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Comparative Study of Base Isolated Building with Fixed Base Building with Time History Analysis

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Abstract: ***These days earthquake is a major problem for development of high rise building in seismic zone areas. Researchers have developed devices to overcome these earthquake problems. So we need to design a structure which can withstand against the seismic loads. There for it became necessity to provide passive control device "base isolation" to resists large horizontal and vertical loads which lead the structure to collapse. Base isolation is one of the best and widely accepted passive control device to resist these forces by isolating the superstructure from the sub structure. The response of base isolated building and fixed base building are evaluated in high rise buildings having irregularities in plan at story level. Response spectrum analysis and time history analysis are carried out in terms of story displacement, base shear, story drift and time period using ETABS software. Then comparative study is done between isolated and fixed base building and results are presented.***
Keywords: Base isolation Techniques, LRB, Base Shear, Time history and Etabs etc.

I. INTRODUCTION

An Earthquake is a sudden movement or activity occurs in the earth's crust and causes enormous damage to several lives, nature and properties. The earthquake occurs due to nuclear test, men maid explosive etc. Scientists have done so many researches to protect our earth or structures from these shock waves. Many innovative systems have been designed to protect structure from earthquakes. The main criterion of design of a structure to protect from seismic loads is that it should be economical and should be strong enough to withstand against the several damages caused due to an earthquake. Hence because of many uncertainties we developed an alternative approach is called "base isolation".

II. BASE ISOLATION

The base isolation is a technique used to protect the structure from earthquake by providing a flexible support to the structure. The basic concept of base isolation is to isolate superstructure from substructure so that motion of ground cannot be transferred to the superstructure and hence building will be safe during seismic loads. A fixed base building will sustain a great damage due to transfer of ground motions. But if a building is isolated resting on flexible bearing or pads known as isolator, it will move a little or not at all during an earthquake. The isolators work in a similar way to car suspension, which allows a car to travel over rough ground without the occupants of the car getting thrown around. Or just like a bird which is flying above the ground and will not have any effect due to ground motion.

The structures which are going to be designed should be always safe under wind loads and earthquake loads because these are most predominant loads that demands lateral design of structure. It is not possible to control the earthquake loads and also we cannot design a structure for indefinite earthquake demand. Only approach is that we can increase the capacity of structure than actual demand. We cannot control the motion of ground under earthquake but we can reduce the effects of earthquake loads on structure by means of base isolation. The main purpose of base isolation is to control the effects of earthquakes on structure. The main principle of base isolation is to reduce the response of structure during earthquake so that ground below the structure can move without transmitting the motion to the above structure. In high intensity earthquake area building cost of isolation structure can be saved 3 ~15% of building cost as compared to conventional structure.

A. Types Of Base Isolation System

There are five major types of base isolation devices which are widely adopted for seismic base isolation.

1) Elastomeric Bearing
2) Lead Rubber Bearing
3) Flat Slider Bearing
4) Curved Slider Bearings or spherical sliding or Pendulum Bearing
5) Ball & Roller Bearing

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III. LEAD RUBBER BEARING SYSTEM

This type of bearing includes of laminated layers of rubber which are sandwiched together with layer of steel. This bearing have solid lead plug in the middle. The top and bottom are fixed by two steel plates which are used to attach the bearing to the building and foundation. The bearing is very stiff and strong in vertical direction but flexible in horizontal direction. Lead experiences the same deformation as the rubber and reduces the kinetic energy by converting that energy to heat.

During the earthquake, an un-isolated building will vibrate back and forth in varying directions due to the inertial forces and result in deformation and damages of the building. In contrast, the base isolated building will also displace but remains its original shapes and avoid damages .That is because the lead rubber bearing effectively dissipates the inertial force upon the building, extends the building's period of vibration and decreases the acceleration of the building.

The lead plug will slid with laminated rubber during earthquake but converts this energy of movement to heat so that it efficiently reduces the inertial force upon the building, which slows the vibration of the building. Meanwhile, the rubber part will preserve its original shape due to high elasticity. They consist of three basic components – a lead plug, rubber and steel, which are generally placed in layers Lead rubber bearing isolation is stiff and strong in vertical direction but flexible in horizontal direction. It can change its bearing shape under large earthquakes and absorbs earthquake forces. Due to high elastic properties of rubber it can bring the structure to its original shape after effect of earthquake. We can adjust damping amount just by changing number of lead plugs. Lead rubber bearing having vertical load capacity ranging from 5 tons to 2000tonf. It is easy to install and no need to provide separated damper.

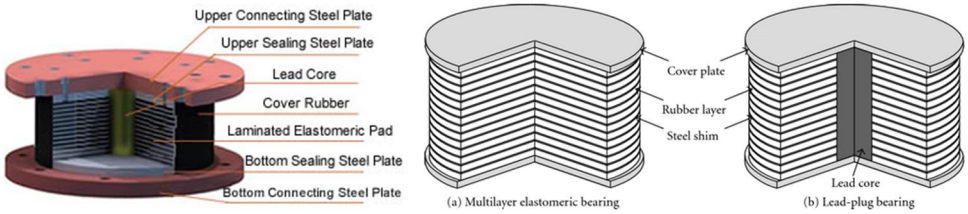


Figure 1. Lead Rubber Bearing (LRB)

IV. MODELING AND ANALYSIS

In present work, the 3 D model of R.C.C. building of different symmetrical and asymmetrical in plan area 1200 m^2 of G+11 Storied of 3.3 m each are Modeled with Fixed base and with Base isolation Devices (LRB) of different shape (Rectangular shape building, C shape building, I shape building and L shape building).The linear Static, Response Spectrum and linear time history analyses are done on these R.C.C. building models using IS 456:2000 and IS 1893:2016 with the help of ETABS Software.

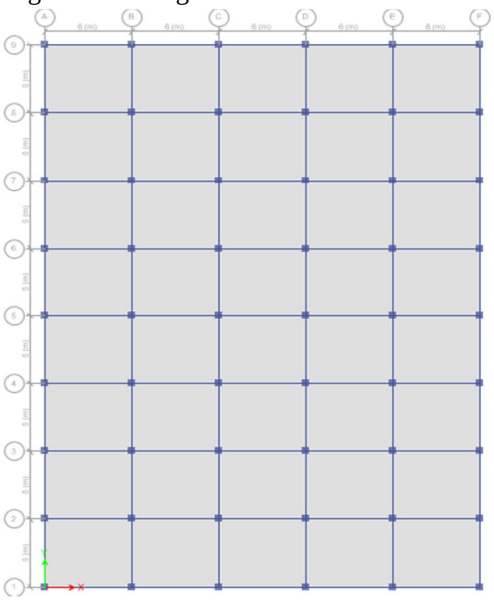


Figure 2. Rectangular Shape Building Model

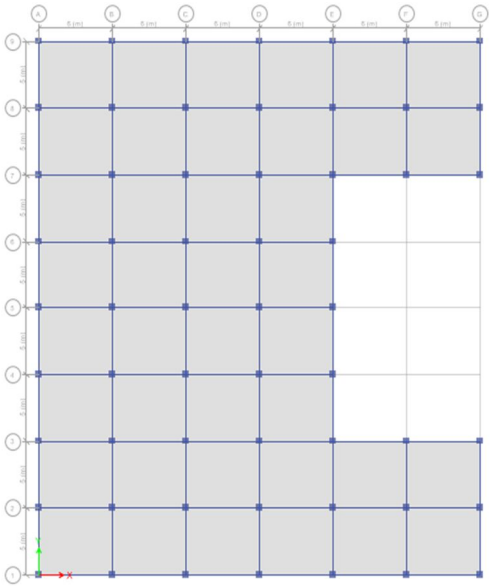


Figure 3. C Shape Building Model

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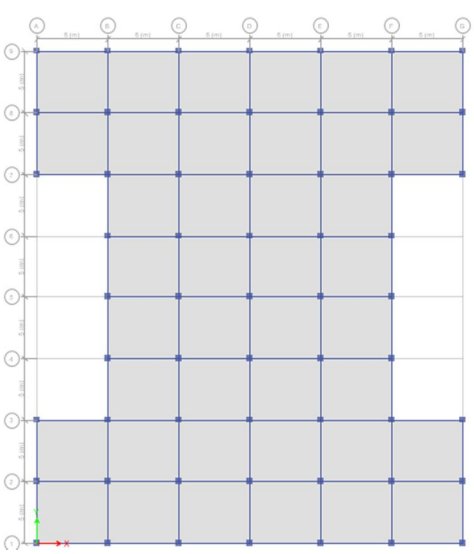


Figure 4. I Shape Building Model

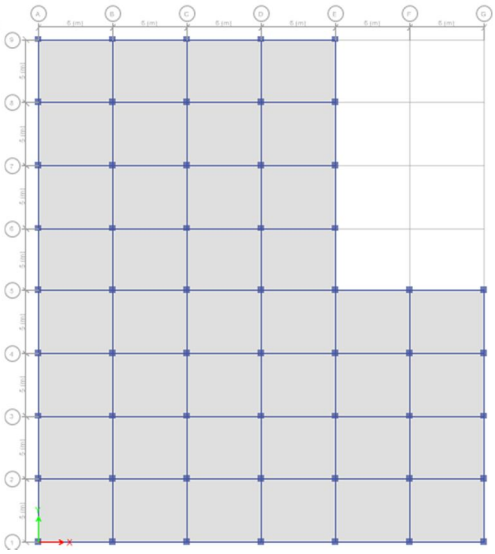


Figure 5. L Shape Building Model

The general specification used in building for analysis shown in table 1.

Table1 Specification of Building

GENERAL PROPERTIES	
SIZE OF COLUMN	500X500mm^2
SIZE OF BEAM	300X500mm^2
THICKNESS OF SLAB	125mm
MATERIAL PROPERTIES	
GRADE OF CONCRETE	30N/MM^2
GRADE OF STEEL	HYSD500
SOFTWARE USED	ETABS 2016
SEISMIC LOAD DETAIL	
SEISMIC ZONE	V (0.36)
RRF	5
IMPORTANCE FACTOR	1
MASS SOURCE	DL+0.25LL
TIME HISTORY DETAIL	
Origin Time	14/12/2005 07:09:48
Lat.	30.9 N
Long.	79.3 E
Depth (Km)	25.7
Magnitude	5.2
Region	Chamoli-Uttarakhand

In Isolated Model the point spring are attached at the base by replace of the fixed support of building with link properties having following properties regarding to the stiffness and damping value as per above calculation given in table 2.

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Table 2 Deign Parameter for Modeling of LRB

Properties	Value
Required Stiffness, U2 & U3 (ken/m)	3835.3
Bearing Horizontal Stiffness, K_b (ken/m)	1257.6
Vertical Stiffness, U1 (KN/M)	22,26,690
Stiffness Ratio	0.1
Damping	0.05

V. RESULT AND DISCUSSION

Analysis carried out under the static and dynamic approach according to Indian standards. And results obtained due to free vibrational analysis, displacement and drift due to static analysis, displacement due to response spectrum analysis, displacement and drift obtained due to time history analysis are compared for both fixed base and base isolated building (having different Shapes like Rectangular shape, C shape, I Shape and L shape) in both X direction and Y direction. And also discuss the base shear and base acceleration under time history analysis.

The model time period of 1st mode are 2.503 sec, 2.46 sec, 2.46 and 2.489 sec respectively in fixed base building of rectangular shape , C shape , I shape and L shape. But when these buildings are base isolated the model time period became 3.434 sec, 3.378 sec, 3.377 sec and 3.415 sec of rectangular shape , C shape , I shape and L shape building respectively. The results show that the time period in base isolated building of different shapes are increased with respect to fixed base buildings of different shapes.

Table 3 Model Participation time period of first mode of different shape of building

Mode	Fixed Base Rectangular Shape model	Fixed Base C-shape Model	Fixed Base I-Shape Model	Fixed Base L-Shape Model	Base Isolated Rectangular Shape model	Base Isolated C-shape Model	Base Isolated I-Shape Model	Base Isolated L-Shape Model
1	2.503	2.46	2.46	2.489	3.434	3.378	3.377	3.415

From linear Static analysis in fixed base buildings the displacements in X direction of rectangular shape, C shape, I shape and L shape buildings at the top story are 118.55mm, 114.459mm, 114.399mm and 118.549mm respectively. This displacements are reduced in Base isolated buildings of rectangular shape, C shape, I shape and L shapes are 63.011mm, 61.91mm, 61.87mm and 63.093mm respectively. And linear Static analysis the displacement in Y direction of rectangular shape , C shape, I shape and L shape buildings at the top story are 100.828mm, 107mm, 103.358mm and 103.096mm respectively. These displacements are reduced in rectangular shape, C shape, I shape and L shape and they are 58.651mm, 60.548mm, 59.329mm and 59.329mm respectively.

Table 3 Static Displacement in different shape building

	Fixed Base Rectangular Shape model	Fixed Base C-shape Model	Fixed Base I-Shape Model	Fixed Base L-Shape Model	Base Isolated Rectangular Shape model	Base Isolated C-shape Model	Base Isolated I-Shape Model	Base Isolated L-Shape Model
In X Direction	118.555	114.459	114.399	118.549	63.011	61.91	61.877	63.093
In Y Direction	100.828	103	103.358	103.096	58.651	60.548	59.329	59.377

In the Time History analysis displacement was reduced up to 56.73% in rectangular shape building, 19.46% in C shape building, 19.71% in I shape building and 20.39% in L shape building when base of building are isolated than the fixed base system in X direction and displacements was reduced up to 51.73% in rectangular shape building, 15.36% in C shape building, 15.5% in I shape building and 15.9% in L shape building respectively when base of building are isolated than the fixed base system in Y direction

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Table 4 Displacement in different shape building due to time history method

	Fixed Base Rectangular Shape model	Fixed Base C-shape Model	Fixed Base I-Shape Model	Fixed Base L-Shape Model	Base Isolated Rectangular Shape model	Base Isolated C-shape Model	Base Isolated I-Shape Model	Base Isolated L-Shape Model
In X Direction	106.957	77.649	77.686	80.255	46.204	62.535	62.519	63.885
In Y Direction	87.225	73.128	72.065	72.052	42.102	61.89	60.856	61.243

In X direction, it is found that maximum acceleration for fixed base rectangular shape building, C shape building, I shape Building and L shape Building are 1441.61mm/s/s, 855.02mm/s/s,854.7mm/s/s and 817.45mm/s/s respectively. And maximum acceleration for base isolated rectangular shape building, C shape building, I shape Building and L shape Building are 209.92mm/s/s, 125.78mm/s/s, 125.71mm/s/s and 120.31mm/s/s respectively. In Y direction ,it is found that maximum acceleration for fixed base rectangular shape building, C shape building, I shape Building and L shape Building are 1336.54mm/s/s, 895.69mm/s/s,895.09mm/s/s and 896.12mm/s/s Respectively. And maximum acceleration for base isolated rectangular shape building, C shape building, I shape Building and L shape Building are 211.78mm/s/s, 117.86mm/s/s, 125.66mm/s/s and 119.06mm/s/s respectively. It has been seen that the value of base acceleration increases by increasing the value of base shear. As the lateral force included the acceleration at the base of structure.

Table 5Base Acceleration in different shape building due to time history method

	Fixed Base Rectangular Shape model	Fixed Base C-shape Model	Fixed Base I-Shape Model	Fixed Base L-Shape Model	Base Isolated Rectangular Shape model	Base Isolated C-shape Model	Base Isolated I-Shape Model	Base Isolated L-Shape Model
In X Direction	1441.61	855.02	854.7	817.45	209.92	125.78	125.71	120.31
In Y Direction	1336.54	895.69	895.09	896.12	211.78	117.86	125.66	119.06

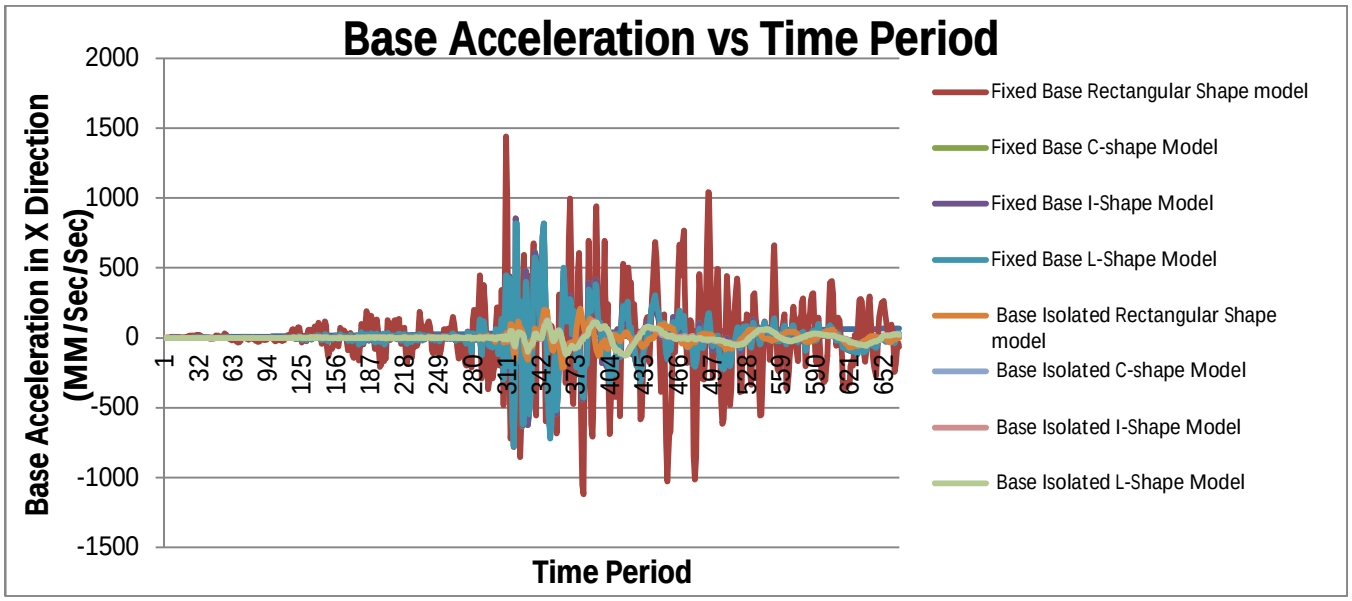


Figure 6. Base Acceleration (mm/s/s) v/s Time Period (Sec.) in X Direction

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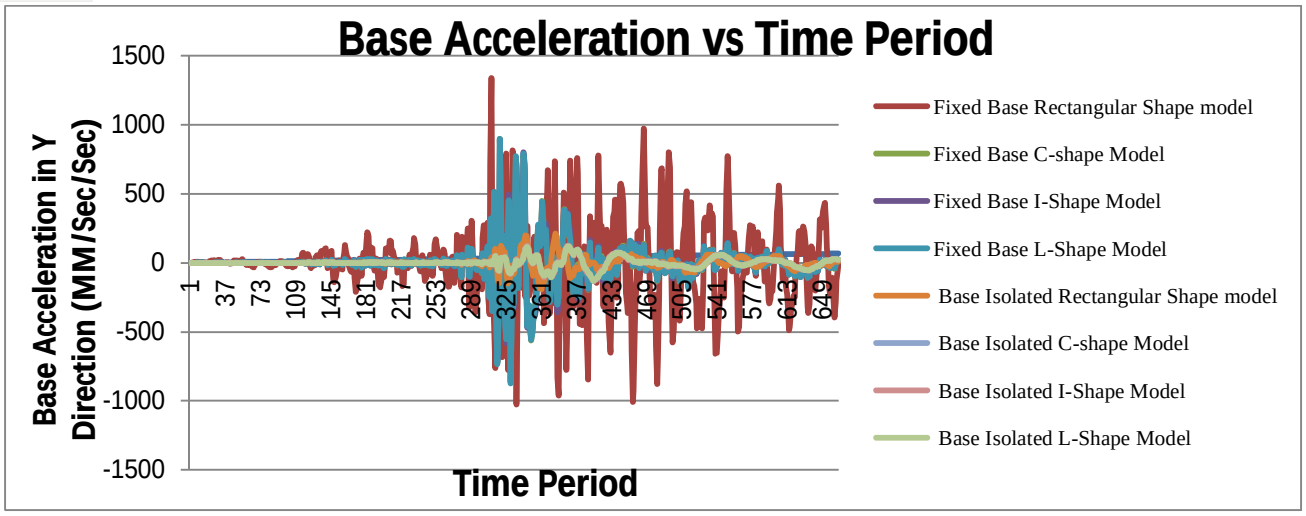


Figure 7. Base Acceleration (mm/s/s) v/s Time Period (Sec.) in Y Direction

The value of base shear depends on the seismic weight and the arrangement of mass from table 4. It can see that the value of base shear in building with fixed base rectangular shape building, C shape building, I shape Building and L shape Building are 7861 KN, 8044 KN, 8044KN and 7922KN Respectively. And the base shear for base isolated rectangular shape building, C shape building, I shape Building and L shape Building are 2718 KN, 2828KN, 2828KN and 2754KN respectively. From the result it can be observed that value of base shear of base isolated buildings of all shapes are reduced approximately 3 times of the fixed base building.

Table 4 Base Shear in different shape building due to time history method

Fixed Base Rectangular Shape model	Fixed Base C-shape Model	Fixed Base I-Shape Model	Fixed Base L-Shape Model	Base Isolated Rectangular Shape model	Base Isolated C-shape Model	Base Isolated I-Shape Model	Base Isolated L-Shape Model
7861	8044	8044	7922	2718	2828	2828	2754

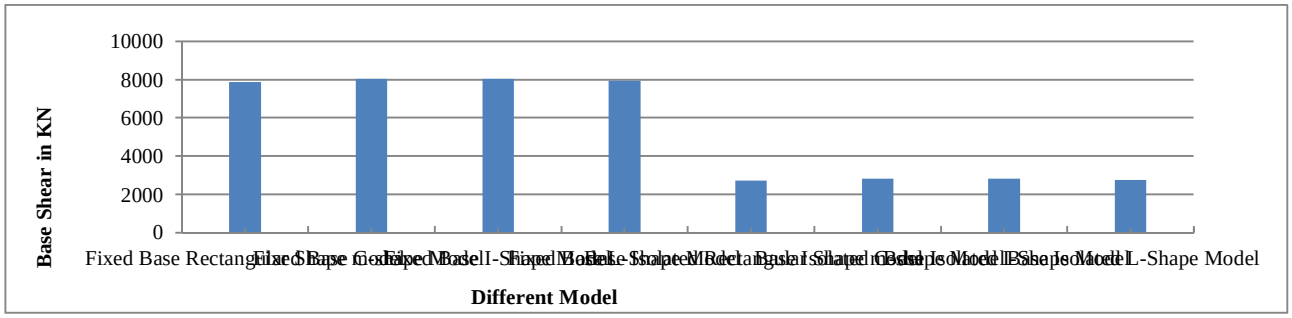


Figure 8 Max Base Shear (KN) due to Time History Analysis

VI. CONCLUSION

This study explains the behavior of Lead Rubber Bearing isolation system under the performance of dynamic loads from the results following conclusion are drawn.

A. The study concludes that the time period of base isolated building of different shapes are increased with respect to fixed base building of different shapes. Due to increase in model time period the frequency are reduces that means the dynamic responses of different shapes of buildings are also reduced.
B. We found that increase in time period is negligible for different shapes of buildings .
C. A result shows that base shear considerably reduces by using base isolation devices over the conventional structure.
D. It is observed that the value of base shear of base isolated building of all shapes reduced approximately 3 times of the fixed base

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building. The base shear of building depends on the damping and the stiffness of the building.

E. On observing the base acceleration value under time history analysis, we found reduction of 6 to 7 times for the all shapes of buildings using Lead Rubber Bearing System in X and Y direction both.

F. After comparison of different shapes of building model, it has been observed that the L shape Building model gave maximum reduction in responses (Base Shear, Displacement, Acceleration) with compare to Rectangular shape Building, C shape Building, L shape Building model for same Lead Rubber Bearing System.

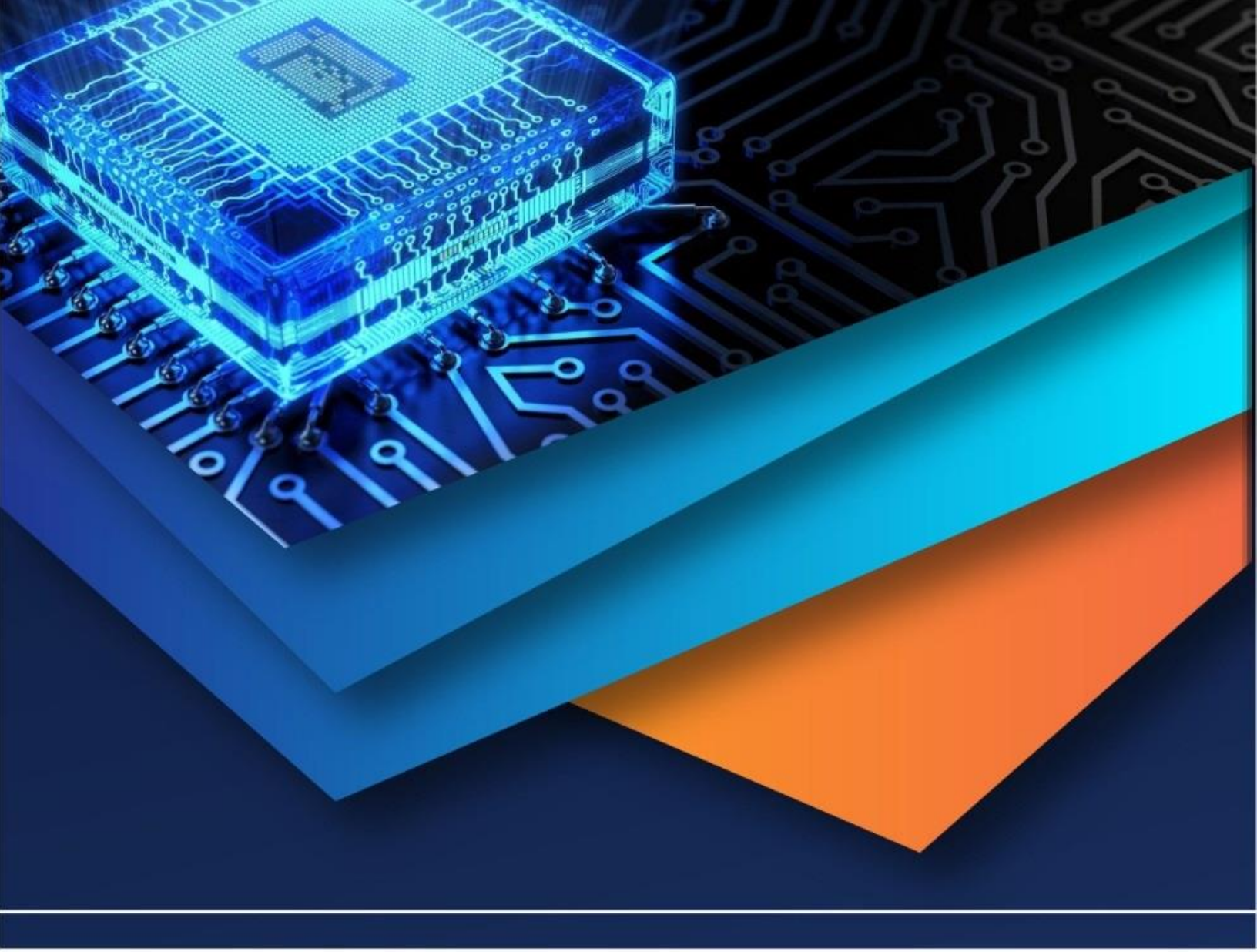
G. In all the shapes the performance of building with base isolation is better than fixed base.

H. In all the shapes the performance of L shape is best in the above study.

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