NON-LINEAR TIME HISTORY ANALYSIS OF ELASTOMERIC BASE-ISOLATED BUILDING STRUCTURE

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The influence of isolator Characteristics on seismic response of multistory base isolated structure is investigated. The force deformation behavior of an isolator is modeled as non-linear hysteretic behavior for different time period with the effect of soil characteristics. Uniform Building Code (UBC-97) is widely used in design of base isolation systems which contains provision according for near fault effect. To assess the effectiveness of base isolation systems, a study was conducted on a four-story building designed in accordance with UBC-97 regulations, specifically for near fault earthquakes. The building is situated near an active fault line. The isolation system utilized in this structure consists of high damping rubber bearings. Design displacements were determined using UBC-97 parameters. The building was subjected to three different earthquake events: the 1979 El-Centro, 1995 Kobe, and 1994 Northridge earthquakes. A comparison was made between the fixed base and base isolated structure, with a focus on the variation of the time period to analyze the parametric changes in isolator characteristics.

Keywords: Base isolator, Effective Stiffness, Hysteresis, Post yield stiffness.

INTRODUCTION

One of the most widely implemented and accepted seismic protection systems is base isolation. Seismic base isolation is a technique that mitigates the effects of an earthquake by essentially isolating the structure and its contents from potentially dangerous ground motion, especially in the frequency range where the building is most affected. The goal is to simultaneously reduce inter-story drifts and floor accelerations to limit or avoid damage, not only to the structure but also its contents, in a cost-effective manner.

1. Horizontal flexibility to increase structural period and reduce spectral demands (except for very soft soil sites)

2. Energy dissipation (also known as damping) to reduce isolator displacements, and (3) sufficient stiffness at small displacements to provide adequate rigidity for service-level environmental loadings. The horizontal flexibility common to all practical isolation systems serves to uncouple the building from the effects of high frequency earthquake shaking typical of rock or firm soil sites, thus serving to deflect the earthquake energy and significantly reduce the magnitude of the resulting inertia forces in the building. Energy dissipation in an isolation system, in the form of either hysteretic or viscous damping, serves to reduce the displacement response of an isolation system generally resulting in more compact isolators.

Structural response and isolator displacement are two key parameters to decide the characteristics of an isolation system. In near-field area isolator displacement plays vital role in governing the design of an isolation system, as large isolator displacements leads failure of isolation system. To check isolator displacement, stiffness of isolation system is increased but such increase adversely affects the structural response, especially floor accelerations. Present study aimed to explore the role of increase of isolation stiffness on structural response of a building. Bi-linear isolation system is selected for the study.

The bilinear model, used to express the relation between the shear force and the lateral displacement, can be defined by three parameters: initial stiffness, post-yield stiffness, and characteristic strength. The characteristic strength, Q, is usually utilized to estimate the stability of hysteretic behavior when the bearing experiences many loading cycles. These three parameters properly reflect the mechanical properties of bearings and provide satisfactory estimations of a bearing's nonlinear behavior. The specific objectives of the study are:

1. to investigate the effects of increase of initial stiffness on structural response
2. to analyze the effect of isolation period on structural response
3. to investigate the effects of characteristic strength ratio of isolator on structural response.

MATHEMATICAL MODELING OF FIXED-BASE BUILDING STRUCTURE

Typical floor plan and elevation of base isolated 4 storey reinforced concrete structure building, which is used as the subject structure in this study as shown in Fig. 1 and Fig. 2 respectively. All columns are 30 x 55 cm. and beams are 40 x 50 cm with floor heights are 3.1 m. There are 3 bays of 5m in X-direction, 3 bays of 2m, 3m and 2m in Y-direction, i.e. plan dimensions are 15 m x 8 m. The total mass of the building is 1400 tons corresponding to the weight of W=14250 kN. All structural members are of concrete with Fck=20 N/mm^2 and Fy=415 N/mm^2. The fixed-base periods of superstructure in each direction are 0.75 seconds and the superstructure modal damping ratios are assumed to be constant for each mode as 5%.The superstructure is placed on an isolation system consisting of high-damping rubber bearings placed under each column. Since, it is considered that the weight is equally transfer to each bearing under the column. There exists a rigid slab at the base level that connects all isolation elements. The three-dimensional model of the base-isolated building and the non-linear time-history analyses are made using a well-known software program SAP2000 version (11).

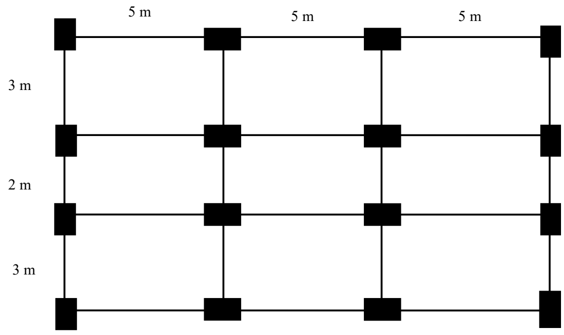


Fig. 1 (a) Typical floor plan

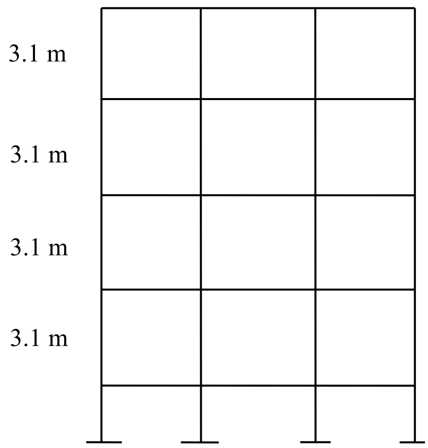


Fig. 1 (b) Elevation

The building is assume to be located in high seismicity region, i.e. Zone 4, and assigned a seismic zone factor Z=0.4 according to Table 16-I of the UBC-97. The actual time history data has been carried out specifying closest distance to a known fault that is capable of producing large magnitude events and that has high rate of seismic activity (Class B seismic source according to Table: 16-U of UBC-97).

Table 1. Time history record for different types of Earthquake

EARTHQUAKE	MAGNITUDE	RECORD/COMPONENT	PGA
EL-CENTRO 1979/10/15	M (6.5)	IMPAVAL/H-AEP 045 Closest to fault rupture- 16 km	0.327 g
KOBE 1995/01/16	M (6.9)	KOBE/KAK 000 Closest to fault rupture-26.4 km	0.251 g
NORTHRIDGE 1994/01/17	M (6.7)	NORTHR/ORR 360 Closest to fault rupture- 22.6 km	0.514 g

The recording stations are just near to an active fault, it is likely to be subjected to the near-fault effects. The UBC-97 takes these effects into account by defining the near source factor $N_{V,}$ based on the closest distance to the known seismic source. The near source factor N_V is obtained from Table: 16-T of UBC-97 as 1. Based on the seismic zone factor and soil profile type for soft soil, stiff soil and hard rock, the seismic coefficient $C_{VD}=C_V$ is obtained from Table :16-R of the UBC-97 as $C_{VD}=C_V= 0.96\ N_V$ (Soft soil), $0.64\ N_V$ (Stiff soil) and $0.32\ N_V$ (Hard rock).

The Fig. has shown the nature of time history with its acceleration (g) and time (t).

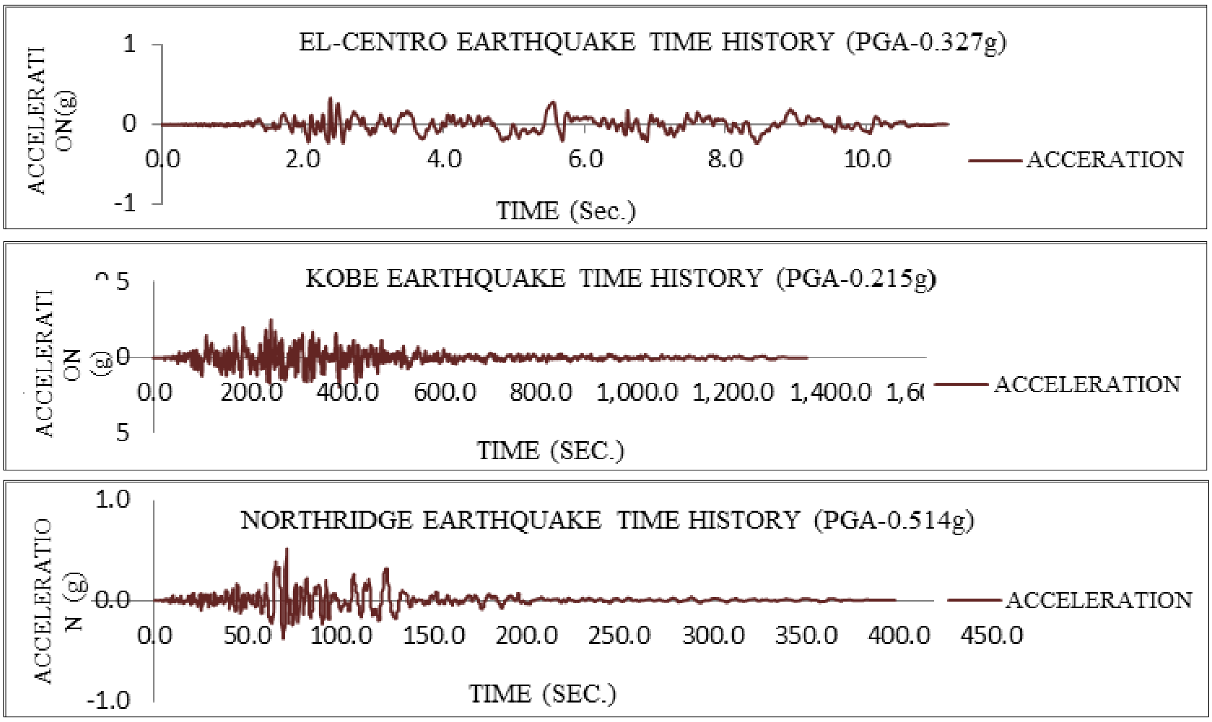


Fig. 2. Actual time history record for El-Centro, Kobe and Northridge Earthquakes.

MATHEMATICAL MODELING OF BASE-ISOLATED BUILDING STRUCTURE

For the present study, the force deformation behavior of isolator is modeled as non-linear hysteretic presented by the bi-linear model. A comparison is made for the response of fixed base and Base isolated structure also the effect of increase in time period with different soil profile. A four story RCC fixed base and base isolated (Elastomeric rubber bearing) building model prepared with design software SAP 2000 (Fig. 3). In analysis the isolator are attached at the plinth level of the structure.

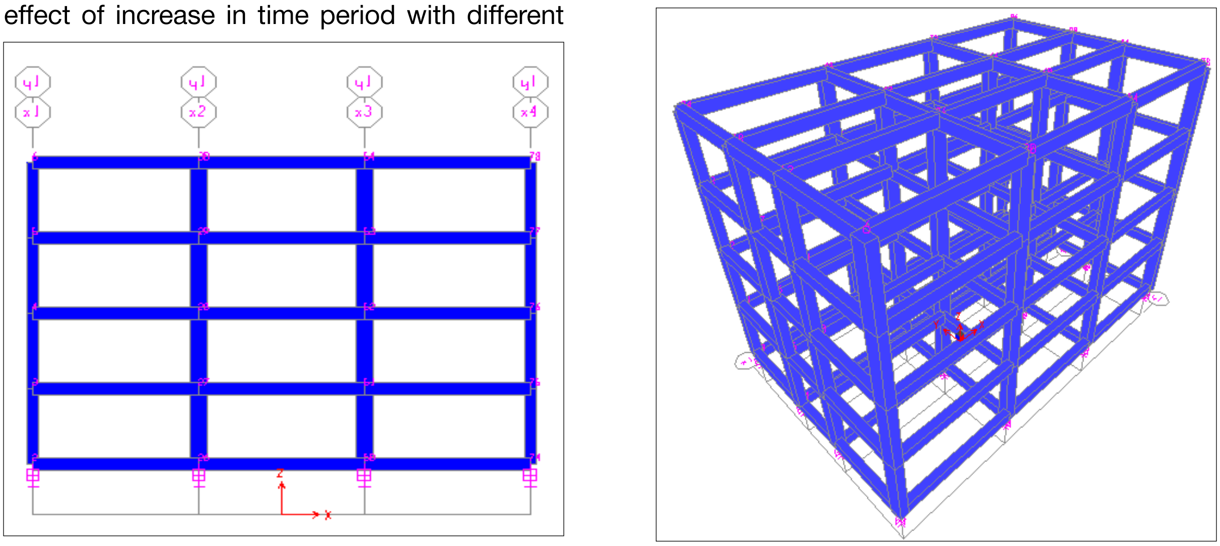


Fig. 3. Front View and 3-D view of BI building structure model

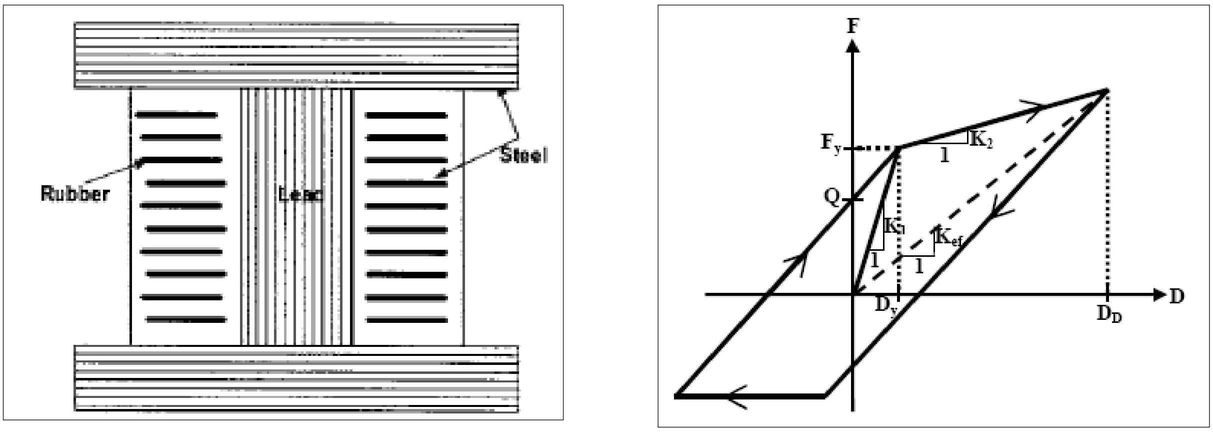


Fig. 4. Force-Deformation behavior of lead rubber bearing

a) Displacement Criteria as per UBC-97

High damping rubber bearings are composed of rubber layers and thin steel sheets. The high damping rubber bearings are composed of rubber layers and thin steel sheets. The damping is increased by adding oils, resins, or other fillers and a damping around 10%~15% can be obtained. The stiffness of the bearing is high in case of small displacements and low in case of high displacements. In this project work has follows the standard design procedure for high damping rubber bearing at MCE level effective isolation period T_M at different increasing values selected are (T_M=2, 2.5, 3, 3.3, 3.5 sec.) with effective damping β_D=0.20 has taken for study. The effective horizontal stiffness of isolation bearing is given by the equation:

$$K_{Mmin} = \frac{W}{\left(\frac{T_M}{2\pi}\right)^2 9.81} = \frac{1000}{\left(\frac{2.5}{2\pi}\right)^2 .9.81} = 643.89\ kN/m$$

Where, W is total weight carried by isolation bearing and T_M is effective isolation period assumed for MCE Level. Providing an effective isolation period

$$T_M = 2\pi\sqrt{\frac{W}{K_{eff}.g}} = 2\pi\sqrt{\frac{1000}{643.89x9.81}} = 2.506\ Sec.$$

This is nearly equal to the target period. Here g is gravitational force and taken as 9.81 m/Scc^2. The damping coefficient corresponding to β_D=0.20 is B_D=1.5 according to Table A-16-C of the UBC-97.

The design displacement of an isolation system along each main horizontal axis at maximum capable earthquake (MCE) level for soft soil at El-Centro earthquake is calculated according UBC-97

$$D_D = \frac{\left(\frac{g}{4\pi^2}\right) C_{VD} T_D}{B_D} = \frac{\left(\frac{9.81}{4\pi^2}\right) 0.96x3.5}{1.5} = 0.557\ m$$

$$D_M = \frac{\left(\frac{g}{4\pi^2}\right) C_{VM} T_M}{B_D} = \frac{\left(\frac{9.81}{4\pi^2}\right) 1.2x2.5}{1.5} = 0.497\ m$$

Minimum design displacement permitted for dynamic analysis

$$D'_M = \frac{D_M}{\sqrt{1+\left(\frac{T}{T_M}\right)^2}} = \frac{0.497}{\sqrt{1+\left(\frac{0.74}{2.506}\right)^2}} = 0.476\ m$$

Where 'T' is the fixed base time period of building structure. Finally the total design displacement including additional displacement due to accidental torsion is calculated according to UBC-97 as follows:

$$D_{TD} = D_D\left(1 + y\frac{12e}{b^2+d^2}\right) = 0.557\left(1 + 4\frac{12x0.75}{8^2+15^2}\right) = 0.626\ m$$

$$D_{TM} = D_M\left(1 + y\frac{12e}{b^2+d^2}\right) = 0.497\left(1 + 4\frac{12x0.75}{8^2+15^2}\right) = 0.559\ m$$

Where b=8 m is the shortest plan dimension of the structure measured perpendicular to the longest plan dimension of the structure, which is d=15 m. Here y is the distance between the center of rigidity of the isolation system and isolation bearing placed at the sides of the plan, measured perpendicular to the direction of seismic loading under consideration, thus y=b/2=4 m in this study. Finally, e is the actual eccentricity plus the accidental eccentricity which is taken as 5 percent of the maximum building dimension perpendicular to the direction of force under consideration. The total design displacement calculated above satisfies the minimum criteria; D_{TD}=0.626 m > 1.10 D_D=0.612 m.

b) Bi-linear Hysteric model of Isolator

The non linear force deformation behavior of the isolation system is modeled through the bi-linear hysteresis loop characterized by three parameters namely:

(i) Characteristic strength Q

(ii) Initial stiffness K_1

(iii) Post yield stiffness K_2,

(iii) Yield displacement D_y (Fig. 4).

The bi-linear behavior is selected because this model can be used for all isolation systems used in practice. The force-Displacement relationship of high damping rubber bearing shows the yield force, F_y, the design displacement D_D, the effectives stiffness, K_{eff}, and characteristic force, Q.

Post yield to pre-yield stiffness ratio ($n=K_2/K_1$) depends on the material used and considered n=0.10 for rubber isolator. The elastic stiffness K_1 is difficult to measure and is usually taken to be an empirical multiple of K_2, which can be accurately estimated from the shear modulus of the rubber and the bearing design. The Post-yield stiffness of the isolation systems, K_2 is 'generally design in such a way to provide the specific value of the isolation period, T_b expressed as:

$$T_b = 2\pi\sqrt{\frac{M}{K_2}}$$

Where, M is the total mass of the base isolated structure.

NUMERICAL STUDY

Seismic response of 4-Story RC fixed base and base-isolated building structure are investigated under various real earthquake time history ground motions for non-linear isolator characteristics. The earthquake motions are selected for the studies are 1979 El-Centro, 1995 Kobe and 1994 Northridge recorded at different stations as the details are given in (Table-1). The isolation bearing characteristics for different isolation time periods are calculated according to the derived equation for rubber isolator.

Parametric Study on Isolation systems

The isolation bearing consist of an isolator to increase the natural period of the structure away from the high energy period of the earthquake, and a damper to absorb energy in order to reduce the seismic force. As the time period increases isolation parameter get changed.

In the given section parametric study have been carry out for different types of soil as per UBC-97, to study the change in values of isolation characteristics and its effect on structural behavior. As the target isolation time period changes from T=2.5 Sec. to 3.5 Sec, the mechanical characteristics values for K_1, K_2, K_{eff}, Q and F_y are found reduced in each increment in time. The values for total maximum displacement (D'_M) and total energy stored in bearing (E_{so}) increase in order T=2.5 to 3.5 Sec.

Table 2. Isolation characteristics for Soft soil with different time period of system.

Sr. No	Isolation Time Period (T) Sec.	CHARACTERISTICS OF ISOLATION BEARING								
		Tot. Max. Disp. (D'_M)	Initial Stiffness (K1)	Post Yield Stiffness (K2)	Effective Stiffness (K_{eff})	Char. Strength (Q)	Yield Disp. (D_y)	Energy Stored (E_{so})	Yield Strength (F_y)	Post Yield Stiffness Ratio (K_2/K_1)
1	2.5	0.476	4416	441.6	643.89	96.3	0.0218	72.94	107.92	0.1
2	2.7	0.517	3786	378.6	552.03	89.7	0.023	73.77	100.49	0.1
3	3	0.579	3067	306.7	447.14	74.94	0.026	74.95	91.165	0.1
4	3.3	0.64	2534	253.4	369.54	74.3	0.029	75.68	83.281	0.1
5	3.5	0.68	2253	225.3	328.51	70.2	0.0311	75.95	78.66	0.1

Table 3. Isolation characteristics for Stiff soil with different time period of system.										
		CHARACTERISTICS OF ISOLATION BEARING								
Sr. No.	Isolation Time Period (T) Sec.	Tot. Max. Disp. (D'_M)	Initial Stiffness (K_1)	Post Yield Stiffness (K_2)	Effective Stiffness (K_{eff})	Char. Strength (Q)	Yield Disp. (D_y)	Energy Stored (E_{so})	Yield Strength (F_y)	Post Yield Stiffness Ratio (K_2/K_1)
1	2.5	0.317	4416	441.6	643.89	64.1	0.0145	32.35	71.87	0.1
2	2.7	0.345	3786	378.6	552.03	59.8	0.0158	32.85	67.06	0.1
3	3	0.386	3067	306.7	447.14	54.2	0.0176	33.31	60.78	0.1
4	3.3	0.426	2534	253.4	369.54	49.5	0.0195	33.53	55.43	0.1
5	3.5	0.454	2253	225.3	328.51	46.9	0.02	33.86	52.518	0.1

Table 4. Isolation parameter of Hard rock for different time period of system										
		CHARACTERISTICS OF ISOLATION BEARING								
Sr. No.	Isolation Time Period (T) Sec.	Tot. Max. Disp. (D'_M)	Initial Stiff-ness (K1)	Post Yield Stiffness (K_2)	Effective Stiffness (Keff)	Char. Strength (Q)	Yield Disp. (D_y)	Energy Stored (E_{so})	Yield Strength (F_y)	Post Yield Stiffness Ratio (K_2/K_1)
1	2.5	0.159	4416	441.6	643.89	32.2	0.0072	8.139	35.05	0.1
2	2.7	0.172	3786	378.6	552.03	29.8	0.0078	8.165	33.43	0.1
3	3	0.193	3067	306.7	447.14	27.2	0.0088	8.327	30.38	0.1
4	3.3	0.213	2534	253.4	369.54	24.7	0.0097	8.383	27.72	0.1
5	3.5	0.227	2253	225.3	328.51	23.4	0.1039	8.46	25.25	0.1

Comparison of Fixed-Base and Base-Isolated Building Structures

In this section a comparison of earthquake response of fixed base structure with the base isolated structure is made with base-isolated building structure. The bi-linear behavior is selected in a way to represent the force-deformation behavior of the commonly used isolation system such as elastomeric bearing (i.e. lead rubber bearing).

Table 5. Output result for El-Centro, Kobe and Northridge Earthquake						
	FIXED BASE STRUCTURE			BASE ISOLATED STRUCTURE		
Earthquake	**El-Centro**	**Kobe**	**Northridge**	**El-Centro**	**Kobe**	**Northridge**
Base Shear (kN)	5202	3102	10710	2052	1713	2723
Acceleration (m^2/sec)	2.8	2.81	3.816	2.38	1.7	3.3
Displacement (m)	$6.5x10^{-3}$	$4.2x10^{-3}$	$1.386x10^{-2}$	0.13	0.049	0.131

The structure analyzed for above time history for soft soil condition. For the analyses structural time period has assumed 2.5 Sec. at MCE level. As result out-put it is found that the response of Base Isolated Structure is predominantly lower than Fixed Base Structure. Acceleration response at base somewhat lesser in case of isolated structure. Base displacement has increased drastically to make the structure flexible and lower damage. Represent the Base Shear response for El-Centro, Kobe and Northridge Earthquake time histories. Here earthquake response comparisons have plotted for fixed base and Base-isolated building structures. The responses are plotted for the assumed Time Period T-2.5 Sec. at the MCE level (soft soil) as per UBC-97 design criteria. The peak values for fixed and base-isolated structure are given in Table-5. During first 6 second the base shear for fixed structure gets instantly increased in El-Centro earthquake showing the undulating response but in case of base-isolated structure it shows the less and smooth response. The same behavior is obtained in Kobe earthquake during 5th to 10th second and for Northridge earthquake it happened during 10th to 15th second.

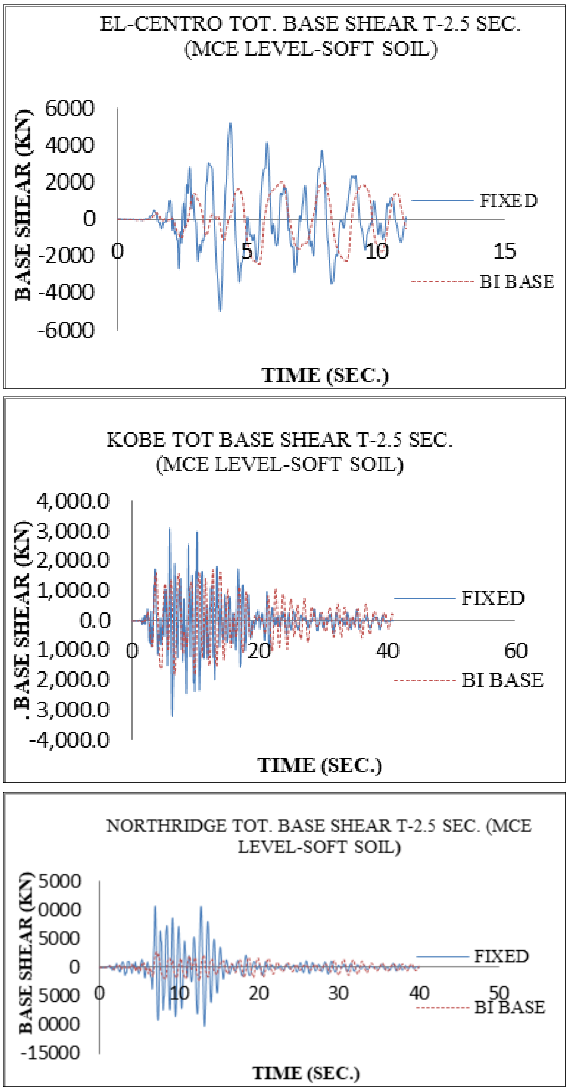
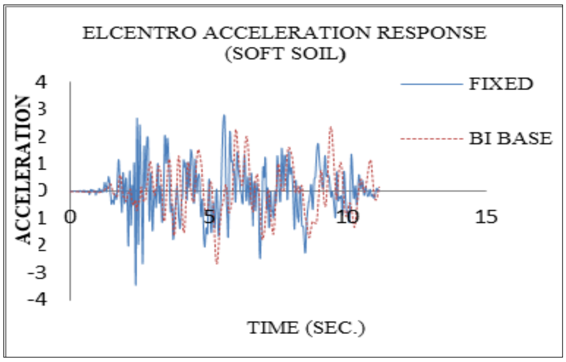
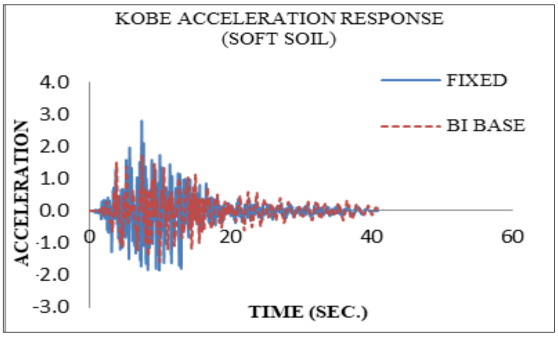


Fig. 5. Base Shear Response comparison, Fixed base and BI structure for El-Centro, Kobe and Northridge Earthquake

Fig. 6 represent the base acceleration response for fixed and base-isolated structures for El-Centro, Kobe and Northridge earthquake time history at MCE level for soft soil. The acceleration values given in Table-5. The acceleration values vary as the nature of time history has changes.





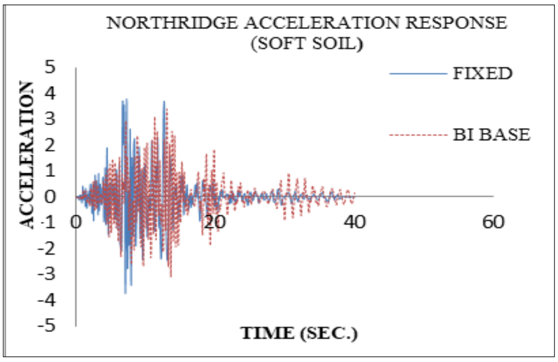


Fig. 6. Acceleration Response for Fixed base and BI base structure for El-Centro, Kobe and Northridge Earthquakes.

Fig. 7 represent the comparisons of roof top acceleration spectra for fixed base and base-isolated structures for El-Centro, Kobe and Northridge earthquake at MCE displacement level (soft soil). For base isolated structure the acceleration response get lowered suddenly in compare to fixed base structures. The response behavior for El-Centro, Kobe and Northridge earthquake has plotted the same.

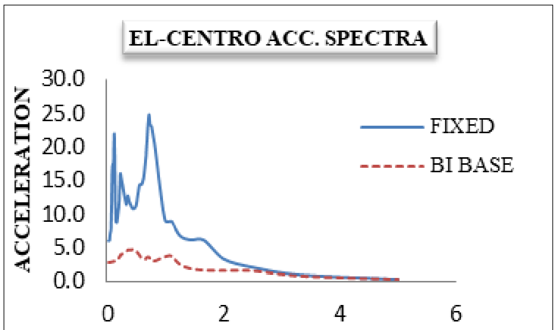


Fig. 7. (a)

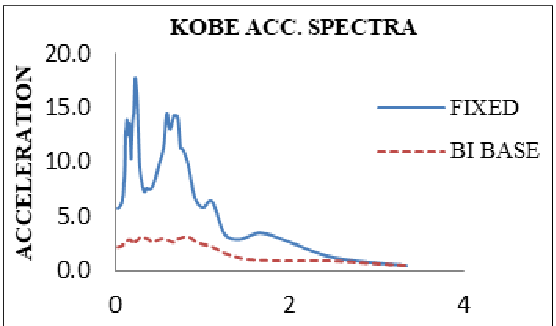


Fig. 7. (b)

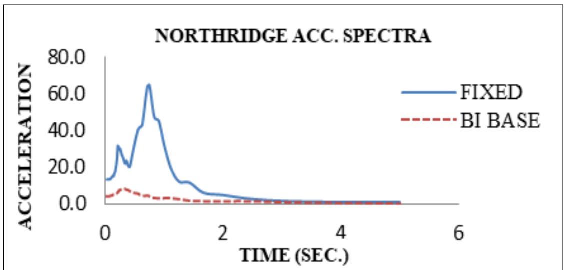
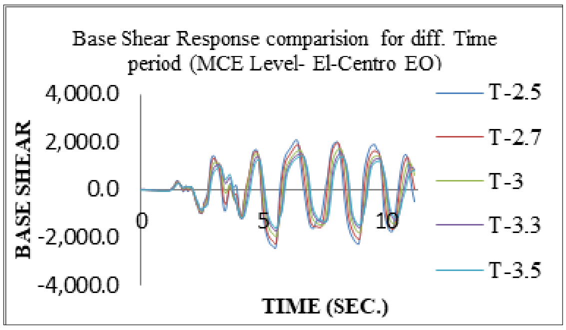


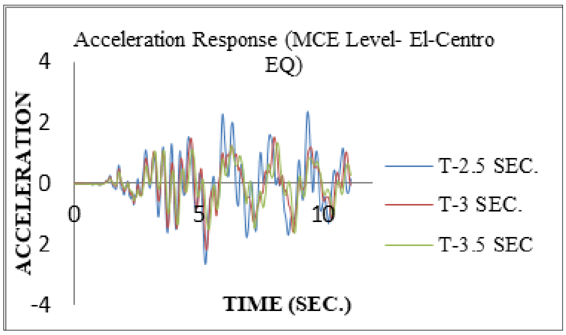
Fig. 7. (c)

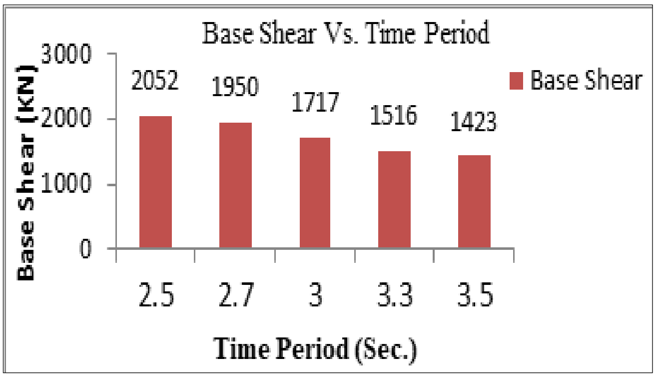
Fig. 7. Acceleration spectra for El-Centro, Kobe and Northridge Time History

Effect of Time Period of Isolation System on Response

In this project work of the isolation system the parametric study on isolation characteristics have taken to check the effect of changed target time period (MCE) on the response of structure. Time considered to calculate total displacement of the system as (T=2.5, 2.7, 3, 3.3, 3.5 Sec.). The parametric studies have been carrying out at these target time period values for different soil condition as per UBC-97. Represent the base shear response for increased time period from T-2.5 Sec. to T-3.5 Sec. From it has been found that as the time period increased the base shear response get decreased.







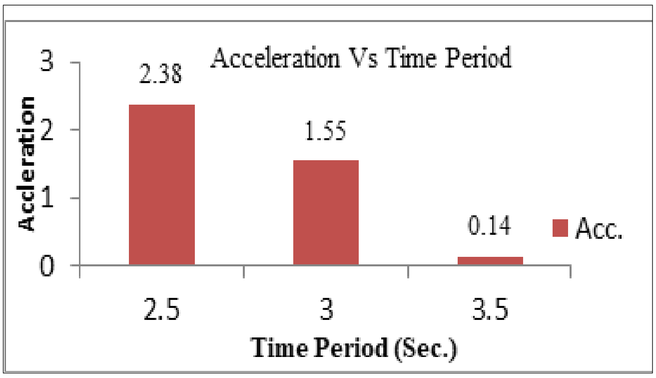


Fig. 8. Showing Base Shear Response for diff. Time period

Effect of Site Soil Condition on Structural Response

The site soil conditions for the dynamic analysis of earthquake response play a vital role. The type of soil selected from Table-16-J from UBC-97 with assuming shear wave velocity.

As the analysis has carried out by selecting the site soil condition the result output are as shown below:

Table 6. Base Shear Values for El-Centro, Kobe and Northridge Earthquake for different types of soil conditions

	BASE SHEAR (KN)		
	Soft Soil	Stiff Soil	Hard Rock
El-Centro EQ.	1717	1117	821.1
Kobe EQ.	1305	942.5	555
Northridge EQ.	1811	1423	1033

Table 7. Acceleration Values for El-Centro, Kobe and Northridge Earthquake for Different types of soil conditions.

	ACCELERATION (M/SEC^2)		
	Soft Soil	Stiff Soil	Hard Rock
El-Centro EQ.	1.356	1.11	0.834
Kobe EQ.	2.014	1.062	0.8043
Northridge EQ.	2.01	1.593	1

Representing the base shear response for El-Centro, Kobe and Northridge Earthquake. The responses plotted for UBC-97, site soil condition for soft, stiff and hard rock. From the base shear response it has found that stiff soil condition has 40% and for hard rock has nearly 50% reduction in response in compare to soft soil.

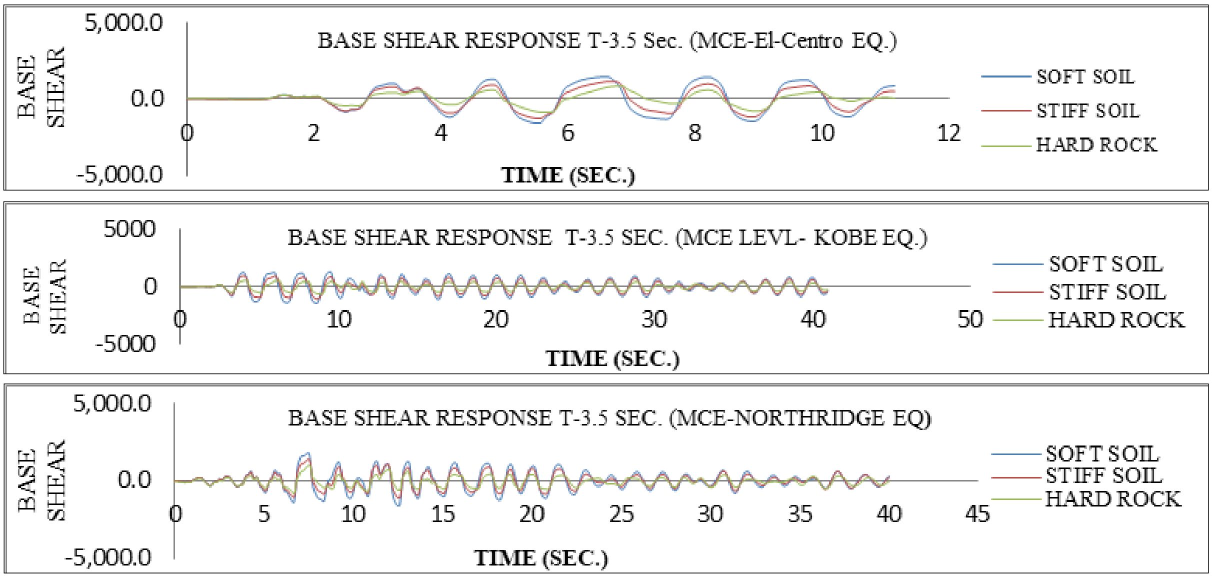


Fig. 9. Showing Base shear response for El-Centro, Kobe & Northridge EQ.

Fig.10 representing the base acceleration response for El-Centro, Kobe and Northridge Earthquake. The responses plotted for UBC-97, site soil condition for soft, stiff and hard rock. From the acceleration response it has been found that for El-Centro earthquake stiff soil has 10% and hard rock has 40% reduction in response in compare to soft soil. For Kobe earthquake stiff soil has nearly 50% and hard rock has 60% reduction in response in compare to soft soil. In case of Northridge earthquake stiff soil has nearly 40% and hard rock has 50% reduction in response in compare to soft soil.

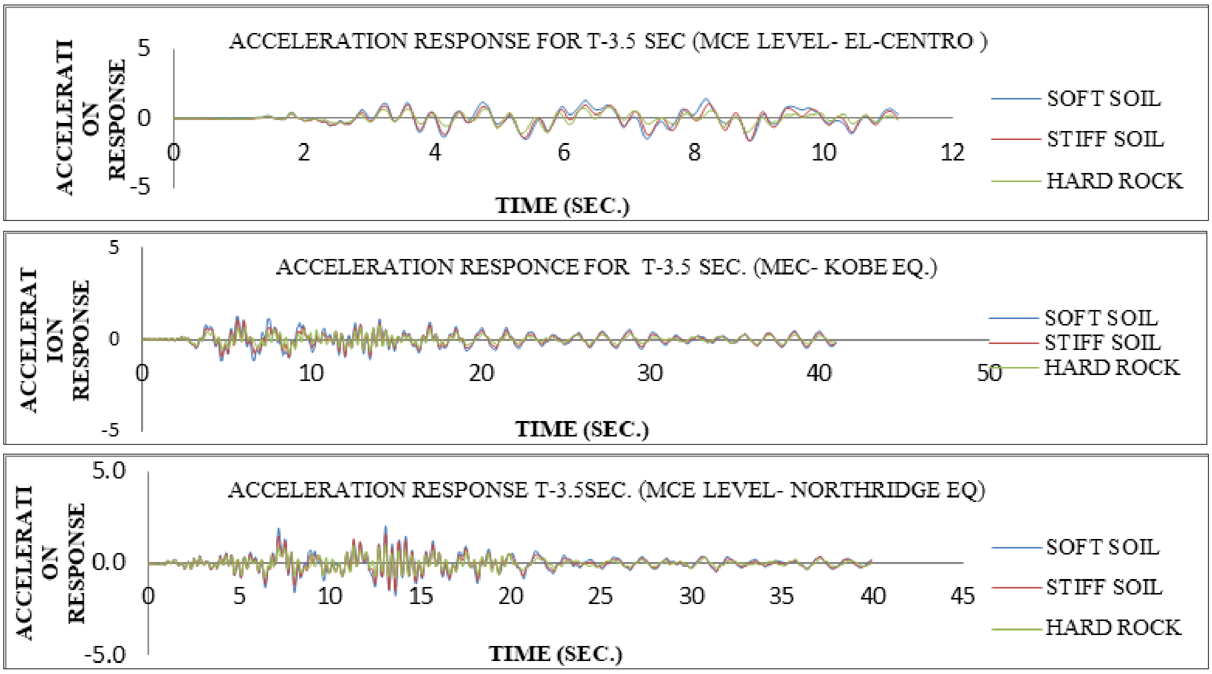


Fig. 10. Showing Base Acceleration response for El-Centro, Kobe & Northridge EQ.

Effect of Time History on Structural Response

In the given project work, model of four-story building structure isolated with rubber bearing to counteract its efficiency for different time history effect. Three-time histories of different magnitude and fault rupture distance from the site are applied through SAP-2000 base isolated building model. Different values of magnitude time histories are taken for analysis to check the effectiveness and compare its output result as per UBC-97. Representing the Base shear response for El-Centro, Kobe and Northridge earthquake (soft soil at T-3.5 Sec). From Fig. it has been found that El-Centro earthquake has 20% and for Kobe earthquake has 30% reduction in base shear in compare to Northridge earthquake.

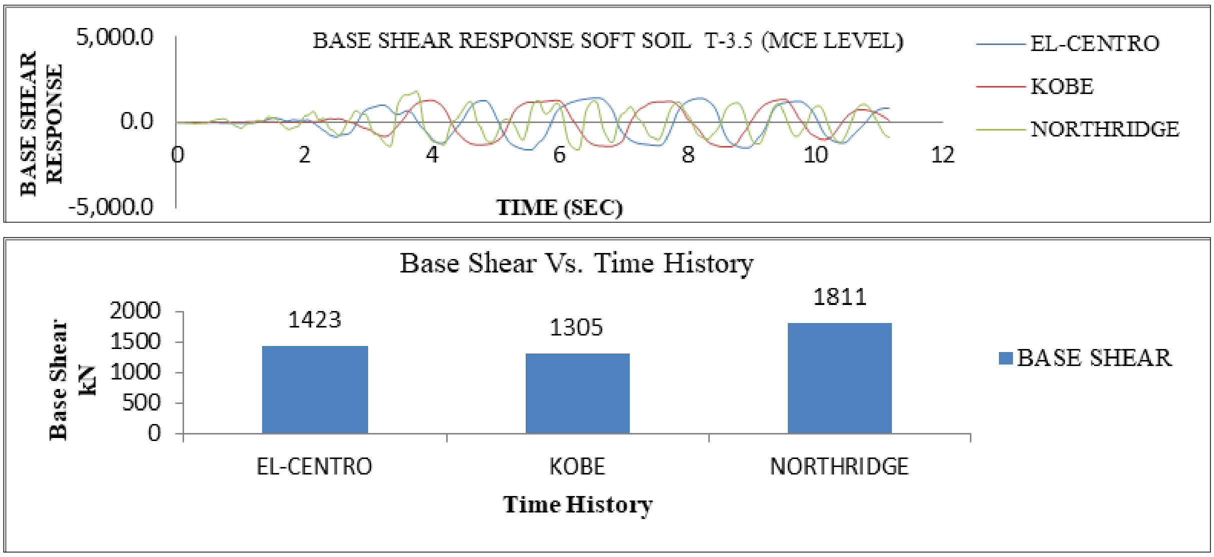


Fig. 11. Showing effect of Time History on Base shear response for Soft soil

In Fig. 12 representing the acceleration response for El-Centro, Kobe and Northridge earthquake (soft soil at T-3.5 Sec.). From Fig. it has been found that El-Centro earthquake and Kobe earthquake has nearly 35% to 40% reduction in acceleration in compare to Northridge earthquake.

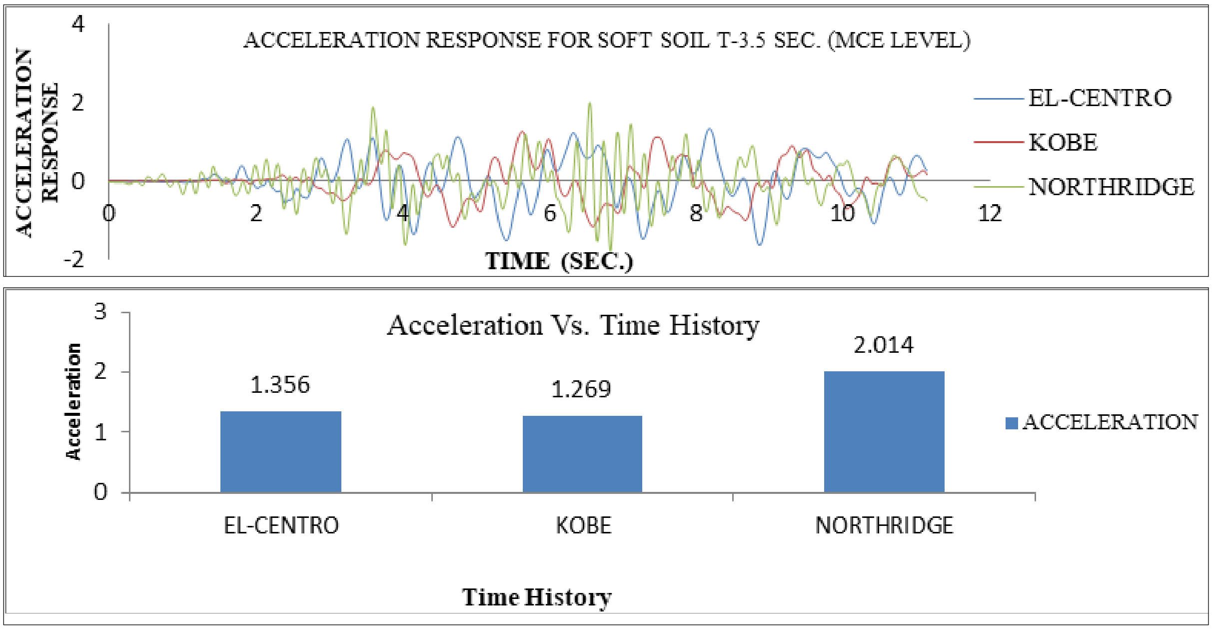


Fig. 12. Showing effect of Time History on Acceleration response for soft soil

Table 8. Showing Base shear and acceleration for soil condition as per UBC-97						
	BASE SHEAR (kN)			**ACCELERATION (m/Sec^2)**		
Time History	El-Centro	Kobe	Northridge	El-Centro	Kobe	Northridge
Soft Soil	1423	1305	1811	1.356	1.269	2.014
Stiff Soil	1117	942.5	1423	1.11	1.062	1.36
Hard Rock	821.1	555	1033	0.834	0.804	1

Damping Effect on Isolator on Structural Response

Showing effects of increased damping on the base displacement and top top storey acceleration Due to increase in damping value of isolator it found that base displacement and storey acceleration spectra lowers down

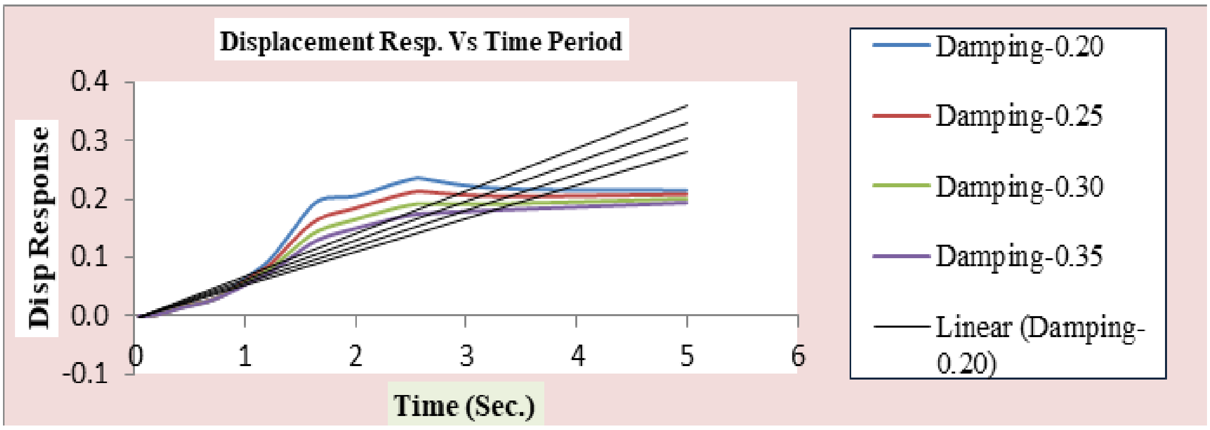


Figure 13. Showing the Base Displacement floor response spectra for different values of damping. (Soft soil, T-2.5 Sec.)

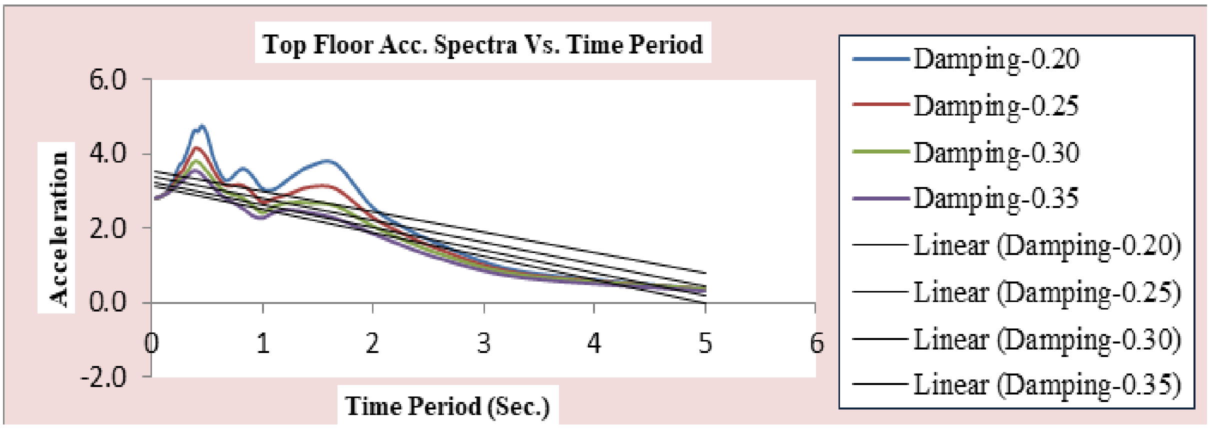


Fig. 14. Showing the Top story Acceleration floor response spectra for different values of damping (Soft soil, T-2.5 Sec.)

HYSTERESIS LOOP

The hysteresis loop associate with viscous damping is the result of dynamic hysteresis since it is related to the dynamic nature of loading. The loop area is proportional to excitation frequency. The non-linearity is well studied by hysteresis loop. In Fig. 15, shown hysteresis loop for El-Centro, Kobe and Northridge earthquake at target time period T=2.5 Sec. at MCE level for soft, stiff and hard rock soil condition as prescribed in UBC-97. The amount of energy dissipated by bearing is equal to the area covered by the hysteresis loop shown below.

Table 9.
Showing Force-Deformation values of non-linear model of bearing for Soft soil, Stiff soil and Hard rock.

	EL-CENTRO		Kobe		NORTHRIDGE	
	Force (kN)	Disp. (Cm)	Force (kN)	Disp. (Cm)	Force (kN)	Disp. (Cm)
Soft soil	154.5	12.9	115.6	4.91	147.4	11.38
Stiff soil	124.4	13.53	84.27	4.53	119.3	12.38
Hard rock	92.24	13.54	59.76	1.84	86.24	12.18

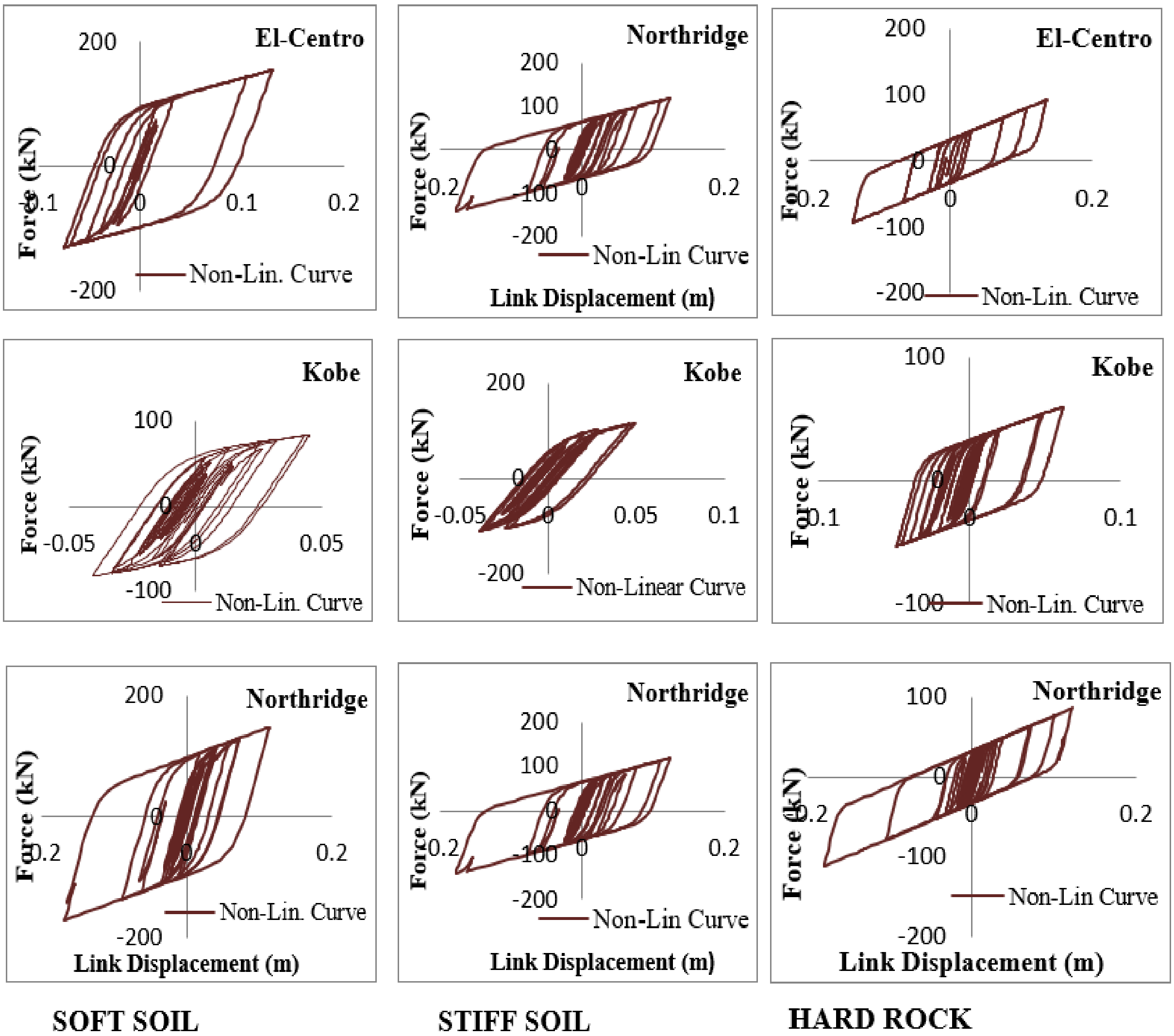


Fig. 15. Comparison of Energy dissipation of bearing for Soft soil, Stiff soil and Hard rock site condition.

CONCLUSION

The analysis of fixed base and base isolated 3-D four storey building is performed in this thesis. An exhaustive study has been performed on the performance of base isolated structures. The behavior of building structure resting on elastomeric bearing is compared with fixed base structure under maximum capable earthquake. Time history analysis has been carried out on conventional as well as Base-isolated structure to compare their base shear, acceleration and displacement response. For the analysis El-Centro, Kobe and Northridge earthquake time histories are chosen for base excitation of the structure. To study the effect of different time period of base isolator, parametric studies have been carried out for isolator for different soil condition as per UBC-97. To check the effectiveness of the isolation system, performance criteria have been carried out for fixed base isolated structure. According to analysis study, following conclusions are drawn

- Base isolation helps in reducing the design parameters i.e. base shear and bending moment in the structural members above the isolation interface by around 4-5 times.
- The base displacement is 2-times in soft soil strata and nearly 3-times increase in case of medium soil when compared to corresponding fixed base structure.
- Base shear and acceleration response reduces as the increase in time period and vice versa.
- During the parametric study on isolation bearing it have been found that, the total maximum displacement (D’), Yield displacement (Dy) and Energy stored in system get increased with increase in time period, also the properties like Initial

stiffness (K1), Post yield stiffness (K2), Effective stiffness (Keff), Characteristic strength (Q) get reduced with increase in time period.

- The base shear, displacement and acceleration response is higher in case of soft soil than the corresponding value for hard rock.
- Time period affects the earthquake response of the structure, as the time period increases the base shear and acceleration values found to be reducing; however the displacement increases with the same.

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