SEISMIC PERFORMANCE OF BASE ISOLATED 3D RC STRUCTURES CONSIDERING EXISTING EARTHQUAKE DATA

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Abstract - *For reinforced concrete (RC) buildings to maintain their structural integrity and the safety of its occupants during earthquakes, seismic performance assessment is essential. The first step in the research is to create ETABS models that faithfully capture the dynamic behaviour of reinforced concrete buildings. Subsequently, the LRB and HDRB isolators are reviewed, chosen, and designed. Time history loads are applied to determine the models' reaction. Assessing the effectiveness of isolators in reducing earthquake-induced damages by contrasting the exceedance probabilities of fixed and base isolated structures. The study's findings offer crucial data for assessing the structure's anticipated seismic performance and creating focused mitigation plans. Various preceding earthquakes are considered and compared to obtain the better performance. Total seven earthquakes with reference to IS 1893:2016 (part 1) are taken. With infill that is with equivalent diagonal strut and without infill having two types of storey- low rise and medium rise with basic beam-column-slab structures are used in this thesis*

Key Words: Base isolation, Lead rubber bearing, High damping rubber bearing, *equivalent diagonal strut.*

1.INTRODUCTION

In earthquake-prone regions, the importance of earthquake-resistant buildings cannot be overstated. They are a critical component of disaster preparedness and risk reduction, helping to protect lives, property, and the overall well-being of communities. Building structures that can withstand seismic forces is a proactive and responsible approach to managing the risks associated with earthquakes. The ground that underpins every building shift during earthquakes. As a result, the building's base moves along with it. However, the building will make an effort to resist this motion because of its inertia. The building gets distorted as a result, and this distortion increases with the building's height.

1.1 Concept of Base Isolation

Base isolation is a seismic-resistant design strategy that seeks to break the direct mechanical link between a building's superstructure and its foundation. With the arrival of multilayer elastomeric bearings, which are created by vulcanizing rubber sheets to thin steel reinforcing plates, the idea of seismic isolation has become a reality throughout the past 20 years. These are extremely rigid bearings although they are highly adaptable, they can support the building's vertical weight in the vertical direction horizontally, allowing the structure to shift laterally in the event of extreme ground motion. their creation represented a growth in the application of elastomeric bridge bearings and bearings for the building's isolation from vibration. The concept of base isolation is now widely accepted in earthquake-prone regions of the world for protecting important structures from strong ground motion; there are currently many examples in the United States and Japan. Other systems that are modifications of the sliding approach have been developed in recent years.

1.2 Objectives

Aims to perform Finite Element Analysis (FEA) for fixed base and base isolation for 3D RC building for Seismic loads. Design and apply base isolators at the supports 3D RC Buildings are done. Carry out Finite elemental analysis which involves modal analysis and Time history analysis and compare the fixed base results with base isolated models for different storey height.

2. DEFINITION OF MODELS

RC framed structure with and without infill is considered, two types of building in terms of height is being considered, low rise (5 Floors) and medium rise (13 Floors). All the models have 5 bays of 8 m width in both perpendicular directions in the horizontal plane. Time history analysis is carried out in ETABS software. The structural material is assumed to be isotropic and homogeneous.

Various loads are applied to the structural models. Part I of the Indian Standard Code of Practice for the Structural Safety of Buildings, IS 875-1987, specifies the loads that were taken into account for the study. The loads taken into account in this work are

i. Dead Load designated as “DL”

ii. Live Load designated as “LL”

iii. Earthquake Load designated as “EQX”, EQY” & “TH”

MODEL	G+4 (low rise)	G+12 (medium rise)
Type of structure	SMRF	SMRF
Grade of concrete	M40 (40 N/mm^2)	M40 (40 N/mm^2)
Grade of Reinforcing steel	Fe 500(f_y = 500N/mm^2)	Fe 500(f_y = 500N/mm^2)
Number of stories	G+4	G+12
Floor height	3.5m	3.5m
Depth of foundation	2.5m	2.5m
Bay width	8m	8m
Height of the Building	21m	48m
Column size	600 X 600 mm	800 X 800 mm
Main Beam size	450 X 600 mm	450 X 600 mm
Secondary Beam size	300 X 600 mm	300 X 600 mm
Dead Load on Floor	3.0 kN/m^2	3.0 kN/m^2
Live Load on Floor	3.0 kN/m^2	3.0 kN/m^2
Importance factor	1.5	1.5
Zone factor or 'Z'	0.36	0.36
Response reduction factor or 'R'	5	5

Table -1: **Structural Configuration of models**

2.1 Models

The floors/slabs are modeled as membrane elements for the Column beam slab system. The floor slab is considered as rigid diaphragm. The typical plan and sectional view of 5-floor and 13-floor buildings are shown in figure 1. The building details and material properties are given in Table -1 above.

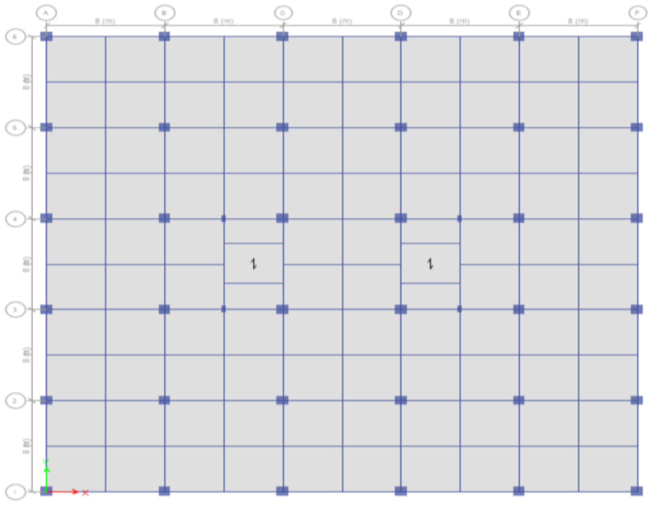

Fig -1: Plan of all the models

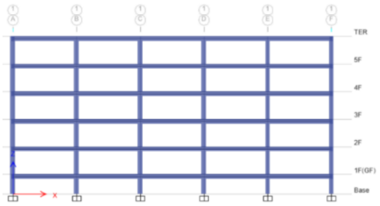

Fig -2: Elevation of 5 floor building

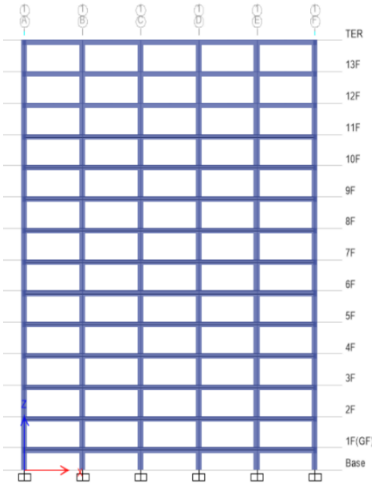

Fig -3: Elevation of 13 floor building

3. METHODOLOGY

The loading standards IS 875 (Part I & Part II):1987 and the Indian Standard Code of Practice for Structural Safety of Buildings have been used as the foundation for the calculation of gravity loads, including dead and live loads, that are applied to the frames. The self-weight of structural and non-structural components, such as wall load and parapet load, is known as the dead load.

A. Dead loads

Floor Finish + Partition load =1.5 kN/m2+1.5 kN/m2 = 3.0 kN/m2 Wall Load +plaster on two sides

(wall loads are considered on the peripheral beams and at staircase lobby)

0.2x(3.5–0.45)X17.65+ 2*.02*3.35*20.4= 13.5 kN/m

B. Live loads

All floors: 3 kN/m2

C. Seismic Loads

In addition to gravity loads, earthquake loads are considered for the analysis of the structure located in seismic zone-v, as per IS: 1893-2016 (Part-I). The seismic details of the building are listed below in Table-2.

Parameter	Values adopted	Reference in code
Zone	V	Table-3
Soil	I	Table-2
Importance Factor	1.5	Table-8
Response reduction factor	5	Table-9

Table-2: Seismic parameters (IS: 1893-2016, Part-I)

For the seismic loads, mass source is to be defined as per codal provisions. As the imposed load for present building is 3kN/m2 (<=3kN/m2), as per IS: 1893-Part I, Table 10, 25% of the imposed load is considered for seismic weight calculation along with total dead loads applied. If imposed load exceeds 3kN/m2, then 50% of such load plus all the dead loads is considered for seismic weight calculation The detailed seismic analysis is carried out for the considered low rise & medium rise building considering primary loads (dead, live & seismic loads) for all the models.

4. TIME HISTORY ANALYSIS

It is an examination of the structure's dynamic response at a certain point in time when its base is exposed to a particular ground motion history. At the proper places and time steps, the chosen time history recordings are applied to the finite element model as input excitations. A multitude of elements are taken into consideration during the intricate process of selecting time history data for time history analysis. Usually, the design parameters and seismic hazard assessments for the area in which the structure is situated are established initially. Next, seek and gather a set of representative ground motion recordings utilizing historical records, probabilistic seismic hazard evaluations, or existing seismic or dynamic data sources.

To guarantee that these records appropriately depict the structure's anticipated dynamic loading scenarios, they should have characteristics such as spectral form, frequency content, amplitude, and length that match the design spectrum. Validation with synthetic data or recorded events demonstrates its applicability and relevance for accurately simulating the dynamic response of the structure being studied. Fast Nonlinear Analysis (FNA) is used in ETABS to analyse the temporal history. The modal analysis technique known as FNA can be applied to the static or dynamic assessment of structural systems that are linear or nonlinear. Due to its computationally efficient formulation, FNA is frequently preferred over direct-integration applications in time-history research. Analytical models used in dynamic-nonlinear FNA applications should generally be linear-elastic, have a small number of preset nonlinear elements, Nonlinear lump behaviour within link objects.

5. GROUND MOTION RECORDS

The ground motion has dynamic characteristics, which are peak ground acceleration (PGA), peak ground velocity (PGV), peak ground displacement (PGD), frequency content, and duration. These dynamic characteristics play a predominant role in studying the behavior of RC buildings under seismic loads. The structure stability depends on the structure's slenderness, as well as the ground motion amplitude, frequency, and duration.

Based on the frequency content, which is the ratio of PGA/PGV the ground motion records are classified into three categories High-frequency content PGA/PGV > 1.2, Intermediate-frequency content 0.8< PGA/PGV< 1.2 and Low-frequency content PGA/PGV < 0.8. The time history data selected for the present analysis is shown in Table 3.

TIME HISTORY	Max. Acceleration (g)	Max. Velocity (cm/sec)	Max. Displacement (cm)
BHUJ (2001)	0.10	11.19	18.15
CHAMOLI (1998)	0.22	0.054	0.28
CHICHI (1999)	0.36	21.54	21.88
EL CENTRO (1979)	0.37	80.4	74.26
KOBE (1995)	0.33	27.67	9.54
LOMA PRIETA (1989)	0.35	44.28	19.04
NOTHRIDGE (1994)	0.57	51.82	9.00
1893 TH MATCHED	0.20	15.42	34.18

Table-3: Time history data of the selected earthquakes for carrying out time history analysis.

6. ISOLATOR PROPERTIES

The parameters chosen for the base isolated models are provided in Figures 2, 3, and Table 4, Table 5 for the LRB Isolator and HDRB Isolator, respectively, which are intended for the forces acquired from the Analysis of Fixed Base Models for the current study.

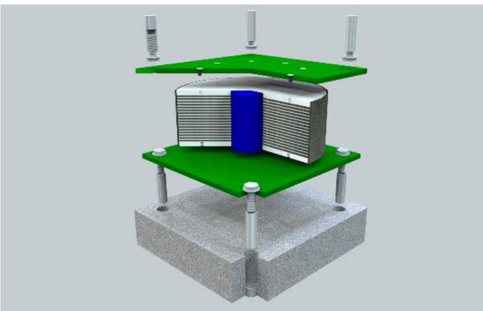

Fig 2

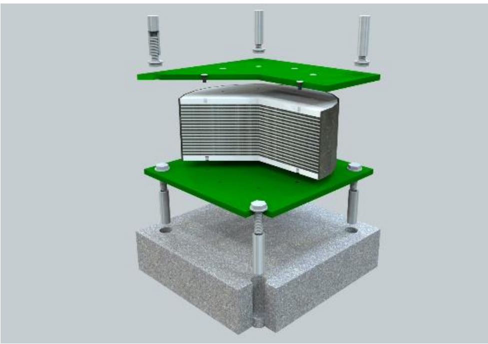

Fig 3

		Unit	LRB-5F	HDRB-5F
Vertical stiffness of the bearing,	K_v	kN/m	7460448.1	1693318.4
Effective damping of bearing,	ξ_{eff}	%	15.0	15.0
Effective horizontal stiffness,	K_{eff}	kN/m	2828.3	3741.0
Effective damping of bearing,	ξ_{eff}	%	15.0	15.0
Initial stiffness of the bearing,	K_e	kN/m	40349.8	33510.3
Yield force of bearing,	F_y	kN	235.3	200.9
Post-yield stiffness ratio			0.1	0.1

Table 4
Isolator properties of 5 floors building

		Unit	LRB 13F	HDRB 13F
Vertical stiffness of the bearing	K_v	kN/m	10743045.2	3809966.5
Effective damping of bearing	ξ_{eff}	%	15.0	15.0
Effective horizontal stiffness	K_{eff}	kN/m	5513.7	7810.4
Effective damping of bearing	ξ_{eff}	%	15.0	15.0
Initial stiffness of the bearing	K_e	kN/m	58103.8	75398.2
Yield force of bearing,	F_y	Kn	518.3	452
Post-yield stiffness ratio			0.1	0.1

Table 5
Isolator properties of 13 floors building

7. RESULTS AND DISCUSSION

The gravity loads such as dead and live loads coming on the frames have been calculated based on provisions given in the Indian Standard Code of Practice for Structural Safety of Buildings, loading standards IS 875 (Part I & Part II):1987. The dead load consists of self-weight of structural and non-structural elements like wall load, and parapet load.

A. Modal Time Period

The fundamental period is the duration of the first vibrational mode. The effects of stiffness (stiffer buildings have shorter natural periods), mass (heavier buildings have longer natural periods), building height (taller buildings have longer natural periods), cracked sections on RC frame analysis (buildings with shorter natural periods are estimated using gross stiffness, while longer natural periods are estimated using effective stiffness), and natural period on design horizontal seismic force coefficient (buildings with shorter translational natural periods attract higher design seismic force coefficient) are some of the factors that affect a building's natural period. Table 6 shows the modal time period obtained for the four types of framing systems for 5 and 13-floor buildings with fixed base and base isolated with LRB and HDRB isolators.

MODEL	FIXED BASE	LRB	HDRB
5F	1.127	3.653	2.525
13F	2.52	4.081	3.714

Table 6
Modal time period

The comparison of the modal time period with fixed base and base-isolated buildings with three types of isolators is shown in Figure 4. It can be observed that the predominant period of the structure is lengthened for the base-isolated buildings as expected.

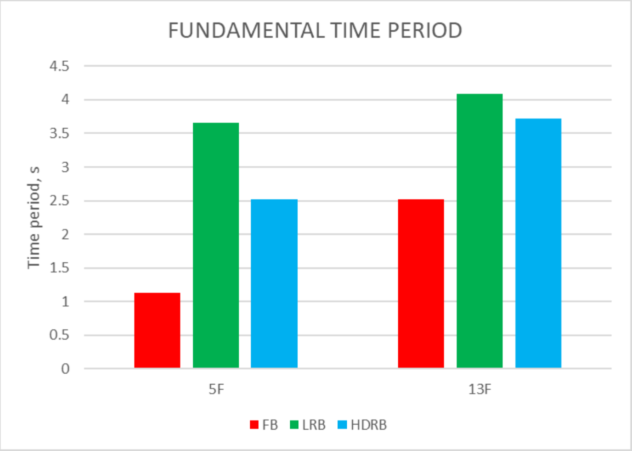

Fig 4
Fundamental time period

It can be observed from Figure 4 and Table 6 that when compared with the fixed base buildings of 5 floors the time period increases by 3.6 and 2.4 times for LRB and HDRB buildings respectively. For 13 Floors buildings this increase is 1.66 and 1.56 times, overall time period increases due to base isolation.

B. Base Shear

Buildings vibrate during an earthquake, inducing an inertia force within the structure. The majority of design codes express the net effect of such random shaking as a design-equivalent static lateral force, which is how earthquake-induced inertia forces are represented. The force that results from using seismic design codes is known as the design seismic base shear or the design seismic lateral force of the building. Seismic design standards offer a design response spectrum. The fundamental quantity in force-based earthquake-resistant structure design is still this force, which is known as the Seismic Design Base Shear (VB). This force is determined by the seismic risk at the building location, which is indicated by the Seismic Zone Factor Z. The seismic coefficient multiplied by the total of the seismic masses at various floor levels yields the seismic base shear (VB).

The change in base shear seen with a fixed base and a base isolated using two different kinds of isolators is shown in Figure 5.

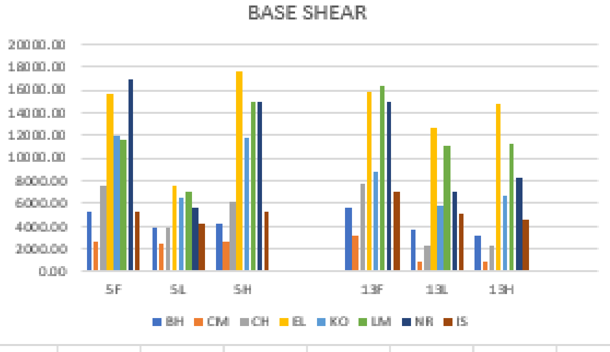

Fig 5
Base Shear

The variation in base shear is shown in Figure 5 with fixed base and base-isolated building with LRB and HDRB isolators. It can be observed that an average of about 80% to 90% reduction in the base shear is observed for the base-isolated building when compared with the fixed base buildings of 5 floors. An average of about 50% reduction is also observed in 13 floors building.

C. Maximum Storey Displacement

The deformation of the structure brought about by the application of lateral forces is known as lateral displacement. Absolute values of the maximum roof storey displacements along lateral directions are selected for the comparative research. At the isolator level, a significant amount of lateral displacement is seen for base-isolated buildings. Models with fixed bases have no displacement at the base. The storey displacement of the isolated models is represented in relation to the isolator displacement for comparison's sake, as the lateral displacement variation for base-isolated buildings is negligible at higher elevations. In contrast, the lateral displacement increased significantly in the case of fixed base buildings. The variations in the peak roof displacements are compared against the fixed base building and base-isolated buildings with LRB and HDRB isolators for 5 floors and 13 floors and are shown in Figure 6.

It can be observed that there is a reduction in roof displacement with both LRB and HDRB isolators for all the time history cases considered.

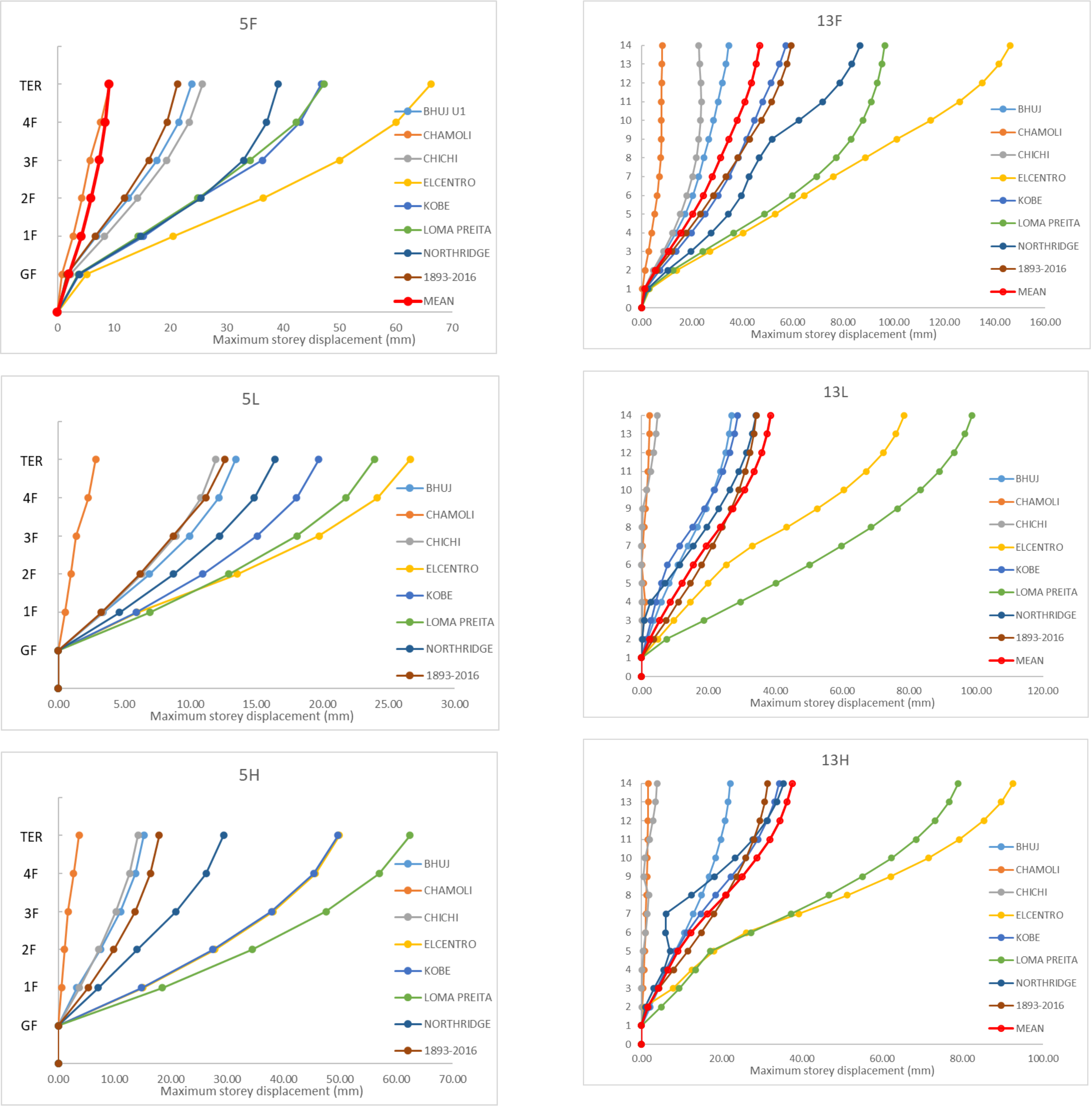

Fig 6
Maximum storey Displacement

8. CONCLUSION

An attempt is made to investigate an RC monolithic building of 5 and 13 storey modeled as a three-dimensional structure in ETABS Software to study the seismic response with base-isolated and fixed base conditions situated in all four seismic zones V with soil type I (hard soil).

1. Lengthening of the fundamental period of the base isolation system results in a reduction of the

maximum acceleration and hence the reduction in earthquake-induced forces in the structure.

2. For the RC monolithic building with a base isolation system, the base shear was reduced significantly.
3. For isolated base models the displacement between the ground floor level and roof level is very less compared with the displacement between the ground floor level and roof level of fixed base models.

The results show that the Base Isolation is very effective at lessening the seismic response of the structure.

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