Seismic Response of Fixed Base and Base Isolated RC Framed Building on Different Soil Conditions

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Abstract: *Base isolation is a technique developed all around the world to protect structures from effect of earthquake. In this paper G+15 storey building is analyzed with and without base isolator under seismic Zone II and Zone V in soft, medium and hard soil conditions. Base isolators used for the analysis of building are High Damp Rubber Bearing (HDRB), Lead Rubber Bearing (LRB) and Friction Pendulum System (FPS).The analysis is carried out by using response spectrum method in ETABS 2018 software using the code IS :1893(part 1)-2016.Using response spectrum method, structural parameter such as time period, storey displacement, storey shear and storey drift are studied and made comparisons with or without base isolator under different seismic zone and different soil conditions.*

***Key Words*: Base isolation, Response spectrum, ETABS 2018, High Damp Rubber bearing, Lead Rubber bearing, Friction Pendulum System.**

1. INTRODUCTION

A. General:

In recent years, earthquake is the most important criteria while considering in the design of building, especially in the earthquake region. Due to earthquake, collapse of structures like schools, houses, hospitals and other buildings resulting in the losses of lives and damages to the society, public infrastructure etc. In the past earthquakes over 95% of the lives are lost due to the collapse of structure that were not seismic resistant.


Fig -1 Damages to the building during earthquake

B. Base Isolation:

There are several construction techniques for the earthquake resistant buildings, in that base isolation is the most commonly used technology to resist seismic phenomenon. First base isolation technology developed in New Zealand for bridge construction. The basic idea involved in the base isolation system is to avoid the transmission of potentially damaging earthquake ground motions into a structure and that can be achieved by the introduction of flexibility at the base of the structure in the horizontal direction and presenting some damping elements to counteract ground motions caused by the earthquake.
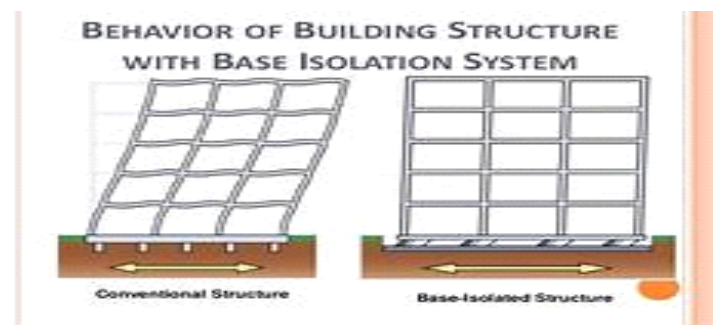
Fixed base building   Base isolated building

Fig-2 Behavior of fixed base and base isolated building during ground movement

C. Base isolators used:

1) Lead Rubber Bearing:

LRB formed of different layers of thin low damping rubbers and steel plates built in alternate layers and lead core cylinder at its center to achieve desired superstructure response. The LRB was first discovered in New Zealand and extensively used in earthquake prone areas like Japan New Zealand etc. By using LRB damp ratio can be achieved in the range of 2 to 4%.
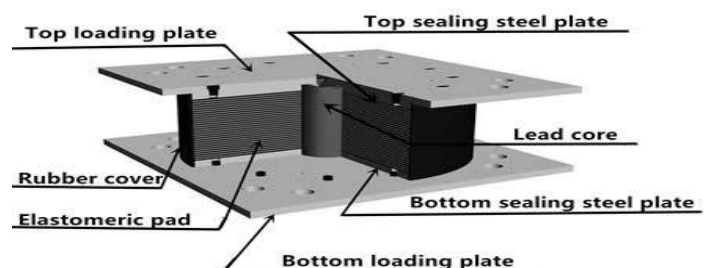

Fig-3 Lead Rubber Bearing isolator

2) High Damp Rubber Bearing:

These are the type of elastomeric bearing and easy to manufacture as compare to other isolators. HDRB can be used in bridge and buildings etc. By using HDRB damp ratio can be achieved in the range of 10 to 20%. HDRB can be used in bridges, buildings etc.
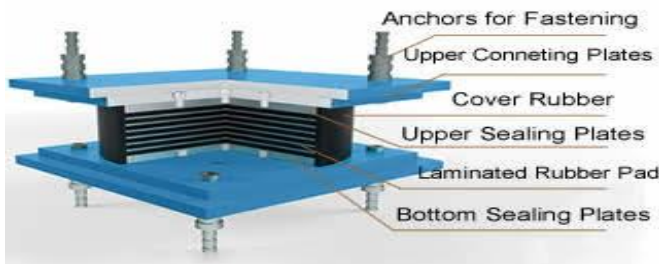

Fig-4 High Damp Rubber Bearing isolator

3) Friction Pendulum System:

FPS is the type of flexible isolation system and sliding bearing. FPS has ability to acquire different magnitudes of displacement just by adjusting the diameter and curvature of bearing surface. It can use in high rise building but too costly as compare to other isolator and also it is difficult to install.
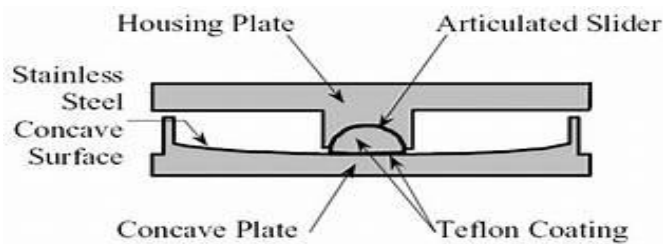

Fig -5 Friction Pendulum System isolator

2. OBJECTIVES

The main objectives of this study are to evaluate the seismic response of fixed base and base isolated building and they are,

1. Modeling of 15 storey building with or without base isolation system using ETABS 2018 software.
2. The model is analyzed by using response spectrum method and knows the performances of LRB, HDRB and FPS base isolator.
3. On the basis of the parameters such as time period, storey displacement, storey shear and storey drift, make a comparison between fixed base and base isolated building on different soil conditions.
4. Identify the best base isolator for the structure.

3. METHOD OF ANALYSIS

3.1 RESPONSE SPECTRUM METHOD:

Response spectrum method is the most important mode to conduct analysis of structure. This method is best over predicting the values of displacement and forces in the system. Response spectrum graph is a plot between maximum response of SDOF system subjected to seismic ground motion and its frequency. The code provision used for response spectrum analysis is as per IS: 1893 (part 1) - 2016.

4. MODELLING OF BUILDING

A. Geometrical Modelling:

A building model of G+15 storey building has been modeled in ETABS software and considered for present project.

Table -1 Structural parameters considered for the study

| BUILDING DESCRIPTION		
Plan	20mx20m	
Spacing of frame	5m c/c	
Grade of concrete	M25	
Grade of Steel	Fe500	
Earthquake Zone	II	V
Seismic Zone Factor	0.1	0.36
Response Reduction Factor (R)	5	
Damping ratio	0.05	
Structure Type	SMRF	
Importance Factor	1.2(As per IS: 1893 (part 1)-2016)	
Soil Type	Type I ,II& III (soft, medium & hard soil)	
Number of storey	G+15	
Height of Typical floor	3m	
Column size	300X300mm	
Beam size	300X450mm	
Slab thickness	150mm	
Types of isolators used	LRB, HDRB and FPS	
Method of analysis	Response spectrum method	
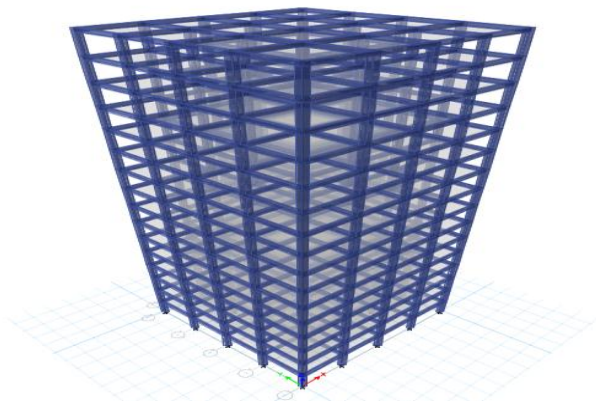
Fig-6 G+15 storey 3D model
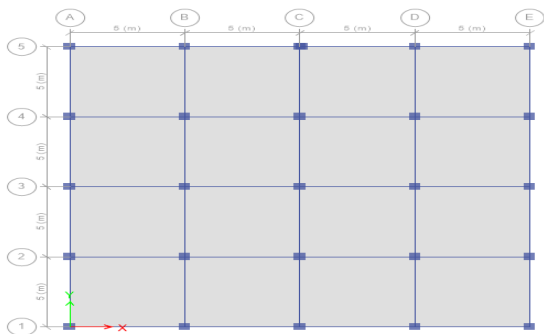
Fig-7 G+15 storey structure model plan

B. Modelling of HDRB, LRB & FPS Base Isolators

In this study HDRB, LRB and FPS are designed according to UBC-97 and IBC-2000. The maximum vertical reaction is obtained from analysis in ETABS software, using this vertical reaction and total mass of structure, isolators are designed manually. Properties of HDRB, LRB and FPS isolators are modeled as spring elements in ETABS 2018 and their properties are given as link properties.

Table-2 Friction pendulum link properties

Parameter	FPS
	Model FPS
Stiffness of bearing (K_{eff}) kN/m	2063.11
Effective damping (ξ_{eff}) %	20
Friction coefficient, slow	0.03
Friction coefficient, fast	0.06
Rate parameter sec/m²	50

Table -3 HDRB and LRB isolators link properties

Parameter	HDRB	LRB
	Model HDRB	**Model LRB**
U1 Linear effective stiffness kN/m	1448.4	1121.6
U2 and U3 Linear Effective stiffness kN/m	3677.07	3677.074
U2 and U3 Non Linear Effective stiffness kN/m	10138.8	7851.22
Yield force (F_y) kN	433.108	160.095
Effective damping (ξ_{eff}) %	20	10
Post yield stiffness ratio	0.1	0.1

5. RESULTS AND DISCUSSIONS

The comparison of different parameters like time period, storey displacement, storey shear and storey drift are carried out and tabulated results obtained from response spectrum analysis in ETABS software. Analysis is done for fixed base, HDRB, LRB and FPS base isolated conditions.

A. Time Period

Table -4 Time period of different isolators under different soil condition

Models	Time period in sec					
	Soft soil		Medium soil		Hard soil	
	ZONE II	ZONE V	ZONE II	ZONE V	ZONE II	ZONE V
Fixed base	3.125	3.468	2.904	3.125	2.511	2.715
HDRB	3.724	3.924	3.573	3.895	3.219	3.698
LRB	3.862	4.336	3.677	4.126	3.302	3.997
FPS	4.195	4.712	3.902	4.526	3.736	4.258

From the table 4, it can be seen that time period of base isolated building are increased as compared to fixed base building due to the reduction in stiffness and also for soft soil time period is more as compare to other type of soil.

The increment in time period of base isolated model compare to fixed base model in zone II for soft soil (HDRB=19.16%, LRB=23.58%, FPS=34.24%), for medium soil (HDRB=23.03%, LRB=26.61%, FPS=34.36%), for hard soil (HDRB=28.1%, LRB=31.5%, FPS=48.76%) ,whereas incase of zone V for soft soil (HDRB=13.14%, LRB=25.02%, FPS=35.87%),for medium soil(HDRB=15.03%, LRB=32.03%, FPS=44.83%), for hard soil (HDRB=36.20%, LRB=47.21%,

FPS=56.83%). The maximum increase in time period can be seen in FPS isolator.
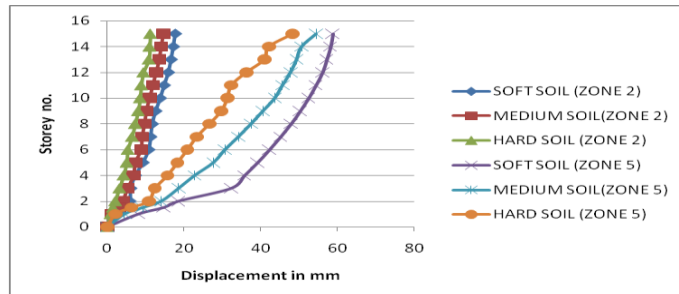
B. Storey Displacement

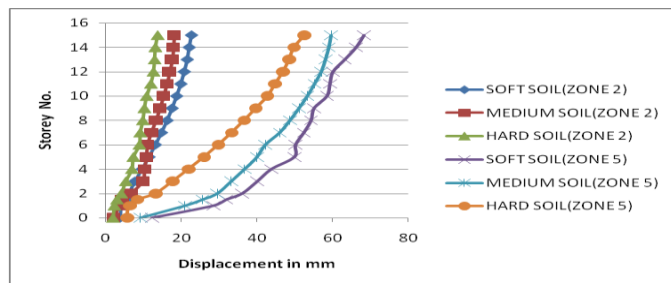**Fig-8** Storey displacement of fixed base model

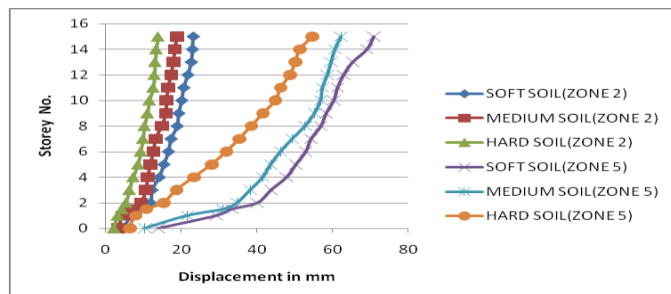**Fig-9** Storey displacement of HDRB base isolator

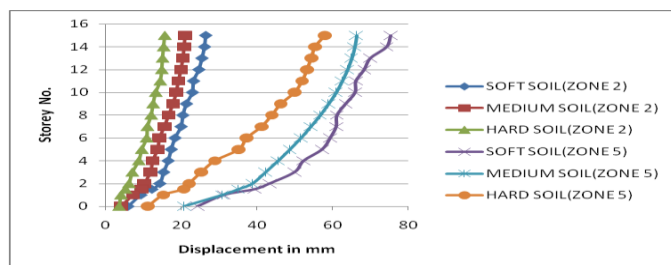**Fig-10** Storey displacement of LRB base isolator

Fig-11 Storey displacement of FPS base isolator

Figures 8, 9, 10 and 11 shows the variation of storey displacement in fixed base, HDRB Base isolator, LRB Base isolator and FPS Base isolator building. It is observed that, the displacement in case of HDRB, LRB and FPS Base isolated models is usually more at top floor level compared to fixed

base model this is due to reduction in stiffness of base isolated models.

The increase in displacement for fixed base (shown in figure 8) in zone II with respect to soft soil at top storey (medium soil = 16.94% and hard soil = 36.15%). Similarly in zone V (displacement: medium soil = 7.31% and hard soil = 17.85%). Results are also compared in zone II with respect to zone V at top storey, increase in displacement for fixed base structure (soft soil = 69.89 %, medium soil = 73.02% and hard soil = 76.60%).

The increase in displacement for HDRB Base isolator (shown in figure 9) in zone II with respect to soft soil at top storey (medium soil = 20.26% and hard soil = 39.64%). Similarly in zone V (displacement: medium soil = 12.59% and hard soil = 22.9%). Results are also compared in zone II with respect to zone V at top storey, the increase in displacement (soft soil = 66.76 %, medium soil = 69.68% and hard soil = 73.95%).

The increase in displacement for LRB Base isolator (shown in figure 10) in zone II with respect to soft soil at top storey (medium soil = 18.18% and hard soil = 39.82%). Similarly, in zone V (displacement: medium soil = 12.12% and hard soil = 22.8%). Results are also compared in zone II with respect to zone V at top storey, the increase in displacement (soft soil = 67.40 %, medium soil = 69.66% and hard soil = 74.58%).

The increase in displacement for FPS Base isolator (shown in figure 11) in zone II with respect to soft soil at top storey (medium soil = 20.07% and hard soil = 40.53%). Similarly, in zone V (displacement: medium soil = 11.9% and hard soil = 23.10%). Results are also compared in zone II with respect to zone V at top storey, the increase in displacement (soft soil = 64.94 %, medium soil = 68.17% and hard soil = 72.88%).
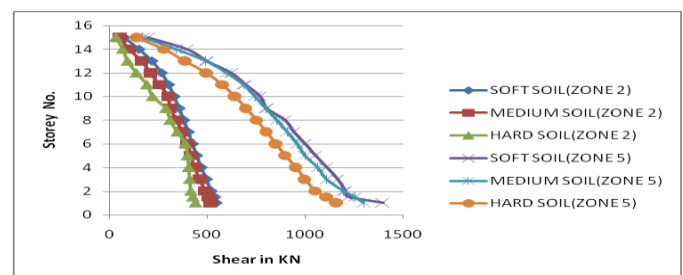
C. Storey Shear

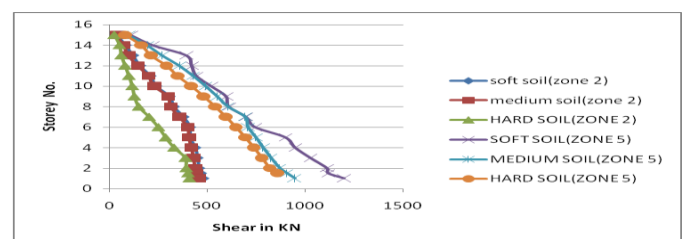**Fig-12** Storey shear of fixed base model

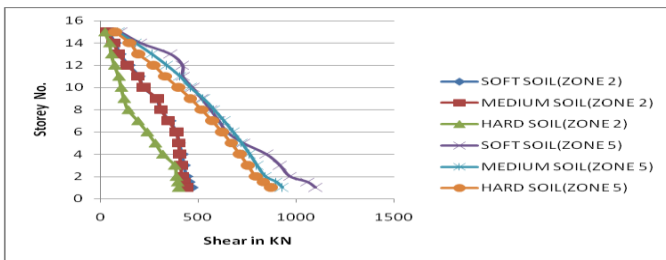**Fig-13** Storey shear of HDRB base isolator

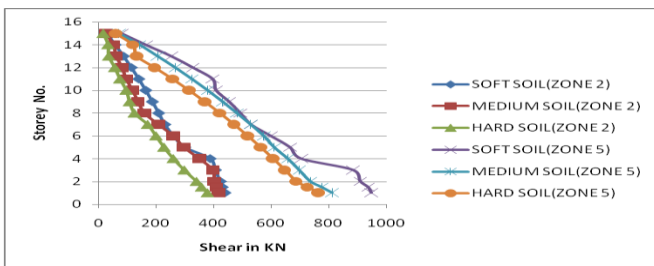**Fig-14** Storey shear of LRB base isolator

Fig-15 Storey shear of FPS base isolator

Figures 12, 13, 14 and 15 shows the variation of storey shear in fixed base, HDRB Base isolator, LRB Base isolator and FPS Base isolator building. It is observed that, storey shear incase of HDRB, LRB and FPS Base isolated models is reduced at base level compared to fixed base model this is due to higher time period of base isolated models.

The decrease in shear for fixed base (shown in figure 12) in zone II with respect to soft soil at top storey (medium soil = 31.19% and hard soil = 54.67%), Similarly in zone V (shear: medium soil=14.09% and hard soil = 30.18%).Results are also compared in zone II with respect to zone V at top storey decrease in shear (soft soil = 63.14%, medium soil = 70.48% and hard soil = 76.07%).

The decrease in shear for HDRB Base isolator (shown in figure 13) in zone II with respect to soft soil at top storey (medium soil = 8.12% and hard soil = 37.17%), Similarly in zone V (shear: medium soil=12.6% and hard soil = 28.23%).Results are also compared in zone II with respect to zone V at top storey decrease in shear (soft soil = 64.76%, medium soil = 62.9% and hard soil = 69.12%).

The decrease in shear for LRB Base isolator (shown in figure 14) in zone II with respect to soft soil at top storey (medium soil = 12.08% and hard soil = 41.8%), Similarly in zone V (shear: medium soil=12.69% and hard soil = 27.802%).Results are also compared in zone II with respect to zone V at top storey decrease in shear (soft soil = 62.83%, medium soil = 62.57% and hard soil = 70.08%).

The decrease in shear for FPS Base isolator (shown in figure 15) in zone II with respect to soft soil at top storey (medium soil = 11.4% and hard soil = 40.09%), similarly in zone V (shear: medium soil=13.55% and hard soil = 28.04%). Results are also compared in zone II with respect to zone V

at top storey decrease in shear (soft soil = 64.99%, medium soil = 64.13% and hard soil = 70.85%).
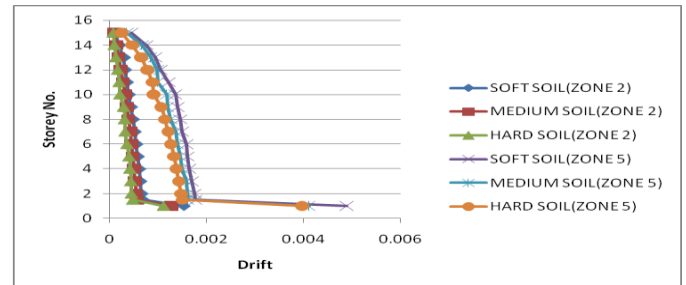
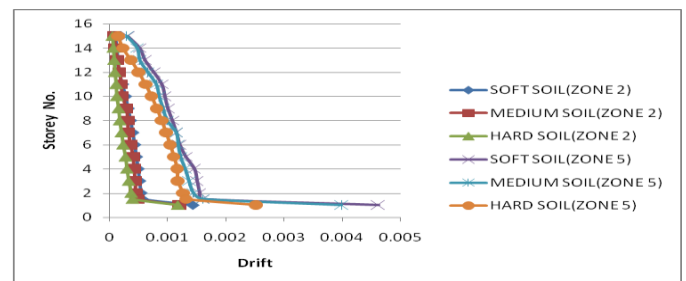D. Storey Drift

Fig -16 Storey drift of fixed base mode

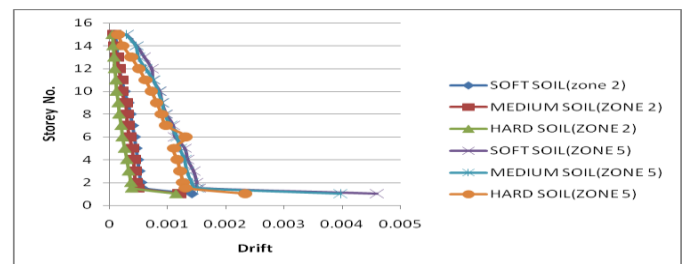**Fig-17** Storey drift of HDRB base isolator

Fig-18 Storey drift of LRB base isolator
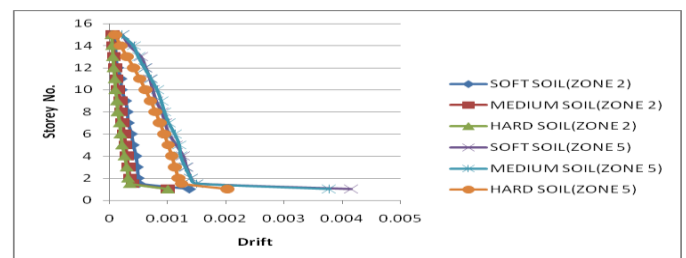

Fig-19 Storey drift of FPS base isolator

Figures 16, 17, 18 and 19 shows the variation of storey drift in fixed base, HDRB Base isolator, LRB Base isolator and FPS Base isolator building. It is observed that, storey drift in case of HDRB, LRB and FPS Base isolated models is reduced at base level compared to fixed base model this is due to higher time period of base isolated models.

The decrease in drift for fixed base (shown in figure 16) in zone II with respect to soft soil at top storey (medium soil = 20.9% and hard soil = 58.7%), Similarly in zone V (drift: medium soil = 20.3% and hard soil = 44.8%).Results are also compared in zone II with respect to zone V at top storey decrease in drift (soft soil = 72.32%, medium soil = 97.25% and hard soil = 96.92%).

The decrease in drift for HDRB Base isolator (shown in figure 17) in zone II with respect to soft soil at top storey (medium soil = 24.75% and hard soil = 47.52%), Similarly in zone V (drift: medium soil = 6.14% and hard soil = 52.4%).Results are also compared in zone II with respect to zone V at top storey decrease in drift (soft soil = 67.3%, medium soil = 97.37% and hard soil = 96.30%).

The decrease in drift for LRB Base isolator (shown in figure 18) in zone II with respect to soft soil at top storey (medium soil = 26.73% and hard soil = 50%), Similarly in zone V (drift: medium soil = 3.35% and hard soil = 52.3%).Results are also compared in zone II with respect to zone V at top storey decrease in drift (soft soil = 66.44%, medium soil = 97.40% and hard soil = 99.64%).

The decrease in drift for FPS Base isolator (shown in figure 19) in zone II with respect to soft soil at top storey (medium soil = 34.8% and hard soil = 55.8%), similarly in zone V (drift: medium soil = 4.48% and hard soil = 54.7%). Results are also compared in zone II with respect to zone V at top storey decrease in drift (soft soil = 96.14%, medium soil = 97.37% and hard soil = 96.23%).

6. CONCLUSIONS

A. Time period increased in all base isolated buildings compared to fixed base buildings due to increase in flexibility of base isolated building. FPS Base isolator shows more time period than HDRB & LRB Base isolator. Also soft soil shows more time period in zone V.

B. Displacement in fixed base structure at base is zero, where as in case of base isolated building shows some amount of displacement at base of structure. Also displacement increases as height of building increases and maximum displacement can be observed at top storey. Due to increase in flexibility of structure displacement of isolated building increases. FPS Base isolator shows more displacement than HDRB and LRB Base isolator in soft soil under zone V.

C. More storey shear is reduced at top storey as compare to base of the structure due to the increase in time period.FPS Base isolator reduces more shear compared to HDRB and LRB Base isolator in soft soil under zone V.

D. More storey drift is reduced at top storey as compare to base of structure due to the decrease in storey stiffness. FPS Base isolator reduces more drift compared to HDRB and LRB Base isolator in soft soil under zone V.

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