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SEISMIC RESPONSE OF RC SHEAR WALL BUILDING WITH BASE ISOLATION

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Abstract: **In order to guarantee the structural integrity of reinforced concrete (RC) shear wall buildings and the safety of its occupants during earthquakes, seismic performance assessment is essential. This study's inclusion of the shear wall, in the form of lift core, has a big impact on how the building behaves as a whole during earthquakes. This work uses the FEA models are created to simulate the dynamic behavior of buildings with reinforced concrete shear walls. Fixed base and Base isolated buildings with Lead rubber bearing isolators are subjected to selected earthquake records and responses such as modal time period, base shear, storey displacements are recorded. The results of fixed and base isolated structures are compared and isolator effectiveness is evaluated**

Keywords: **Base isolation, Lead rubber bearing, High damping rubber bearing, Base Shear**

I. INTRODUCTION

Civil engineering is constantly striving to develop methods for coping with natural phenomena that are causing damage to the built environment or structures. Earthquakes are natural consequences of the incessant evolution of our planet. In response to the destruction by the recent/past tremors in densely inhabited areas, seismic codes have improved to lead to improved seismic performance on the background of technological development all over the world, including India. Worldwide, the ductility design concept has been used for earthquake-resistant design of building structures over the past decades. The intended performance of the ductile structures during major earthquakes has proved to be unsatisfactory and indeed far below expectations. Significant damage in buildings under strong ground shaking can be avoided by modifying the structure's features through external interference such that during the strong ground shaking, the demand is less than the design strength of the Structure. To improve structural safety and integrity of the Structure, effective and reliable methods for aseismic design based on structural control concepts are desired. Seismic base isolation and energy dissipation are some of the approaches adopted to enhance the seismic resistance of the structure. 'Seismic Base Isolation' is one of the most favorable options among the structural concepts available, which is being adopted for new structures and retrofit of existing structures, and is one of the most promising alternatives.

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II. 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. Traditional fixed-base buildings are rigidly connected to the ground, meaning that during an earthquake, the entire building moves as one unit. This can lead to the amplification of seismic forces and significant structural damage. In contrast, base isolated buildings are equipped with flexible bearing systems, which allow the building to move independently of the ground motion. The flexible bearings effectively decouple the superstructure from the foundation, isolating it from the intense lateral forces generated by the earthquake. The fundamental principle of base isolation lies in extending the building's natural period of vibration. Every building has a characteristic natural frequency at which it vibrates when subjected to lateral forces. By introducing flexible bearings with a low stiffness, the natural period of vibration is elongated, reducing the building's sensitivity to seismic excitations. This elongation is critical because most earthquakes' ground motion frequencies are higher than the elongated natural period, leading to a phenomenon known as frequency mismatch. As a result, the building absorbs less energy from the seismic waves, protecting it from damage and ensuring occupant safety.

III. OBJECTIVE

The present paper evaluates the seismic response of a low rise(6-floors) and a medium rise(14-floors) fixed base and base isolated building with two types of isolators viz., Lead Rubber Bearing (LRB) and High-Density Rubber Bearings (HDRB). The low rise buildings (G+4 storey) and the medium rise buildings (G+ 12 storey) reinforced concrete buildings with Column-beam-slab system (with lift core walls) are considered and analysed in etabs software adopting Non Linear Time History Analysis for the ensemble of selected earthquake data ignoring the infill effect on the external masonry walls on the periphery of the building plans selected. The buildings are assumed to be located in zone V and soil type hard with an importance factor of 1.5 as per IS 1893-

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2016. The selected building plans resemble a typical realistic construction in the present times for commercial buildings.
Fixed base building and Base isolated building specified above are considered to study the variation of Modal time period, Base shear, Peak roof displacement and peak floor acceleration obtained upon analysis by Time history analysis for a set of selected earthquakes.

IV. METHODOLOGY

Time history analysis is carried out in ETABS software adopting Fast Nonlinear Analysis (FNA). The structural material is assumed to be isotropic and homogeneous. The column beams are modeled as line elements and the lift core walls are modeled as shell elements. The floors/slabs are modeled as membrane elements for the Column beam slab system. The floor slab is considered as rigid diaphragms. The typical plan and sectional view of 6-floor and 14-floor buildings are shown in. The building details and material properties are given in Table -1

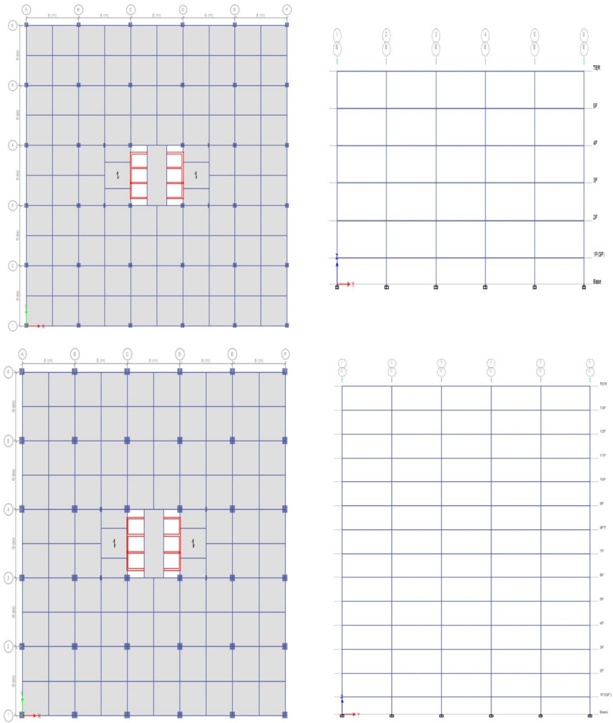

Fig. 1. Plan and Elevation of 6Floor and 14 Floor building

Table -1 Properties of buildings

Building Type	Column-Beams -Slab (with Lift Core walls)	
Number of floors	G+4 Floors: **Low rise**	G+12 Floors: **Medium Rise**
Number of Slabs	6	14
Height of each floor	3.5 m	
Bay width	8.0m	
Number of Bays	5	
Total height of building from foundation level	20m	48m
Depth of Foundation	2.5 below GL	
Thickness of the slab	150 mm	
Main Beam Size	450x600 mm	
Secondary Beam Size	300x600 mm	
Column Size	600x600 mm	800x800 mm
Material Properties		
Grade of concrete	M40	
Grade of reinforcing steel	Fe 500	

V. METHODOLOGY

The structural models are subjected to different loads. The loads considered for the analysis are as per the provisions of Indian Standard Code of Practice for the Structural safety of Buildings, IS 875-1987 Part I. The loads considered in the present work are

i) Dead Load designated as "DL"
ii) Live Load designated as "LL"
iii) Earthquake Load designated as "EQX" EQY", "RSX", "RSY" & "TH"

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

A. Dead loads

Floor Finish +	1.5 kN/m2+1.5 kN/m2 = 3.0 kN/m^2
Partition load =	
Wall Load +plaster on two sides (wall loads are considered on the peripheral beams and at lift/staircase lobby)	0.2*(3.5–0.45)*17.65+(2*.02*3.35*20.4)= 13.5 kN/m

B. Live loads

All floors: 3 kN/m^2

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.

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

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

For the seismic loads, mass source is 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. 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. The behaviour of the structure under application of seismic loads for different models is studied based on equivalent lateral load method, Response Spectrum method and Time history analysis. Of these, important results relevant to the comparative study of the building for the present investigation are taken for discussions.

VI. TIME HISTORY ANALYSIS

It is an analysis of the dynamic response of the structure at instant of time, when it's base is subjected to a specific ground motion history. The selected time history records are applied as input excitations to the finite element model at appropriate locations and time steps. The selection of time history data for time history analysis is a complex procedure that takes into account numerous factors. Typically, the design criteria and seismic hazard ratings for the region where the structure is located are defined first. Then, using existing seismic or dynamic data repositories, historical records, or probabilistic seismic hazard evaluations, locate and obtain a set of representative ground motion records. These records should have properties that correspond to the design spectrum, such as spectral shape, frequency content, amplitude, and length, to ensure that they accurately reflect the structure's predicted dynamic loading scenarios. Validation using recorded events or synthetic data shows their relevance and suitability for effectively reproducing the dynamic reaction of the structure under investigation. In ETABS, Fast Nonlinear Analysis (FNA) is adopted for the time history analysis. FNA is a modal analysis method useful for the static or dynamic evaluation of linear or nonlinear structural systems. Because of its computationally efficient formulation, FNA is well-suited for time-history analysis, and often recommended over direct-integration applications. During dynamic-nonlinear FNA application, analytical models should, be primarily linear-elastic, have a limited number of predefined nonlinear members, Lump nonlinear behaviour within link objects.

VII. 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 predominant rule in studying the behavior of RC buildings under seismic loads. The structure stability depends on the structure slenderness, as well as the ground motion amplitude, frequency and duration.

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Based on the frequency content, which is the ratio of PGA/PGV the ground motion records are classified into three categories as 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

Table-3 Ground motion data

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

For the analysis, as shown in Table 3,a set of 8 earthquake records have been taken from the Pacific Earthquake Engineering Research Centre(PEER) Strong motion database, Berkeley **(http://ngawest2002.berkeley.edu/** and **https://www.strongmotioncenter.org/.**

VIII. ISOLATOR PROPERTIES

For the present study, LRB Isolator and HDRB Isolator are designed for the forces obtained from the Analysis of fixed base models and the properties adopted for the base isolated models are given in Figure 2, Figure 3 and Table 4, Table 5 respectively

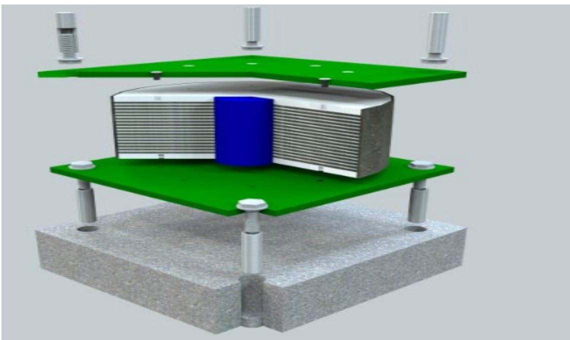

Fig. 2. Image showing LRB isolators

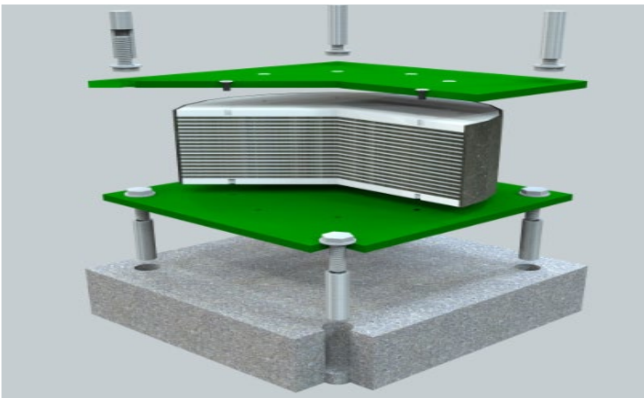

Fig. 3. Image showing HDRB isolators

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			LRB-5F	HDRB-5F
Vertical stiffness of bearing,	Kv	K N/m	7460448.1	1693318.4
Effective damping of bearing,	ξeff	%	15.0	15.0
Effective horizontal stiffness,	Keff	kN/m	2828.3	3741.0
Effective damping of bearing,	ξeff	%	15.0	15.0
Initial stiffness of bearing,	Ke	kN/m	40349.8	33510.3
Yield force of bearing,	Fy	kN	235.3	200.9
Post yield stiffness ratio			0.1	0.1

			LRB13F	HDRB-13F
Vertical stiffness of bearing,	Kv	K N/m	10743045.2	3809966.5
Effective damping of bearing,	ξeff	%	15.0	15.0
Effective horizontal stiffness,	Keff	kN/m	5513.7	7810.4
Effective damping of bearing,	ξeff	%	15.0	15.0
Initial stiffness of bearing,	Ke	kN/m	58103.8	75398.2
Yield force of bearing,	Fy	kN	518.3	452
Post yield stiffness ratio			0.1	0.1

IX. RESULTS AND DISCUSSIONS

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

A. Modal Time Period

The time period of the first mode of vibration is the fundamental period. The factors that influence the natural period of a building are the Effect of Stiffness(Stiffer buildings have a smaller natural period), the Effect of Mass (Heavier buildings have a larger natural period), the Effect of building height(taller buildings have a larger natural period), Effect of Cracked Sections on Analysis of RC Frames(Natural Period of building is estimated using Gross Stiffness is lower than natural period of building estimated using Effective Stiffness), Effect of Natural Period on design horizontal seismic force coefficient(buildings with smaller translational natural period attract higher design seismic force coefficient). 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	0.99	3.624	3.166
13F	2.29	3.993	3.706

The comparison of modal time period with fixed base and base isolated building 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.

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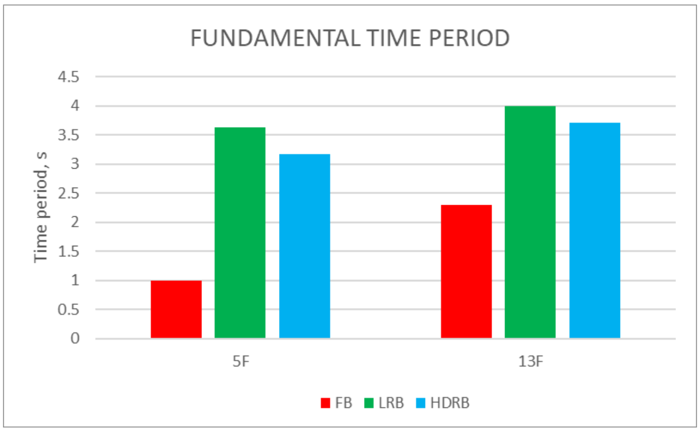

Fig. 4. Fundamental time period

It can be observed from Figure 13 and Table 6 that when compared with the fixed base buildings of 5 floors the time period increases by 3.6 and 3.2 times for LRB and HDRB buildings respectively. For 13 Floors buildings this increase is 1.74 and 1.62 times, overall time period increases due to base isolation

B. Base Shear

In the event of an Earthquake, buildings oscillate causing inertia force to be induced in the building. Most design codes represent the earthquake-induced inertia forces as the net effect of such random shaking in the form of design equivalent static lateral force. Seismic design codes provide a design response spectrum and the corresponding force obtained is called the design seismic lateral force of the building or the design seismic base shear of the building. This force is called as the Seismic Design Base Shear (VB) and remains the primary quantity involved in the force-based earthquake-resistant design of buildings. This force depends on the seismic hazard at the site of the building represented by the Seismic Zone Factor Z Seismic base shear (VB) is the product of the sum of seismic masses at different floor levels multiplied by the seismic coefficient. Figure 14 represent the variation in base shear observed with fixed base and base isolated with two different types of isolators.

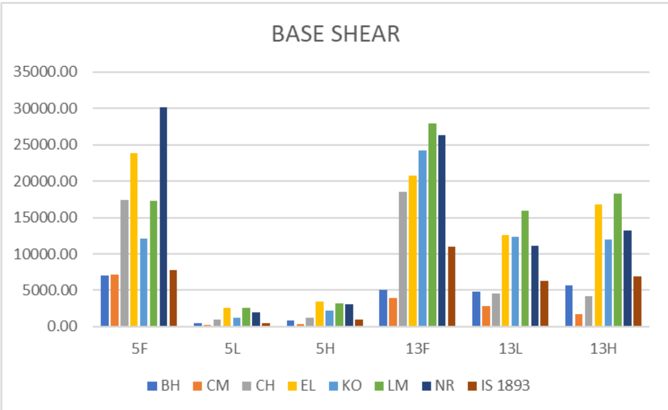

Fig. 5. Base Shear

The variation in base shear is shown in Figure 14 with fixed base and base isolated building with LRB and HDRB isolators. It can be observed that an average of about 70% to 90% reduction in the base shear is observed for 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

Lateral displacement is the deformation caused in the structure due to application of lateral forces. For the comparative study absolute values of maximum roof storey displacements along lateral directions are chosen. For base isolated building, appreciable amount of lateral displacement is observed at the isolator level. Fixed base models have zero displacement at base. For base isolated buildings the lateral displacement variation is negligible at higher elevations, therefore for the sake of comparison the isolated models' storey displacement

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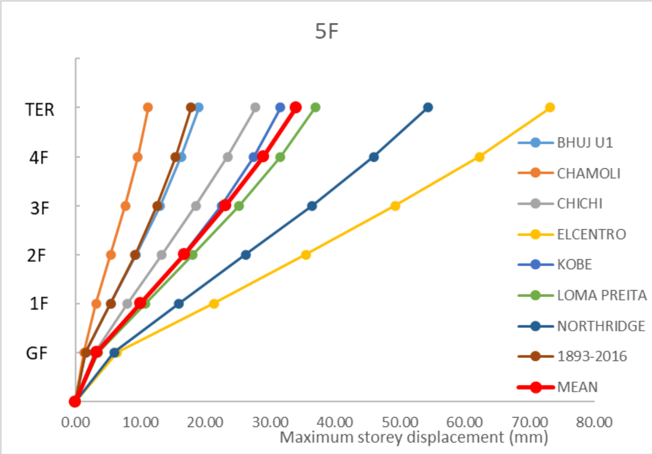
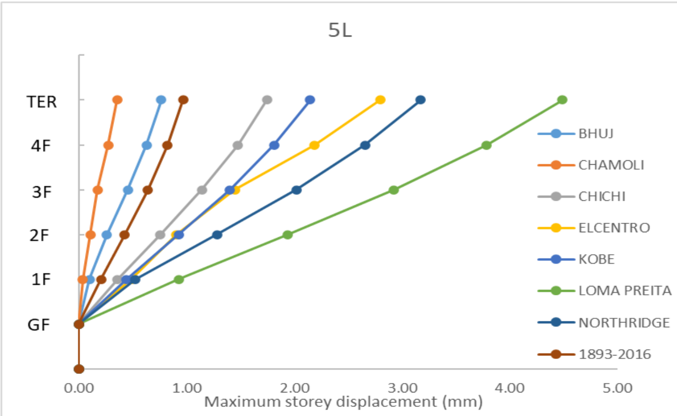
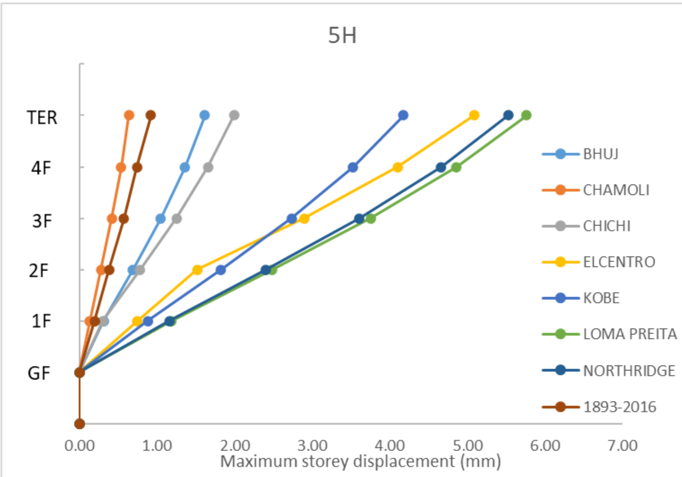
is represented relative to the isolator displacement, whereas the lateral displacement increased significantly in case of fixed base buildings.

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 floor and 13 floors and are shown in Figure 6.

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







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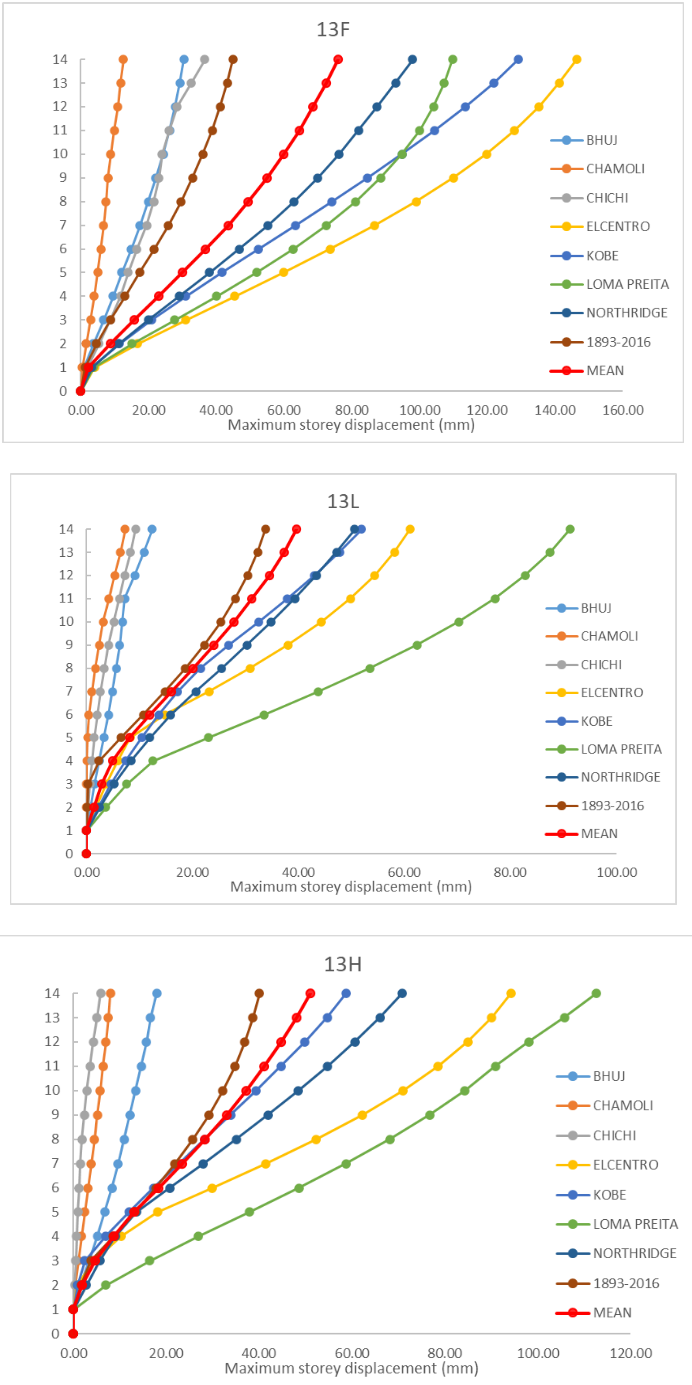

Fig. 6. Storey displacement

X. CONCLUSIONS

An attempt is made to investigate a Reinforced Concrete monolithic G+5 and G+13 storey building 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 ground floor level and roof level is constant. In fixed-base

models, the displacement between the ground floor level and roof level increases

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

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