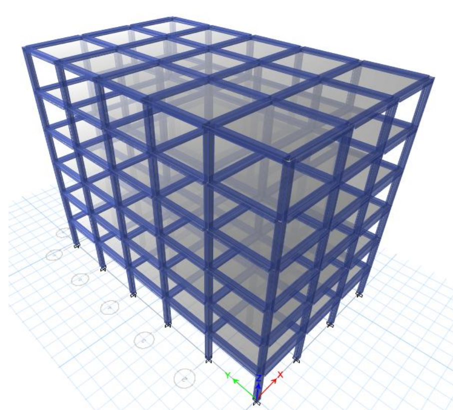

Fig.6: 3D View of RCC frame Models

TABLE 1: MODEL PROPERTIES AND DESIGN PARAMETERS

Sl. No.	Description	Data
1.	Structure Length& Width in X and Y Direction	12m X 20m
2.	Each Bay Width	4m in X-Direction & 4m in Y-Direction
2.	Structure Height	18m (G+5)
3.	Each Floor Height	3m
4.	Column Size used	300 X 300 MM
5.	Beam Size used	200 X 450 MM
6.	Thickness of Roof	150mm
7.	Grade of Concrete (f_{ck})	M30
8.	Grade of Rebar (f_y)	Fe 500
9.	Load Combination	DL+0.5BL 1.5DL+1.5LL

TABLE-2: MODELS CONSIDERED FOR THE ANALYSIS

Model Type
100 Kg TNT distance of 5m
100 Kg TNT distance of 10m
100 Kg TNT distance of 15m

V. RESULTS AND DISCUSSION

A. *Base Shear*

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. The structure is analyzed with gravity load, static earthquake loading method and the resulting base shear is tabulated in the table below.

TABLE-3: RESULTS OF MAXIMUM BASE SHEAR VALUES OF FIXED BASE MODEL

MODEL TYPE	MAX BASE SHEAR (kN)	
	FIXED BASE	
	X Dir	Y Dir
100 Kg of 5M Standoff Distance	63.54	65.20
100 Kg of 10M Standoff Distance	15.09	15.48
100 Kg of 15M Standoff Distance	4.11	4.22

TABLE-4: RESULTS OF MAXIMUM BASE SHEAR VALUES OF BASE ISOLATION MODEL

MODEL TYPE	MAX BASE SHEAR (kN)	
	BASE ISOLATION	
	X Dir	Y Dir
100 Kg of 5M Standoff Distance	61.55	63.05
100 Kg of 10M Standoff Distance	14.61	14.97
100 Kg of 15M Standoff Distance	3.98	4.08

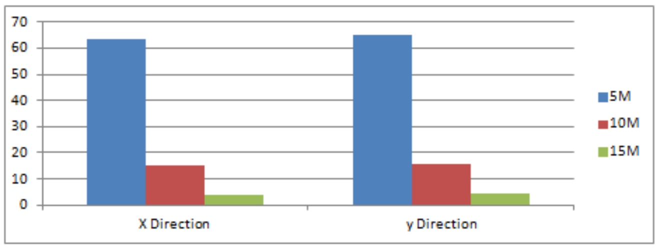

Fig.7 Max Storey Shear of Models for Fixed Base

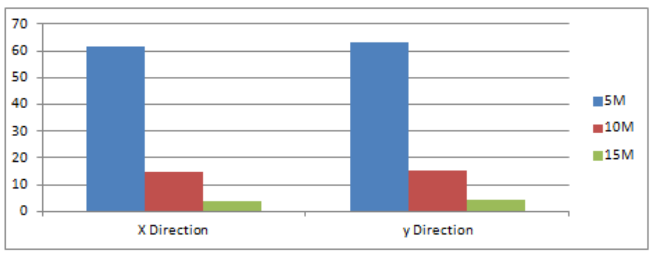

Fig.8 Max Storey Shear of Models for Base Isolation

The comparison of maximum base shear values indicates that the Base Isolation Model consistently reduces base shear when compared to the Fixed Base Model under all blast loading scenarios. The reduction in base shear demonstrates the effectiveness of the isolation system in limiting the transfer of blast-induced forces to the structural foundation.

These results confirm that base isolation contributes to improved structural performance by reducing the forces transmitted to the foundation, thereby enhancing the building's resistance to blast effects and reducing the potential for structural damage.

B. Displacement

The storey displacement is the lateral displacement of the storey with respect to the ground. The maximum storey displacement along X and Y direction obtained Blast loading condition is shown in below table.

Table-5: Results Of Maximum Displacement Values Of Fixed Base Model

MODEL TYPE	STOREY DISPLACEMENT, (mm)	
	FIXED BASE	
	X Dir	Y Dir
100 Kg of 5M Standoff Distance	4.17	4.22
100 Kg of 10M Standoff Distance	0.99	1.00
100 Kg of 15M Standoff Distance	0.27	0.27

Table-6: Results Of Maximum Displacement Values Of Base Isolation Model

MODEL TYPE	STOREY DISPLACEMENT, (mm)	
	BASE ISOLATION	
	X Dir	Y Dir
100 Kg of 5M Standoff Distance	3.35	3.25
100 Kg of 10M Standoff Distance	0.79	0.77
100 Kg of 15M Standoff Distance	0.21	0.21

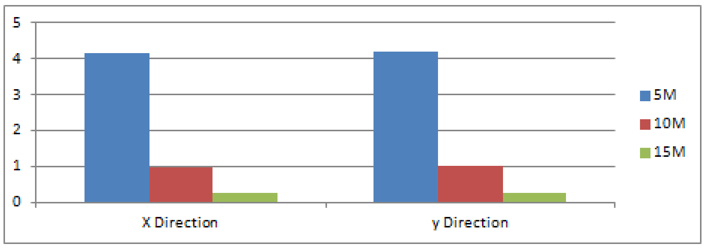

Fig.9 Max Displacement of Models for Fixed Base

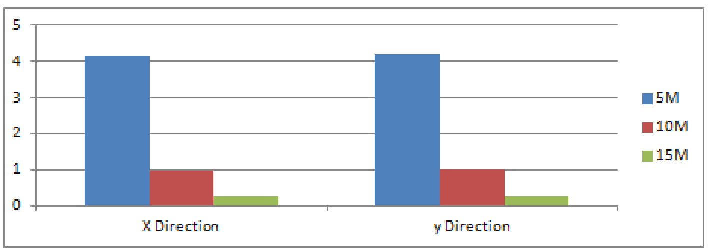

Fig.10 Max Displacement of Models for Base Isolation

The comparison of maximum storey displacement results demonstrates that the Base Isolation Model consistently performs better than the Fixed Base Model under all blast loading conditions. Base isolation effectively reduces the lateral displacement of the structure by absorbing and dissipating a portion of the blast-induced energy before it reaches the superstructure.

These results confirm that base isolation is highly effective in controlling structural movements and enhancing the blast resistance of buildings by reducing the transmission of blast forces to the structure.

VI. CONCLUSION

The G+5 storey models of a 100KG TNT of standoff distance 5M 10M & 15M system were conducted by using ETABS software. The Time history analysis was carried out with respect to Blast Loading. The results are extracted with respect to storey shear, displacement & storey drift of different kinds of frame models. The conclusion of this project is mentioned below.

1) The base isolation really helps the G+5 RCC structure do better when there is a blast.
2) When we look at the storey shear it is always lower in the base-isolated structure than in the fixed-base structure.
3) we have a 100 kg TNT blast that's 5 meters away the maximum base shear goes down from 63.54 kN to 61.55 kN in the X-direction and from 65.20 kN to 63.05 kN in the Y-direction. This means the base shear is reduced by 3.13% and 3.30%, respectively.
4) If the blast is 10 meters away the maximum base shear decreases from 15.09 kN to 14.61 kN in the X-direction and from 15.48 kN to 14.97 kN in the Y-direction. So, the reductions are 3.18% and 3.29%, respectively.
5) If the blast is 15 meters away the maximum base shear goes down from 4.11 kN to 3.98 kN in the X-direction and from 4.22 kN to 4.09 kN in the Y-direction. The reductions are 3.16% and 3.08%, respectively.

6) Overall, the base isolation reduces the maximum base shear by between 3.08% and 3.30%. The biggest reduction, 3.30% happens when the blast is 5 meters away in the Y-direction.
7) We see the reduction in shear and displacement when the blast is closer at 5 meters and 10 meters.
8) The base isolation also helps control the storey displacement, which means the structure does not move much.
9) For the 5m distance the maximum storey displacement goes down from 4.17 mm to 3.35 mm in the X-direction and from 4.22 mm to 3.25 mm in the Y-direction. This is a reduction of 19.66% and 22.99%
10) At 10 meters the maximum displacement decreases from 0.99 mm to 0.79 mm in the X-direction and from 1.00 mm to 0.77 mm in the Y-direction. The reductions are 20.20% and 23.00%, respectively.
11) At 15 meters the maximum displacement goes down from 0.27 mm to 0.21 mm in both the X and Y directions, which is a reduction of 22.22%.
12) The biggest reduction in displacement is 23.00% in the Y-direction at 10 meters. The smallest reduction is 19.66% in the X-direction at 5 meters.
13) When the blast is away it is not as strong so the difference between the two systems is smaller.

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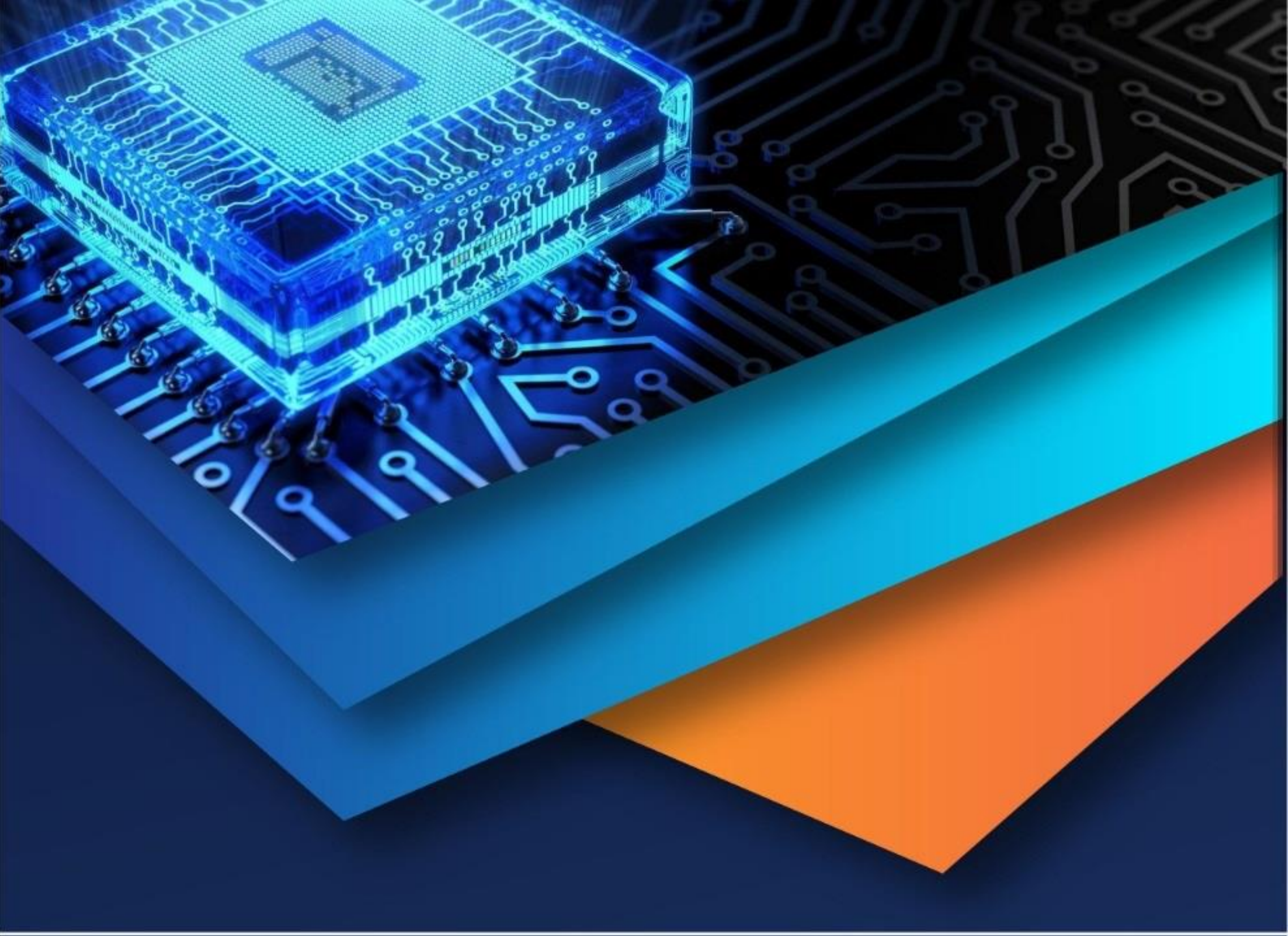

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