Isolating system using U Shaped steel damper

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Abstract: In this work the performance of U-Shaped Steel Isolator is evaluated for a 5-story building subjected to seismic and blast vibrations. The structure is analysed using SAP 2000 software and a nonlinear time history analysis is carried out. The effectiveness of using base isolation is studied by comparing the structural responses of the building with isolator and without isolator and noticeable difference was observed. As the U-Shaped isolator absorbs the energy in all directions, it effectively controls the structural responses. In this study, the building is subjected to four different seismic and four different blast induced ground motions. It was observed that by the use of supplementary energy device there is reduction in top story acceleration, base shear and less deformation in the structure. This study concludes that the use of isolator has been effective in minimizing structural responses.

1 Introduction

In the field of Earthquake Engineering, many methodologies are being developed to safeguard the structure & to control the responses in the structure. During an Earthquake and blast, a lot of energy is being created which cause damage to the structural assets and human life. To protect the structure from such natural calamities many techniques were developed now a days and being implemented to lesser the damages and withstand safety against such large forces. Base Isolation is one such implementation where the building is supplemented with passive, semi active and active control devices. In the recent years, many researchers have started working in civil engineering field by evaluating the performance of Base Isolation, assessing the condition of the building. Praveen and Gopalakrishna has focussed mid-rise configured models with and without setbacks under earthquake vibrations to evaluate seismic performance. Vinothini and Elavenil presents the response of a concrete framed structure of high-rise model which is loaded dynamically is analysed in SAP 2000. The dynamic responses of steel structures during external detonations through different charge weights at 3m standoff distances is studied by Mohammad Abdallah. Omprakash and Atul Manchalwar has supplemented a RC building with X- Plate damper and evaluated the structural responses which is subjected to blast and earthquake forces. Figuli et al., analysed blast loaded steel structure and derives an issue based on explosive and explosion type under dynamic load. A detailed computational study of a 2-story steel frame is considered to show the capacity of Nitinol & SMA damper to minimise vibrations in the structure when subjected to blast is studied by Dutta and Mujunder.

In this research behaviour of five story model subjected to both Earthquake and Blast induced ground motions are studied with and without Isolator. For this purpose, U-shaped steel damper is used as an isolator and supplemented to the building and non-linear dynamic analysis i.e., time history analysis is conducted for earthquake and blast ground acceleration data.

1.1. U- Shaped Damper

During a blast, large amount of energy is released and shock waves are developed which are compressive in nature. As Earthquake and Blasts are two different scenarios, U-shaped damper is used in this research as to control the responses because the structure undergoes deformation in every direction 360 degrees, as to absorb the energy U damper has been used and evaluated its performance for different Earthquakes and blasts. Homogeneous damping is required as the building deforms in horizontal direction, as steel is plastic in nature it dissipates the energy in all directions for the ground vibrations.

Table. 1. Properties of U-Shaped Isolator for 4 arms

Properties			
1.Yield Force (N)	2.Initial Stiffness (ki)(N/m)	3.Post yield Stiffness(kp) (N/m)	4.Post yield stiffness ratio (α)

$112x10^3$	$5920x10^3$	$100x10^3$	0.0169

Table. 2. Earthquakes records taken from FEMA 695 P

EARTHQUAKE	YEAR
Kern County Earthquake	July 21, 1952
Loma Prieta- Oakland Outer Harbour Wharf	October 17, 1989
San Fernando Earthquake- Pacoima Dam	February 9, 1971
Parkfield Earthquake- Cholame, Shandon	June 27, 1966

For the numerical analysis, the acceleration data include most commonly cited four different Earthquake records (Kern County Earthquake, Loma Prieta -Oakland Outer Harbour Wharf, San Fernando Earthquake, Parkfield Earthquake) Which were taken from FEMA P-695.

1.2. *Ground Motion Data*

Hinman, Carvalho and Battista have calculated the accelerations of blasts for different charge weights ẍg(t) which is an exponential decay function given as follows

$$\ddot{x}g(t) = -\frac{1}{td} ve^{\frac{-1}{td}} \quad (1)$$

In the above equation, td is the time for arrival which is evaluated using the formula td=R/C, here R is the distance from the point of charge (m) and C is velocity of propagated wave (m/s). V is the maximum velocity of a particle, these empirical formulae to calculate 'V' is proposed by Kumar et al., derived from field data available for different cases is given as

$$v = \frac{f^{0.642} SD^{-1.463}}{\gamma D} \quad (2)$$

Where, f is uniaxial compressive strength of granite rock deposit and taken as f =$70x10^6$ Pa, SD (Scaled Distance) which is given as $R/\sqrt{Q}$,R is the mass of charge. The charge weight Q in present study is taken as $10x10^3$kg, $25x10^3$ kg,$50x10^3$ kg and $75x10^3$ kg.

γD is the average mass density taken as 26.50x10^3 KN/m3 and young's modulus E=73900 MPa, which depends on the material properties of granite.

2 Building Model

In the present study, a simple low-rise building, a 5-story base isolated structure is adopted from Zhang and Philips (2016). The model used in the study is a lumped mass system. The variables of the model are listed in the table. Under all external dynamic excitations, the model is assumed to be remained linearly elastic which facilitates with a scenario where non-structural components may be damaged and non-structural components remain functional.

This structure is modelled using Sap 2000 software for isolated base and another for fixed. The natural period of the building with which base is fixed is 0.54 sec whereas, for the base isolated model the fundamental natural period is 2.5 sec. By supplementing the building with base-isolation device, there is a shift in the natural period of the building such that maximum amount of energy is dissipated during an earthquake and blast vibrations.

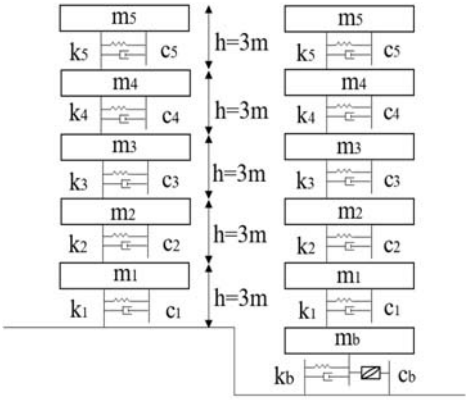


Fig. 1. Diagrammatic representation of five-story model

Table. 3. Variables of five-story building

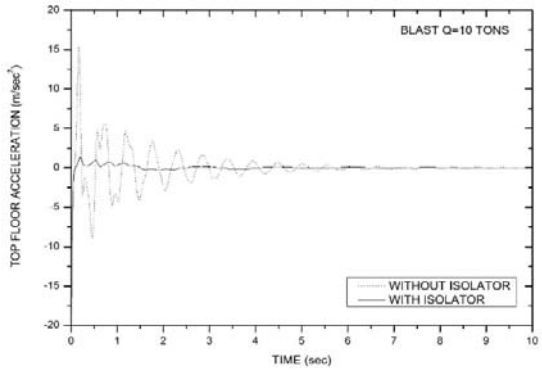
Stories	**Mass on Floor M (tons)**	**Story's Stiffness K (N/m)**	**Damping Coefficient C (kg/s)**
Floor 1	m_1 = 53.073	k_1 =101196x10^3	c_1 = 348.14 x10^3
Floor 2	m_2 = 53.073	k_2 = 87279 x10^3	c_2 = 301.38x10^3
Floor 3	m_3 = 53.073	k_3 = 85863 x10^3	c_3 = 296.18 x10^3
Floor 4	m_4 = 53.073	k_4 = 74862 x10^3	c_4 = 259.81 x10^3
Floor 5	m_5 = 53.073	k_5 = 57177 x10^3	c_5 = 197.45x10^3

The Isolator parameters such as initial stiffness, post yield stiffness is calculated by standard formulae of Time period i.e., Tb=$2\pi\sqrt{\frac{M}{K}}$ and post yied stiffness ratio α=$\frac{kp}{ki}$

where, α is taken as 0.1 and Tb is taken as 2, 2.5 and 3 sec. Yield strength of the isolated is calculated by equating the ratio of $\frac{Q}{W}$ to 0.05,0.075 and 0.1 where, W is the total weight of the building.

3 Dynamic Responses

By the use of U-Shaped steel Isolator there is reduction in the responses like accelerations at top story level under dynamic excitations. The graphical representation shows the amount of reduction in acceleration for four different Earthquake and Blast induced ground motions for a building with damper and without damper.



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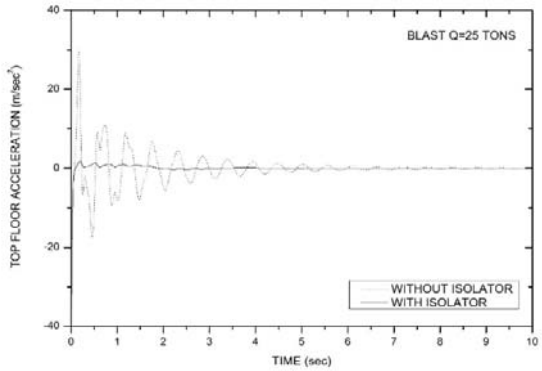

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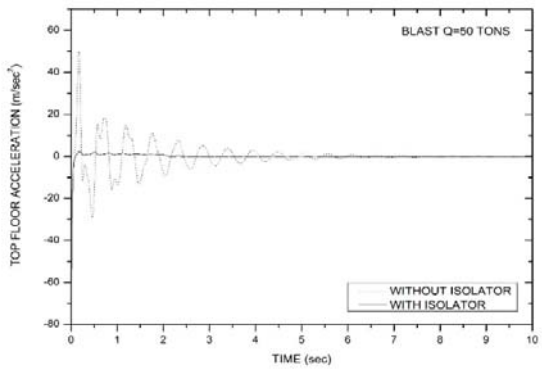

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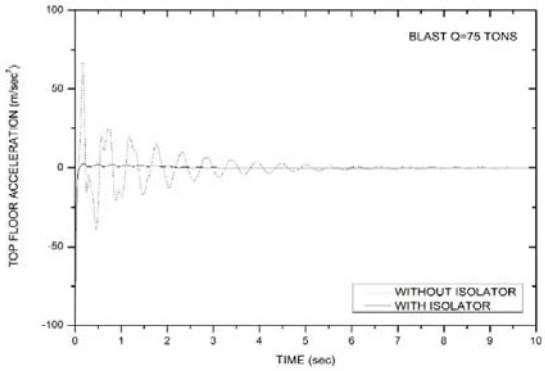

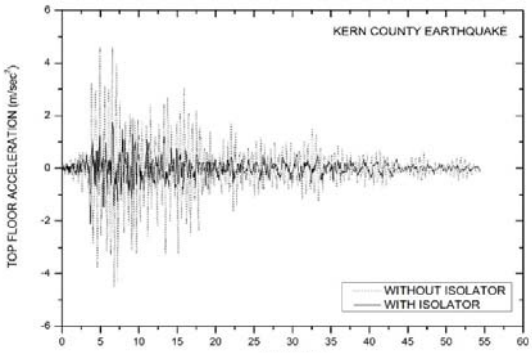

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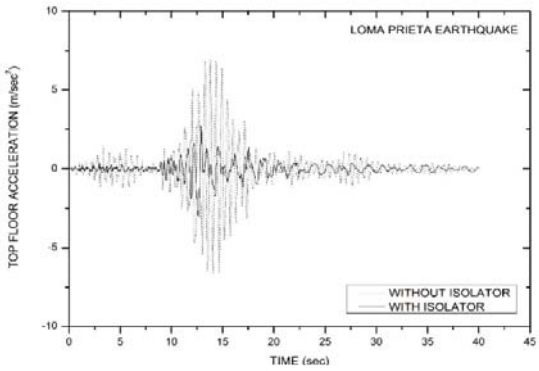

2(f)

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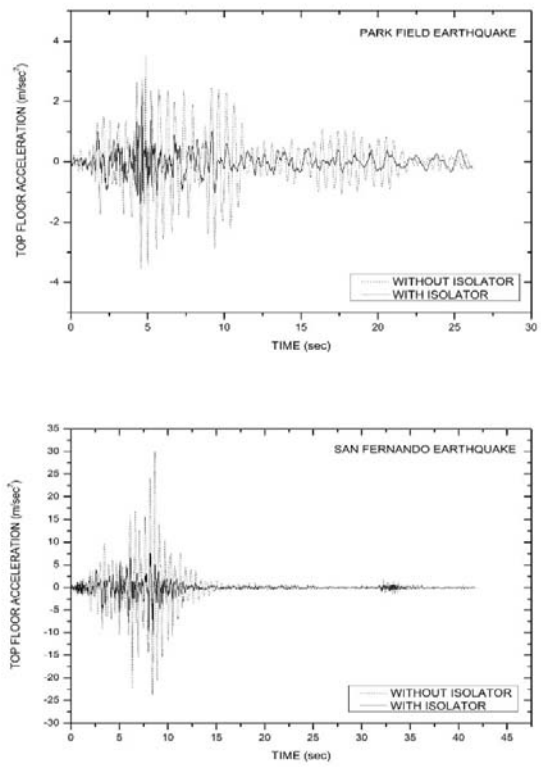
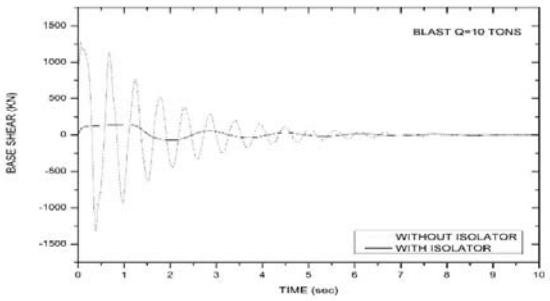


Fig. 2

U-Shaped Isolator is also effe ıcing Base Shear values and thus it enhances the performance of the structure. The results are shown below in the form of graphs for different Earthquakes and four different blast induced ground motions and comparison was made for building with isolator and without isolator by performing nonlinear time history analysis.



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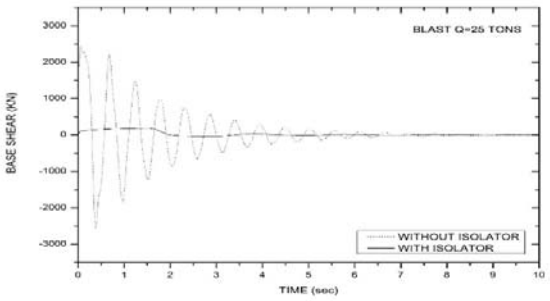

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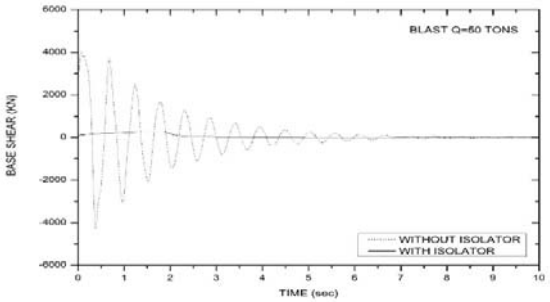

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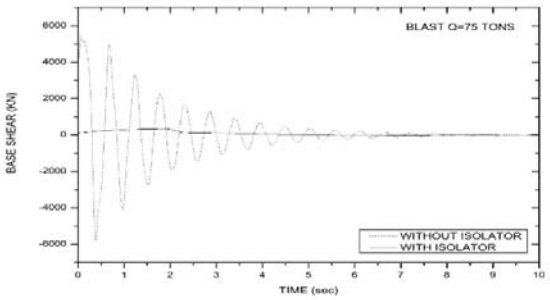
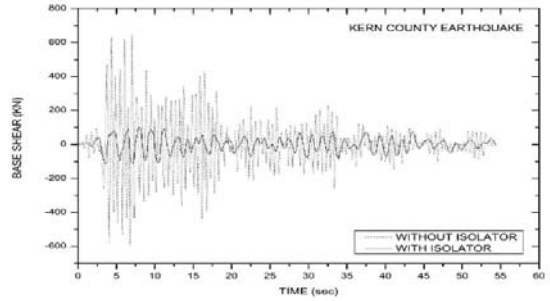




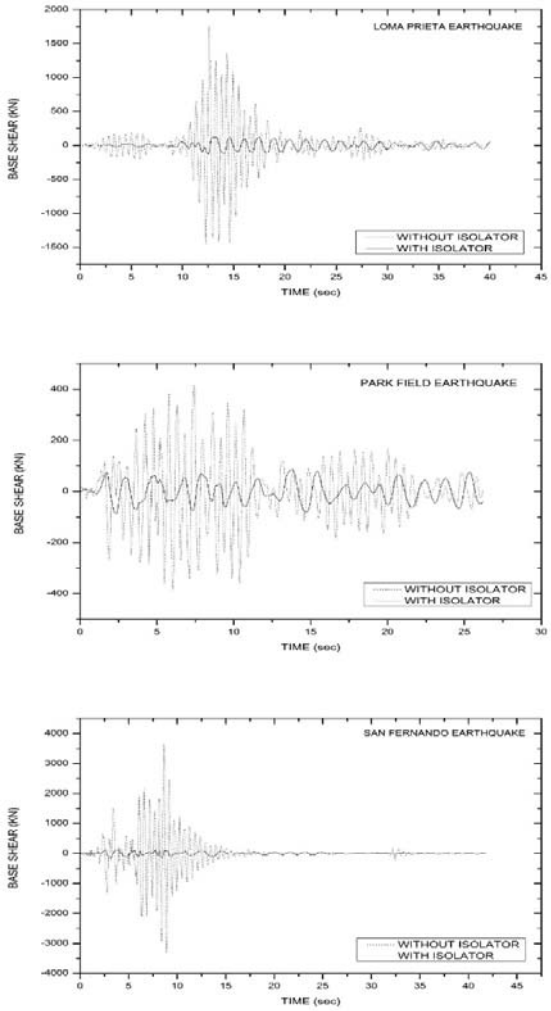
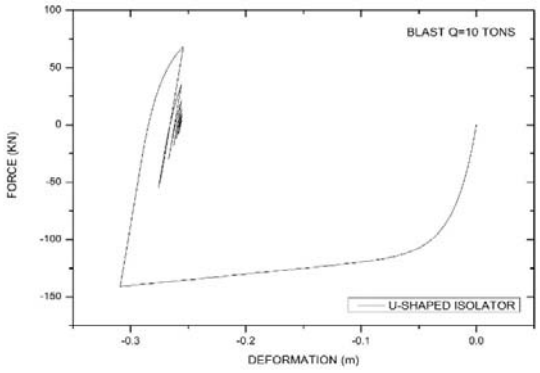


Fig. 3

The U-Shaped Isolator is effective in controlling the structural responses. By supplementing the building with damper causes less deformation for four different Earthquakes and four different blasts which is shown in the form of graphs. Thus, U- Shaped Damper absorbs maximum amount of energy during an Earthquake and Blast vibrations.



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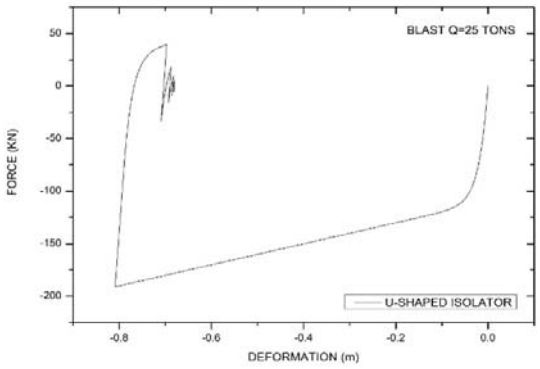

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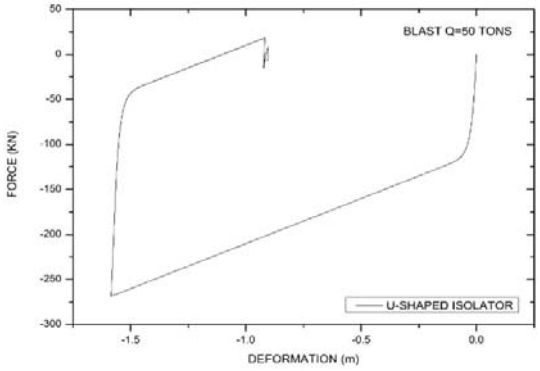

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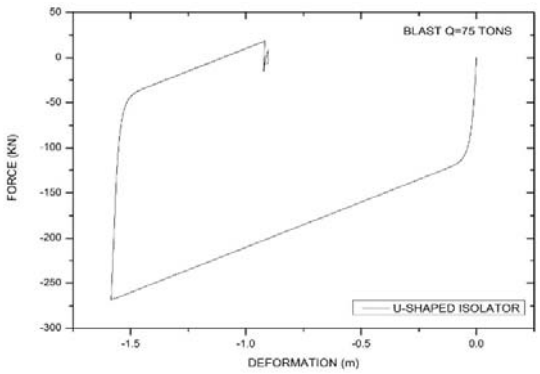
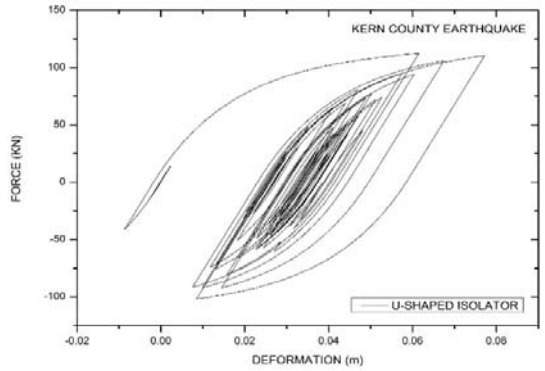
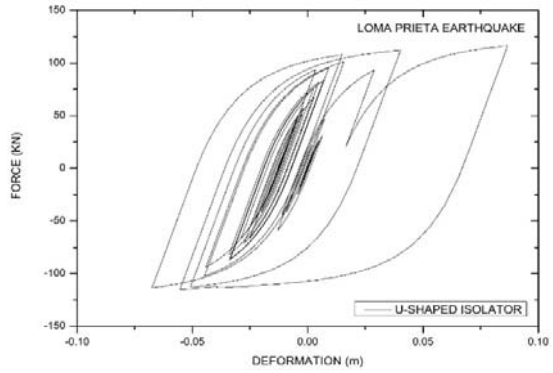
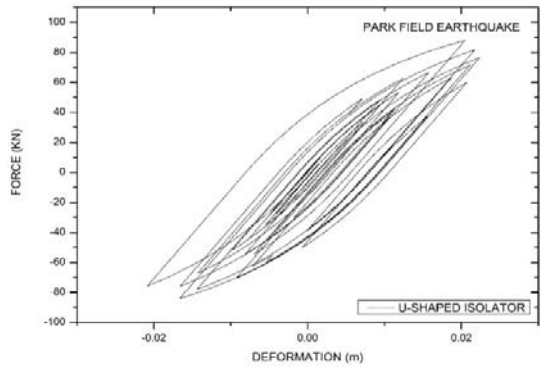
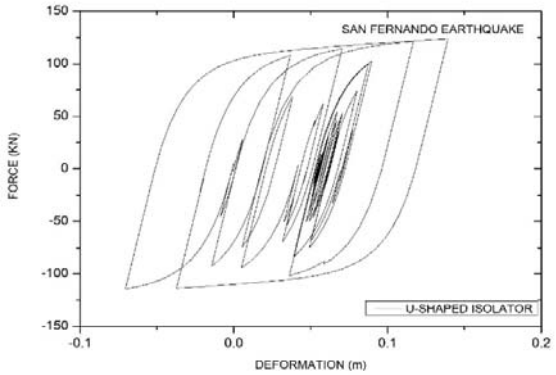


4(d)









4 Conclusion

A 5- story building with isolator and without isolator was analysed using nonlinear time history analysing in SAP 2000 software. The present research evaluates the performance of isolator under seismic and blasting forces. This research aims to study the responses of the structure under four different blast ground motions and four different seismic ground motions, the structural responses are as follows:

By using the supplementary energy device, the top story accelerations were eventually reduced under both seismic and blast induced ground motions.

The base shear values have been reduced for the building with isolator when compared to the building without isolator.

It is concluded that, by the use of isolator the building is subjected to less deformation and, thus, Base Isolation is effective in dissipating maximum amount of energy under seismic and blast induced ground motions.

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