iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** VII **Month of publication:** July 2022

DOI: https://doi.org/10.22214/ijraset.2022.45990

Effect of Base Isolation using LRB on Stepped Building

Sooraj Kumar[1], Ganesh Jaiswal[2]
[1]M. Tech, Structural Engineering, Institute of Engineering and Technology, Lucknow, Uttar Pradesh, India
[2]Assistant Professor, Civil Engineering Departmen, Institute of Engineering and Technology, Lucknow, Uttar Pradesh, India

Abstract: The base isolation design strategy uncouples the superstructure from the foundation, reducing the effects of earthquake ground motion. The structure is isolated from the ground motion by a flexible base. Installing base isolators in columns. The structural response accelerations are usually less than the ground motion acceleration. In general, base isolation reduces storey shear and acceleration while simultaneously increasing time period, and storey drift, allowing rigid buildings to be more flexible by dispersing energy to the foundation. The basic seismic isolation design provides a shielding technique, allowing the structure to function without harm even after significant earthquakes. The current study explores the seismic effects of a G+6 stepped building with an LRB isolator. An isolator with a lead rubber bearing was used. E-tabs is used to conduct the base isolation study and seismic analysis. The reaction of the structure, lateral shear force, time period, and base shear, was observed. This paper presents time-history analysis and performance assessment analyses on a base isolated stepped building using Bhuj Earthquake ground motion data.

Keywords: Base isolation1; stepped building2; lead rubber bearing3

I. INTRODUCTION

In hilly locations, population growth has resulted in increased infrastructure development. Due to the lack of flat land in the hills, RC structures has to be constructed on steep slope land as a result, when seismic forces are applied on constructed on hill slopes, they behave differently than those built on level ground.[1] When buildings situated on hill slopes are subjected to earthquake loads, It is noted to be more vulnerable to seismic damage because the centre of mass and stiffness change over various floors, imparting twisting moment in structural elements in addition to lateral forces.[2]

According to prior studies, a base isolation system is the most efficient regulatory method for reducing seismic disturbances in structural systems. By using the proper reinforcement & ductility, the capability of the structure in conventional earthquake-resistant RC structures is improved to satisfy the seismic demand. On the other side, a base isolation system adjusts the building's dynamic characteristics so that the shear requirement for which the building should be designed is lower. This approach increased damping and horizontal flexibility of the building by establishing a flexible system in between foundation system and base of the columns.

A considerable dynamic amplification impact results from the basic time period of Reinforced Concrete structures often falling within the range of the predominating period of seismic ground motions.[3], [4] Thus, adopting foundation isolation, time period of a building can be extended above 2.0 s, significantly reducing seismic demand. [3]

The most popular type of base isolator is the lead rubber bearing isolator, as it has been proved to be particularly successful in decreasing high-frequency motions or extreme accelerations. These have minimal horizontal rigidity, to isolate strong vertical stiffness and horizontal vibrations.[5], [6]

Progressive research to date has focused on the structural behaviour of hilly stepped buildings & frame-infill interaction in conventional buildings built on level ground, but none have focused at the behaviour of buildings with base isolation systems.[1], [2] Buildings having irregular geometrical stiffness and mass should be subjected to three-dimensional dynamic analysis, according to IS-1893 Part.1.[7] Buildings' actual response subjected to lateral masses, additionally to the rigidity of hill structures, will be investigated. To induce the structure's actual response, A typical research review investigated at how two hill construction configurations—step back and setback-step back—performed seismically in relation to the impact of Lead rubber bearing (LRB), a widely utilised base isolation device. The Etabs 2016 software is used to model all of the configurations, and a time history analysis was performed. Variations in storey shear force, time period were discovered using numerically as seismic elements. Finally, the different configurations' vulnerability and effectiveness against seismic excitations was compared.

II. MATERIALS AND METHODOLOGY

Under seismic loads, the response of two distinct types of building stepped structures on hilly slope ground, viz step back & setback-step back, is examined. The impact of a lead rubber bearing LRB base isolation system on the seismic functioning of the configurations under consideration has been investigated. The seismic response of building structures was determined using the time history method. The differences in the values of the fundamental time period, lateral shear at foundation level were compared using the seismic parameters generated from the analyses. The concrete material's elasticity modulus and poissons ratio are 25000 N/mm^2 and 02, respectively. The concrete mix M25 and the reinforcement steel grade Fe500 were taken into consideration. The rigid frame diaphragm is taken into consideration in the floor systems for seismic analysis, and support conditions were considered to be installed at foundation level

III.BUILDING CONFIGURATION

In the study, two different models of step back & setback-step back building configurations were studied, both with and without base isolator systems. The structures were designed with five bays in along and across the slope directions. The length of each bay varies in each of the models. along and across the slope was set to 5 and 4 metres, respectively. The ground was supposed to be inclined at 27 degrees to the horizontal.[8] At the periphery, the load caused by masonry infills has been taken into account.

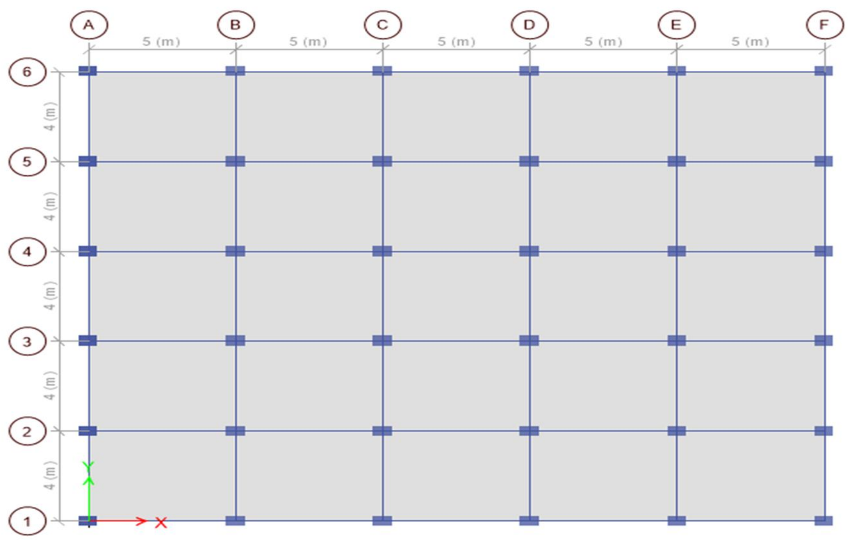

Fig.1 Building Plan

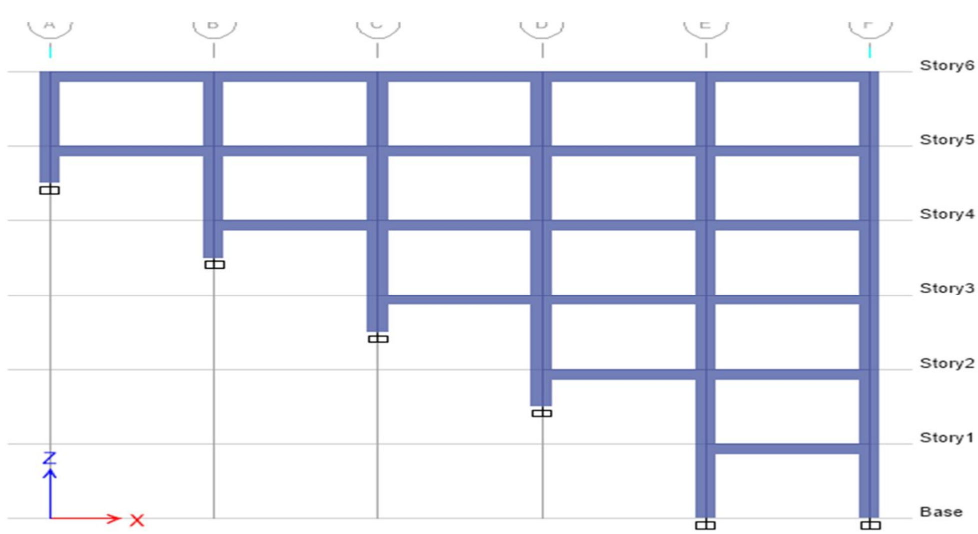

Fig.1(a) Stepped Building with Fixed Base

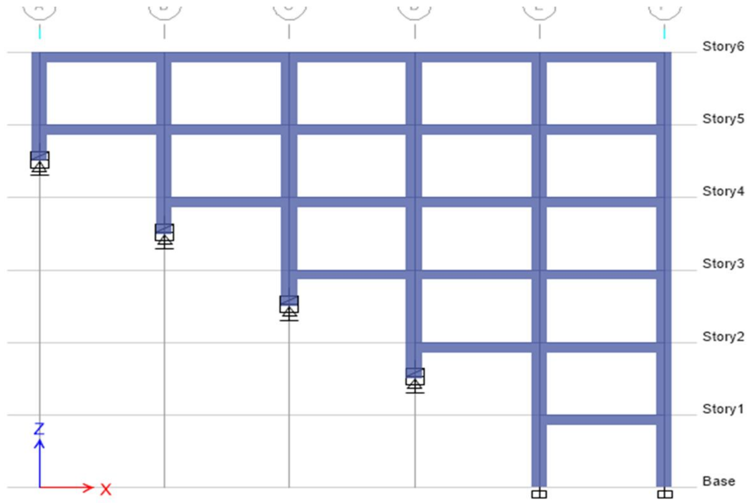

Fig.1(b) Stepped Building with LRB

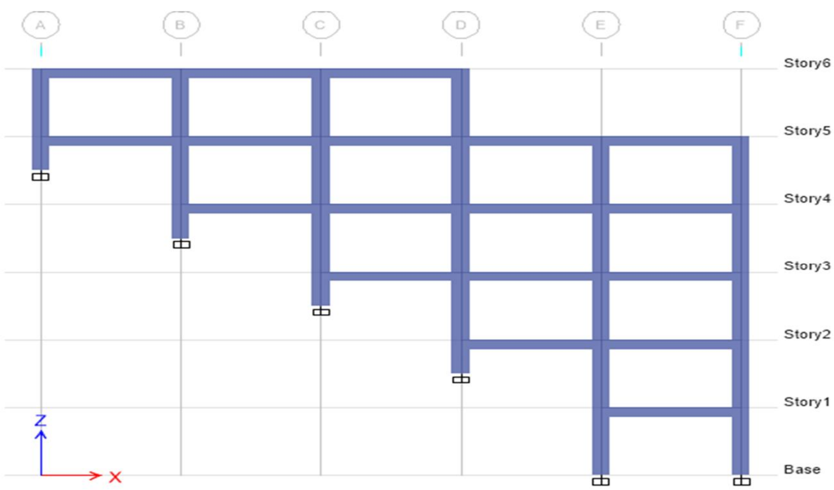

Fig.2(b). Step back setback structure with Fixed Base

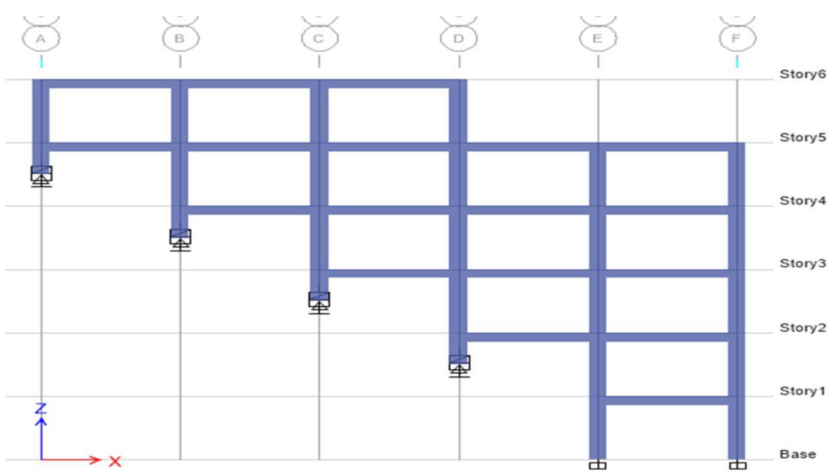

Fig.2(a). Step back setback structure with LRB

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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In analysing different building configurations, the following parameters are considered: -

TABLE.I

Geometric parameters	Seismic parameters
Plan dimension 25m×20m	Zone = V
Building Height=19.2	Soil type = II (i.e. medium)
Each storey's height = 3.2 m	I = 1
size of Beam = 0.30 m × 0.45 m	Live load = 3 kN/m^2
Column size = 0.45 m × 0.60 m	R = 5
slab's thickness = 0.150 m	Damping ratio=5%
Time history Analysis	Bhuj Earthquake (2001)

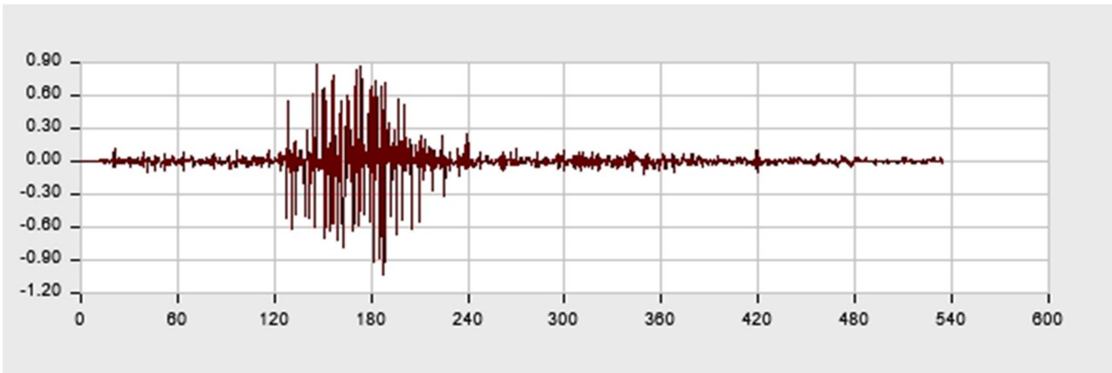

Fig.3 Time history function (Bhuj,2001)

IV. BASE ISOLATION SYSTEM DESIGN

The following are the primary requirements for designing an effective base isolation system:

1) Vertical load carrying capacity,
2) Low horizontal stiffness sufficient to extend the Building's Time Period till it reaches the desired amount,
3) To decrease amplification in vertical direction, utilise large vertical stiffness.
4) Adequate damping to avoid too much isolation level displacements
5) Initial stiffness to restrict movement caused by minor vibrations.[9]

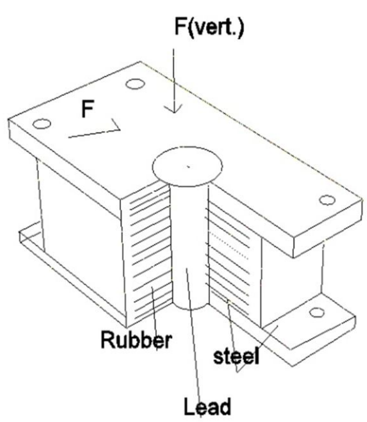

Fig.4. Lead Rubber Bearing

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VII July 2022- Available at www.ijraset.com

The following operations are performed, while designing a base-isolated building:[3]

a) (The vertical load applied to base isolators for the stated zone and soil type was used to design them.
b) The isolated base building was designed to meet the required standards.
c) Finally, non-linear dynamic analysis was used to check the design. Datta's correlations were used to design the base isolators.

$$K_{eff} = \frac{W}{g}\left[\frac{2\pi}{Tb}\right]^2 \quad (1)$$

where Keff is the base isolator's effective stiffness, highest vertical load beneath any column is W. for the load case '1.2DL + 1.6LLo' (where LLo reduced live load)[9] , The isolated time period is denoted by Tb, 'Tb = nT', (where n may be taken as 3 to 4), T denotes the time period for structure with a fixed base.

$$A_r = \frac{W}{p} \quad (2)$$

$$T_r = \frac{GA_r}{K_d} \quad (3)$$

$$A_{pb} = \frac{F}{\sigma_{pb}} \quad (4)$$

where, thickness of one layer of rubber is T, rubber's rigidity modulus is G, G varies from 0.69 to 0.86 MPa for the strain range recommended for rubber bearing, i.e. $\gamma = 100 - 150\%$ [10], Ar denotes the area of the rubber layer., F is the characteristic strength calculated during determining the base isolator's bilinear curve properties, σ_{pb} denotes the yield shear strength of lead. σ_{pb} has a value of 8–10 MPa. [11]

Hill buildings with two configurations, stepback and setback-stepback, were studied in this paper. Base isolators for both buildings were proposed, and their reactions were compared to those of fixed-support buildings (see Fig. 2a and 2b). Base isolators were not put beneath all of the columns to preserve the design cost-effective. During an earthquake, base isolators were placed on supports that were higher than the base support system and then were subjected to stronger shear stresses.

Initially, the buildings model was examined using time history technique, using IS 1893:2016.[7] Each column's vertical load was assessed, and base isolator was developed separately. For illustration, while designing base isolator for a setback-step back setup under a column, the values of effective stiffness, Design displacement, energy dissipation per cycle, were computed as follows: Wd = 81.54 kNm, K_{eff} = 2110 KN/m, and d = 0.214 m., correspondingly, according to Eq. 1, for zone V & damping coefficient = 0.15. After iterations, the values of the base isolator's backbone curve have been determined. The geometric characteristics have been computed using Eqs. 2–4.[9]

V. RESULTS AND DISCUSSION

The seismic loads over slopes and across slopes, as well as the effects of accidental eccentricity, were computed for hill structure layouts with fixed support and base isolator systems, according to IS code provisions.[7] The time history analysis of the three-dimensional models was performed using the Bhuj earthquake of 2001. Discussion and comparison of the analysis's findings were done in terms of time, total base shear, and lateral shear force at foundation.

TABLE.II

Type of building	Type of support	Time Period by THA (sec)		Base shear (kN)
		Along Slope	Across Slope	Along Slope
Step back	Fixed	0.154	0.229	2527.98
	Base isolated	0.349	0.512	1263.99
Setback-step back	Fixed	0.119	0.229	2289.23
	Base isolated	0.318	0.433	1144.61

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Table 2 shows the dynamic properties derived from numerical analyses. As can be observed, the base isolator system has a significant impact on seismic performance of both step back & setback-step back systems.

The use of a base isolator system instead of fixed isolated supports improved time period (TP) in the along slope direction by 126.6 percent in step back buildings. The variation in Time Period across slope direction was found to be 123.5 %. In comparison to fixed supported buildings, base-isolated setback-step back buildings had a 167.2 % and 89.08 % Time Period increases in both the along and across slope directions respectively.

Total base shear for building slopes were significantly reduced in both the along and across slope directions. Configurations with isolated base, indicating that structural components of base-isolated buildings are subjected to less shear demand than fixed support system. After isolated base technique was installed for step back structure, the base shear outcome was found lowered by 50% along slope directions. The base shear values were likewise decreased by 49% for isolated base setback-step back arrangement, along slope directions. Furthermore, setback-step back structures gives less base shear as setback design for stepped buildings, indicating that they are less earthquake-prone.

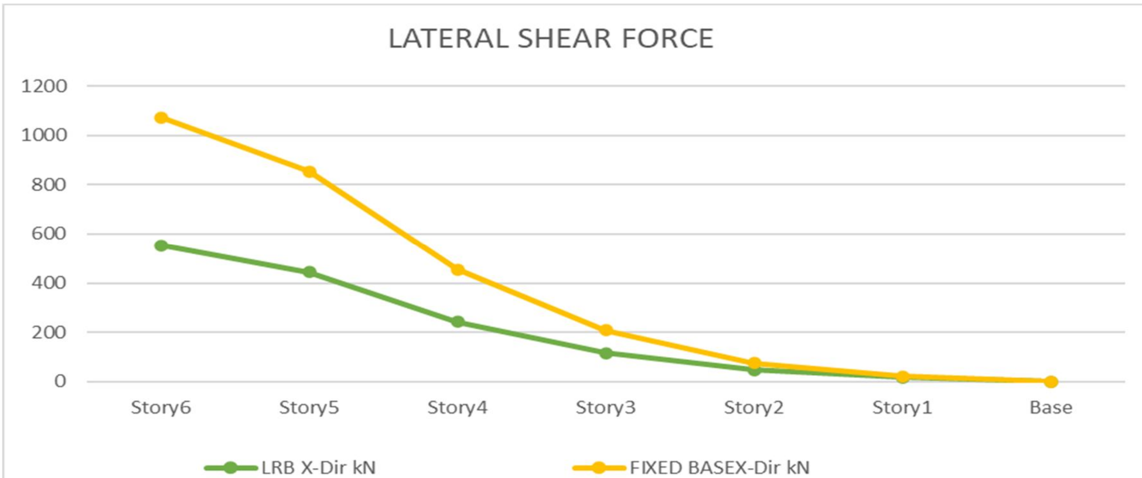

Fig.5 (a) Shear force distribution in columns at the building's foundation level in step back along the building's slope

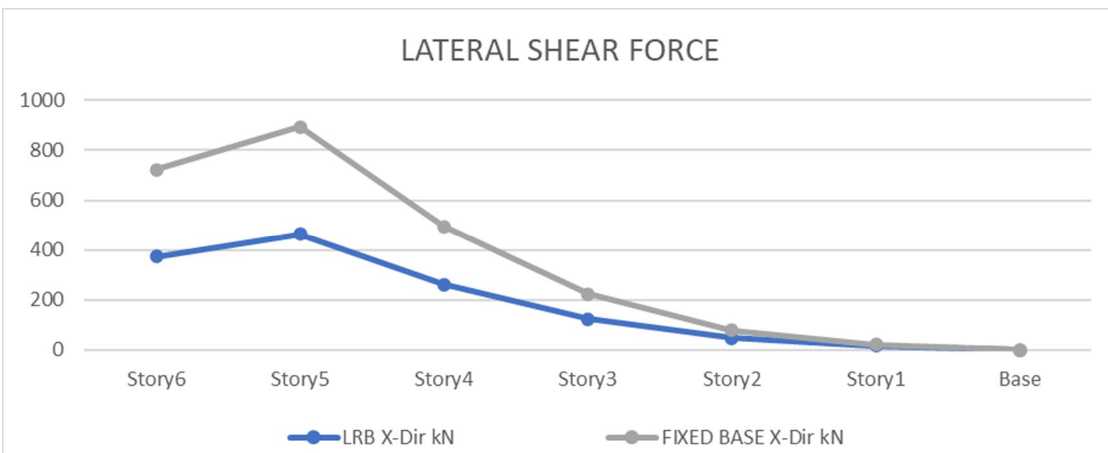

Fig.5(b) Shear force distribution in columns at the foundation level with a setback-step back in the slope direction

The lateral shear stress segmentation for an interior frame for stepped structure layouts is illustrated in figures 5. (a) and 5. (b). Because of their higher lateral stiffness and shorter length, buildings for fixed support system tends to generate more shear forces in columns at the top storey level.

However, after installing base isolators in columns, base shear outcomes were significantly decreased, notably at the topmost story level. As a result, isolated base system for stepped structure arrangement lower lateral shear require in structural components with more lateral stiffness. A significant drop in base shear outcomes was found at the 3rd & 4th story level. While, the column at the base of the frame were left fixed to avoid lateral drift for structure construction.

After developing reinforced concrete frames, the structure arrangement was analysed by Time history analysis to determine the structure's seismic reaction. Due to high storey shear, plastic hinge developed initially in column of the top storey, and complete foundation yielding was observed at the upper hill frame in step back buildings with fixed support systems. While, after installation of isolated base, hinges emerged in beams, follow by column in the lower storey. As result, shear demand for columns with high lateral stiffness was found to be significantly reduced. Furthermore, base isolators have been shown to greatly improve a building's performance on an across-hill slope. The columns yielded before the beams both on uphill and downhill sides, while the isolated base model only given hinge formed at protected level in beam components. Furthermore, in fixed support conditions, setback-step back design perform improved and showed minimum yielding, while none of frame components for the isolated base arrangement show yield for any position, demonstrating the efficiency of isolated base system for hill building configuration results.

VI. CONCLUSION

The seismic performance of two stepped structure configurations for fixed and isolated base-support system was explored in this study. The Time history analysis technique were used for analyse the three-dimensional models. The stepped structure's dynamic properties were assessed and compare by the installation of isolated base at the base of structure, in step back and setback-step back structures, the fundamental time period was significantly increased. In both configurations, a significant reduction in base shear outcomes was observed in both the uphill and downhill slope directions. Furthermore, Plastic hinges occurred on the top storey column for step back buildings with fixed support systems, foundations at upper hill frame completely yielded due to high storey shear. While, after the placement of base isolators, hinges in beams were observed, followed by hinges for columns in the lower levels. Furthermore, setback-step back arrangement gives superior and demonstrates minimum yielding for fixed support conditions due to its lower seismic weight, whereas no members in the isolated base arrangement yielded at any point, showing the efficiency of isolated base system. As a result, isolated base system in stepped building construction arrangement lower lateral shear require for structural components by more lateral stiffness. Furthermore, the outcome of isolated base on Seismic significance could be determined. Structures with a setback-step back configuration gives less base shear as hill buildings with a setback configuration, and hence are less vulnerable to earthquake effects.

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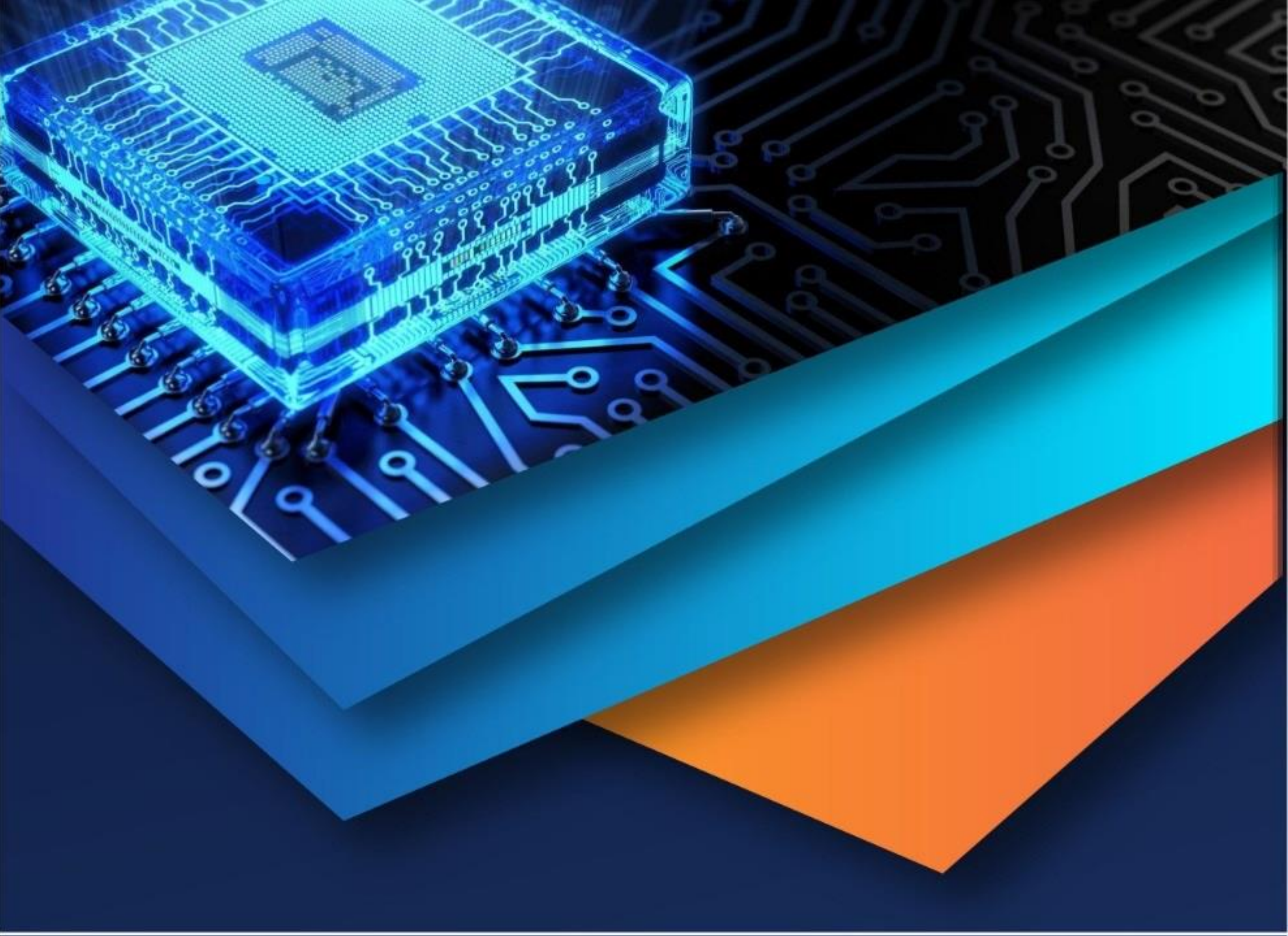

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