SEISMIC PERFORMANCE INVESTIGATION OF BASE ISOLATION SYSTEM FOR TYPICAL RESIDENTIAL BUILDING IN BANGLADESH

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ABSTRACT

Base isolation system for building structure is a popular technique to release extensive energy by allowing displacement and hence to protect structures from earthquake excitation. This paper aims to investigate the performance of a base isolated building against seismic hazard compare to typical fixed base building using ETABS 2015. Commonly used isolator like rubber bearing and friction pendulum bearing are used at the base of the building. Parametric studies are conducted to study linear time history analysis and to investigate the performance of different type of isolator. In the parametric study, comparisons are made among fixed base, rubber and friction pendulum isolated based structure on the basis of base shear, story drift, displacement, acceleration and time period. Finally nonlinear static pushover analysis has also been conducted as per FEMA-440. It is observed from the study that a base isolation system in building significantly reduces base shear with the increment of displacement and time period compared to fix based building significantly.

Key Words: base isolation, rubber isolator, friction pendulum system, linear time history analysis

1.0 INTRODUCTION

Earthquake hazard is one of the most devastating influences on civilization that takes millions of life, demolishes the infrastructures and also changes the geography of the earth surface within just few seconds. Bangladesh being close to the Indian and Eurasian plate, it is likely to experience frequent earthquake due to collision of the north ward movement of Indian plate with respect to Eurasian plate.Seismic isolation is a process of increasing the earthquake resistance property of the building structure and reducing the probability of damage[1-2]

In recent years the concept of seismic isolation process has developed as the alternative to the conventional seismic strengthening process. The principles of base isolation were evolved by Skinner, Robinson and McVerry in 1993 and later extended by Naiem and Kelly in 1999. This base isolation technique grabs the attention of researchers, professors and engineers and day by day it is becoming a promising sector for improving the present concept of the building structure design in view of earthquake resisting structures. Base isolation system works on a principle which tends to modify the response of a building so that the ground can move below the building without transmitting motions into structures. In isolated structures displacements are often large and efforts are made to releases the earthquake energy. It lengthens the natural period of vibration of the structure so that the responses are greatly reduced. Moreover isolator system is installed so that the building can move horizontally to ground and the displacement is limited up-to 100 mm to 1m. Base isolation does not make a building earthquake proof but enhances the earthquake resistance [2]. There are four types of base isolator generally used in building structures:

1) Lead Rubber Bearing (LRB).
2) Laminated Rubber (Elastomeric) Bearing.
3) High Damping Rubber (HDR) Bearing.
4) Friction Pendulum (FPS) System Bearing

In this paper a low to medium rise building (12 storey) building is modeled considering actual condition using ETABS-2015. Typical rubber isolator and friction pendulum are used to investigate their performance against seismic load. In order to figure out the improvement of isolation system, Non-linear Time History Analysis is conducted in both fixed based and base isolated conditions of the building.

2.0 MODELING OF STRUCTURE

In this paper, a12 storey reinforced concrete (RC) building located at Gazipur, Bangladesh which is nearly 30 km away from Dhaka city is taken for investigation. The building is modeled using FE package ETABS 2013 and parameters are considered as per Bangladesh National Building Code (BNBC 2014). In order to investigate the performances of base isolators, in this study, rubber isolator and friction pendulum system are used. Typical rubber isolator and FPS system are discussed below.

2.1 Lead Rubber Bearing (LRB):

A lead-rubber bearing is formed of a lead plug force-fitted into a pre-formed hole in an elastomer Bearing. The lead core provides rigidity under service loads and dissipates energy under high later loads. The rubber cover protects the steel from environmental effect. Lead yields at higher loads and thus lateral stiffness is reduced. For these properties the lead-rubber bearing is the most common type of isolator used.

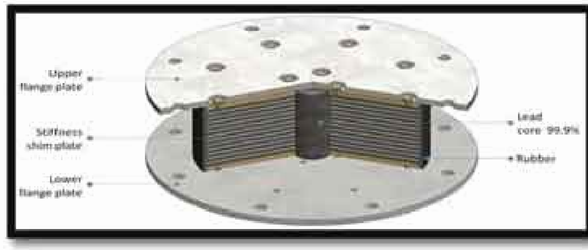


Fig 1: Lead Rubber Bearing

2.2 Friction Pendulum (FPS) System Bearing:

In friction pendulum, bearing the sliding surface is spherical in shape. It gives resistance to service load by coefficient of friction. After overcoming the friction coefficient the slider moves and for the spherical shape a lateral movement is accompanied with vertical movement. This isolator allows the displaced structure to return to its original position.

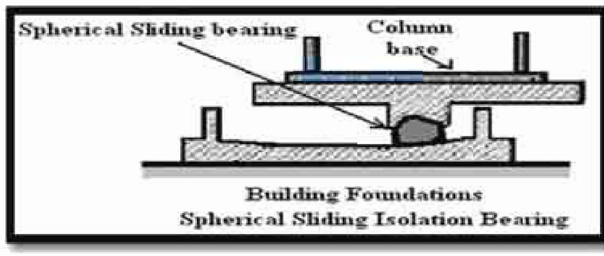
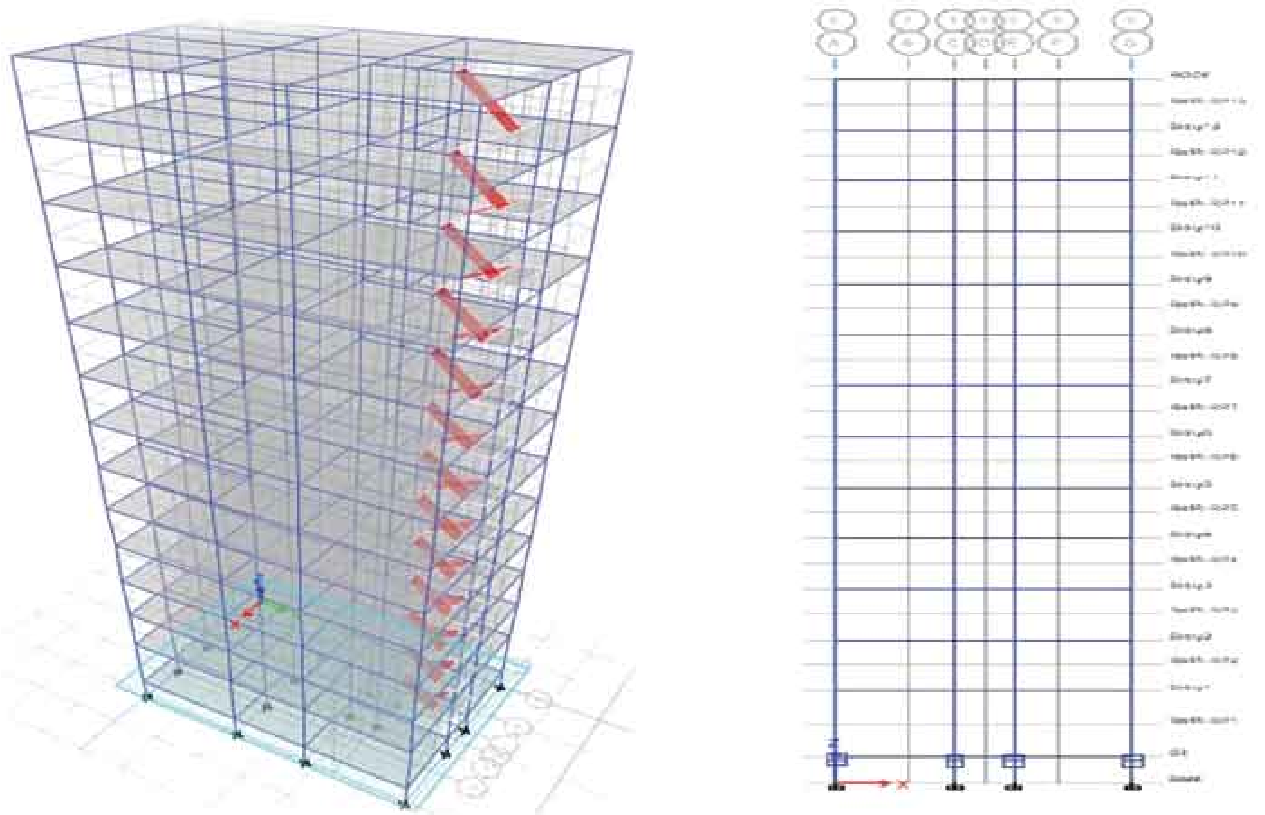


Fig 2: Friction Pendulum Sliding Bearing

Table 1. Building Details

The dimensions of structural members are presented in Table 1

Name of structural member	Specification
Typical Beams	12 inch X 20 inch
Grade beam	14 inch X 24 inch
Columns	Varies (12"X 16"to 16"X 20")
Slab thickness	6.5 inch
Thickness of periphery wall	10 inch
Height of typical floor	10 feet
Height of parapet wall	3 feet
Compressive strength of concrete	4000 psi for all
Grade of steel	50ksi
Dead load	PW(60psf), FF(30psf), periphey wall(400 plf)
Live load	story(40psf), roof ((30psf)



(a) (b)

Fig 3: (a) 3D model and (b) elevation of 12 Storey RC building

Table 2. Properties of Isolators

PROPERTIES OF ISOLATOR	RUBBER ISOLATOR	FRICTION PENDULUM
Linear Effective Stiffness UI (KN/m)	45000	1000
Linear Effective Stiffness U2 And U3(KN/m)	60000	250000
Non -linear Effective Stiffness U2 And U3(KN/m)	1500000	500000
Yield Strength (KN)	80	40
Post Yield Stiffness	0.1	-
Effective Damping	0.05	0.05
Rate Parameter	-	40
Net Pendulum Radius	-	2.23
Friction Co-Efficient Fast	-	0.05
Friction Co-Efficient Slow	-	0.03

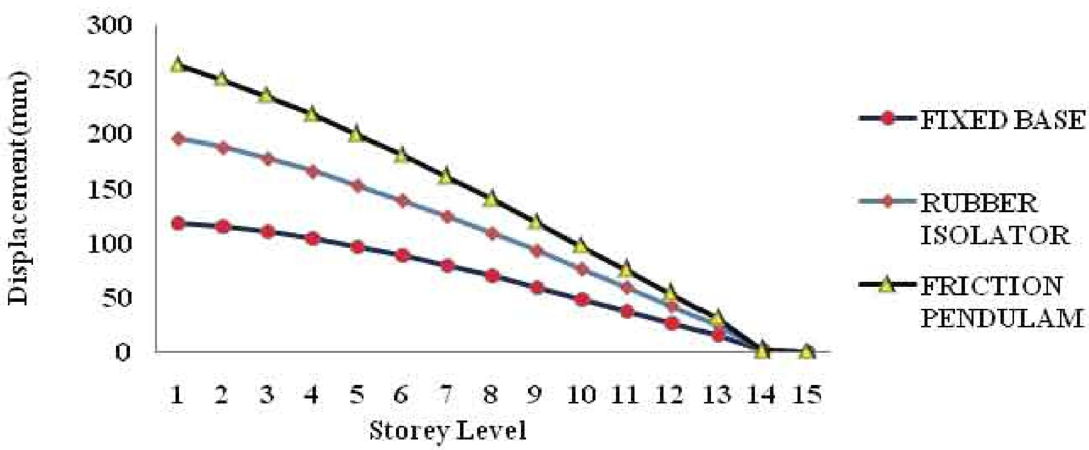
3.0 ANALYSIS & RESULT

In this study, a series of Finite element analyses is conducted under different condition to evaluate the seismic behavior of structures in earthquake motion. The seismic analyses of the buildings are carried out both in the longitudinal and the transverse directions. The parameters selected to define the rubber and friction pendulum isolators in the ETABS 2015 model are as follows:

3.1 Comparative study of structural performance parameters:

Maximum storey displacement in X direction at different storey level for different base condition is presented in Figure 4. It can be shown from the figure that rubber isolated building displacement which increases up-to a maximum of 39.76% and in friction pendulum isolated building it increases up-to 55% than fixed based building with respect to earthquake in X direction.

Figure 5 shows displacement curve of earthquake in Y direction. Where rubber isolated building shows increment in displacement up-to 8.74% and in friction pendulum it increases up-to 25.52% than fixed based building.



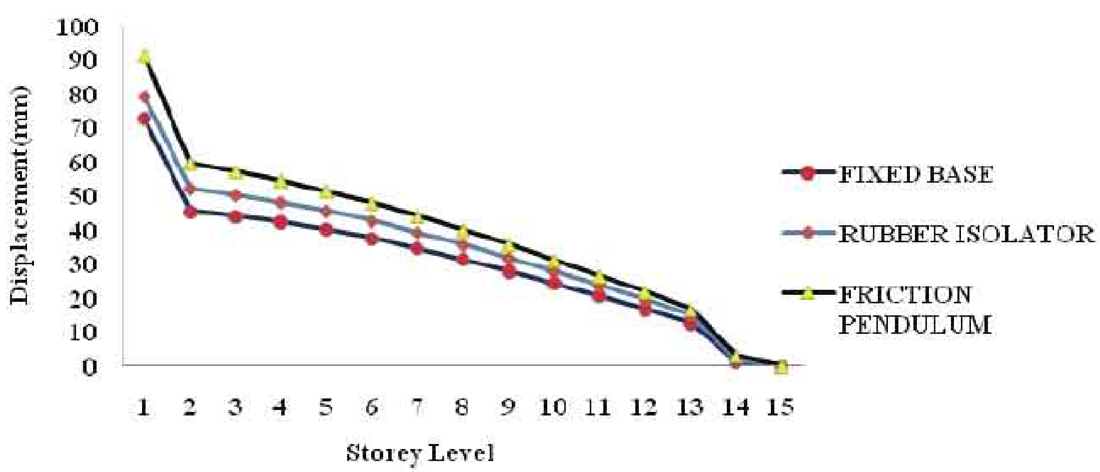


Fig 5: Displacement in Y direction

Figure 6 illustrates rubber isolated building story drift which increases up-to 60% and in friction pendulum isolated building it increases up-to 99.8% in story-1 than normal fixed based building with respect to earthquake in X direction.

Figure 7 shows displacement curve of earthquake in Y direction. Where rubber isolated building shows increment in story drift in story-1 up-to 14% and in friction pendulum it increases up-to 20.19% than fixed based building.

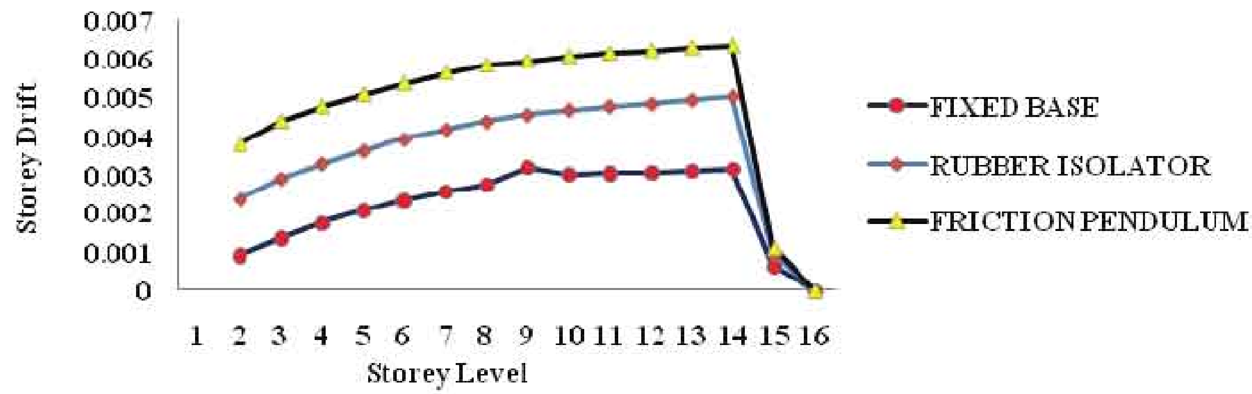


Fig 6: Storey drift in X direction

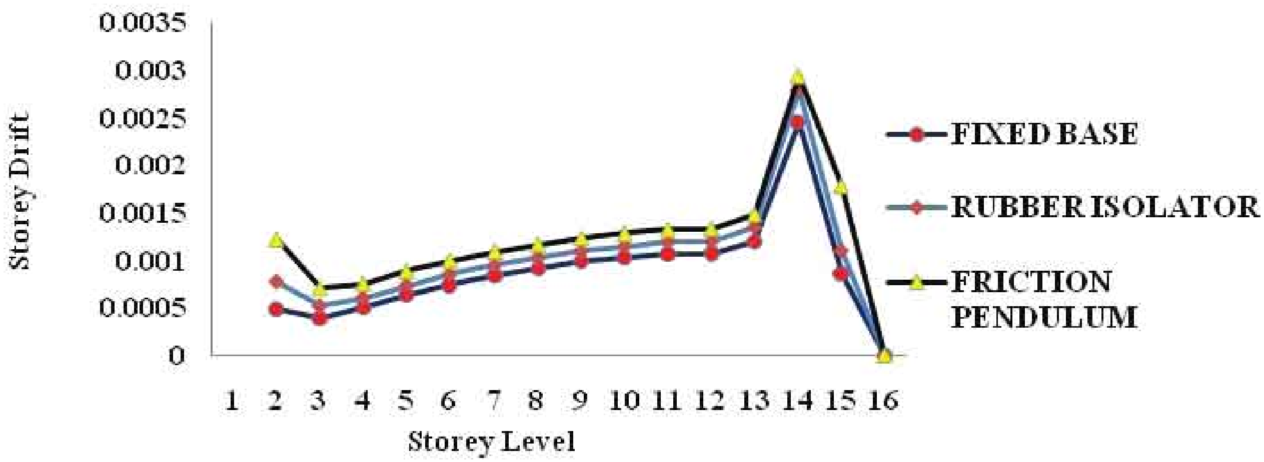


Fig 7: Storey drift in Y direction

4.0 TIME HISTORY ANALYSIS

Time history analysis is commonly used to observe performance of a structure at various well known ground motions.Non linear time history analysis is conducted in this paper to investigate resistance of the model 12Storey building under various real earthquake motions. The earthquake motion are used for this analysis are Corralit-1,Lacc Nor-1 (Northridge earthquake) and Holliste. Criteria of BNBC 2014 are fulfilled for setting up the maximum capable earthquake level.[3]

4.1 Comparative study of structural parameter from time history analysis:

In this section, effectiveness of base isolation is conducted by making comparison between fixed base structures and isolated structures which is done by rubber isolator and friction pendulum system. The results shows resistance against earthquake increases after using isolation system. Base shear reduces 17% after using rubber isolator bearing and around 22 % after using friction pendulum system. The base shear reduces dramatically.

Displacement increases 5% after using rubber isolator bearing and around 6 % after using friction pendulum system. There is a significant increment observed in the result. But acceleration reduction is comparatively less than other parameter after using both isolator. The results also shows friction pendulum system is more effective than rubber elastomeric bearing.

Table 3: Comparison results of structural parmeters of test model under three difeerent earthquake

Structural Parameters	Earthquake	Fixedbase	Rubber isolator	Reduction Or increment (%)	Friction pendulum	Reduction Or increment (%)
Base Shear (KN)	CORRALIT	3032.21	2504.81	17	2392.37	21.10
	HOLLISTE	3654.31	3393.03	7.15	3381.27	7.47
	LACC NOR	2567.62	2529.25	0.1	2310.35	10.2
Displacement (mm)	CORRALIT	39.03	39.86	2.08	40.72	4.15
	HOLLISTE	45.127	47.52	1.00	47.98	1.74
	LACC NOR	43.46	43.9	5.04	44..227	5.95
Acceleration (mm/s^2)	CORRALIT	37774.79	3632.47	3.77	3599.28	4.65
	HOLLISTE	2488	2485.15	0.1	2452.52	1.43
	LACC NOR	1909.13	1856.99	2.73	1843.47	3.44

4.2 Comparative study of base shear at different earthquake:

Figure 8 illustrates significant reduction of base after incorporating base isolation system. Behavior of base isolation system is distinctive for different earthquake. For Corralit earthquake Base shear reduced maximum 17% for rubber isolator and for friction pedulum system this percentage of reduction increases into around 22%. But for other earthquake motion like Lacc Nor this percenage is lower than that of Corralit and Holliste earthquake motion, almost near to the fixed base structure for rubber isolation process. Using friction pendulum system as seismic isolation system base shear reduced almost 11 % at the same earthquake motion (Lacc Nor earthquake motion).

4.3 Comparative study of acceleration at different earthquake:

Figure 9 represents significant reduction of accelration after incorporating base isolation system. Acceration reduced maximum 4 % for rubber isolator and for friction pedulum system this percentage of reduction increases into 5 %. But for Holliste earthquake motion acceleration of rubber isolated structure almost near to the fixed base structure. Using friction pendulum system as seismic isolation process acceleration reduced a little around 1.5 % at the same earthquake motion.

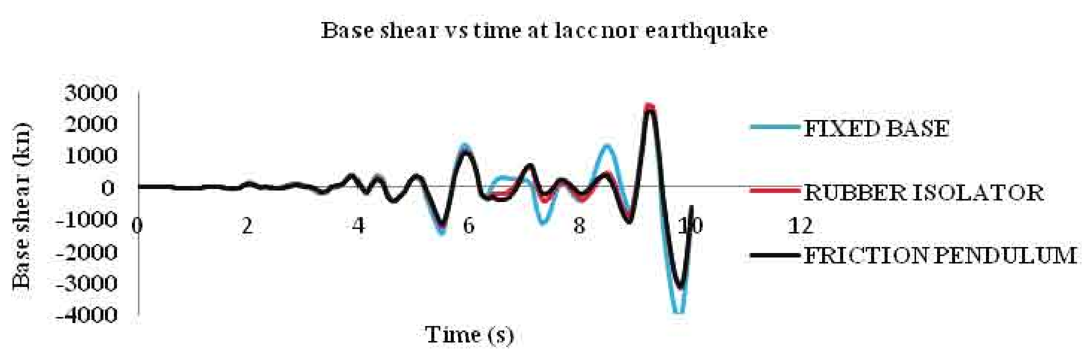


Fig 8: Comparison of base shear at different earthquake motion between base isolated and fixed base structure.

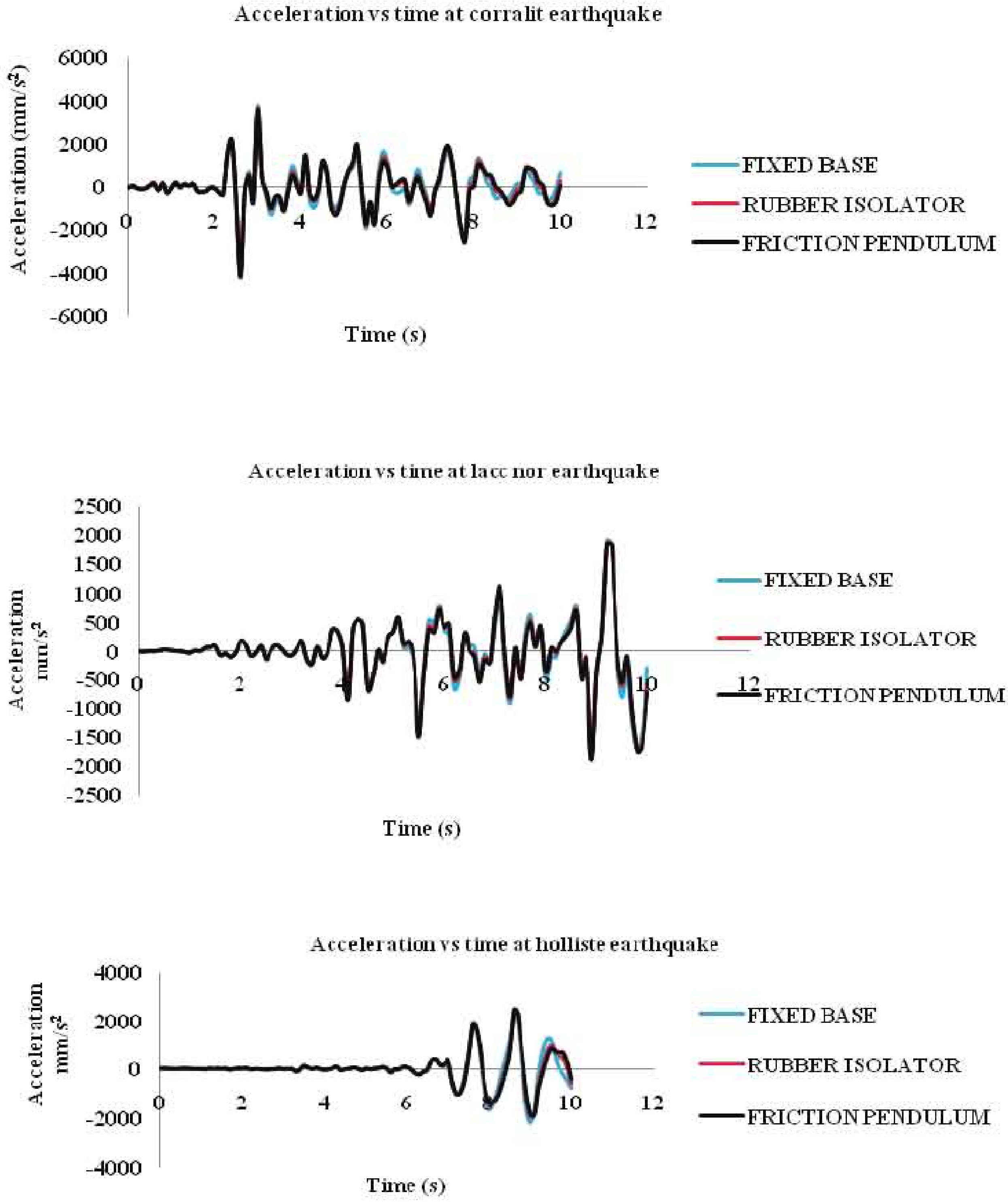


Figure 9: Comparison of acceleration at different earthquake motion between base isolated and fixed base structure.

4.4 Comparative study of displacement at different earthquake:

Figure 10 represents significant increment of displacement after incorporating base isolation system. Displacement increases maximum 5% for rubber isolator and for friction pedulum system this percentage of reduction increases upto 6 % (Holliste earthquake motion).

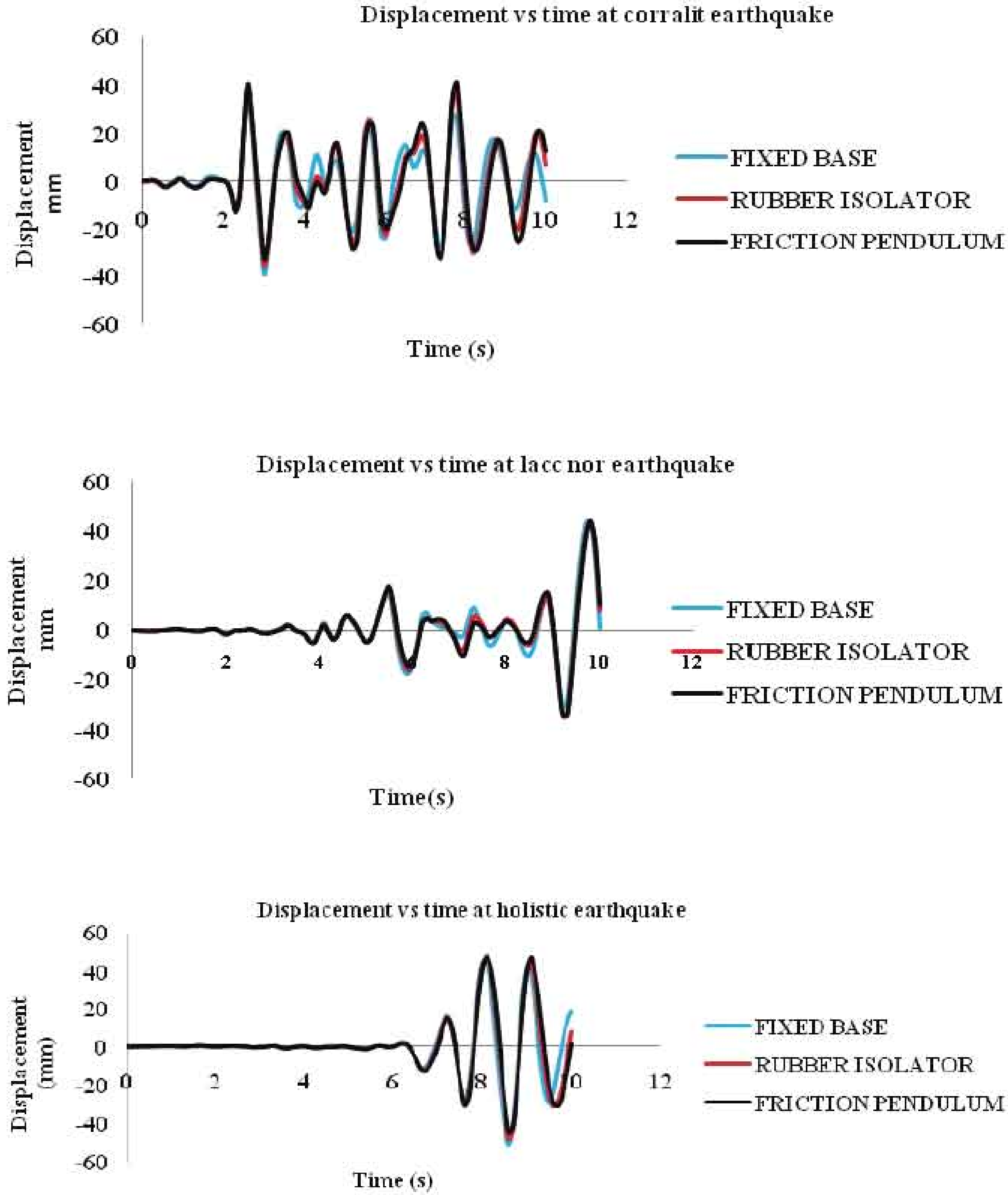


Fig 10: Comparison of displacement at different earthquake motion between base isolated and fixed base structure.

4.5 Hysteresis curve of the isolator in the test model:

Hysteresis curve of this building are shown in figure 11 (a), (b), (c) .The area covered by hysteresis curve represents the amount of energy dissipated by bearing. The area of hysteresis curve depends on frequency of excitation. The non linearity of a building is ovserved through this particular curve which is a presenter of the typical behavior of isolator[17].Hysteresis curve of isolator at a link is presented in the following graphs.

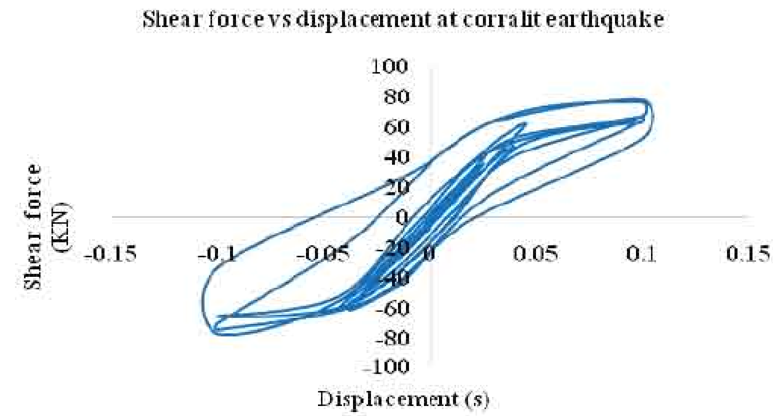


Fig 11 (a): Hysteresis curve of rubber Isolator at Corralit earthquake

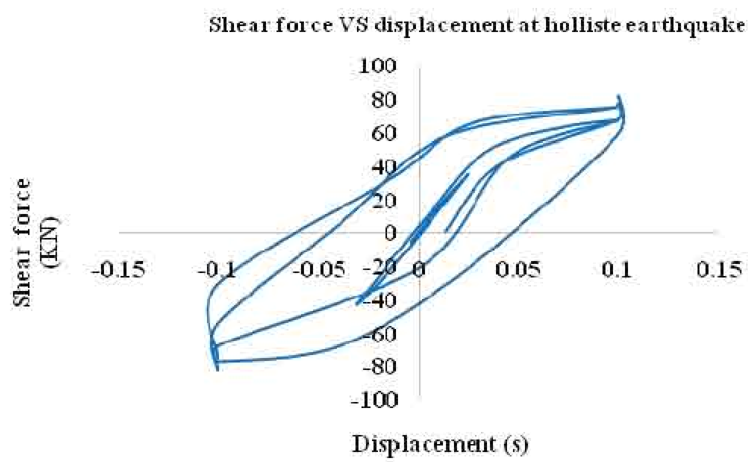


Fig 11 (b): Hysteresis curve of rubber isolator at Holliste earthquake

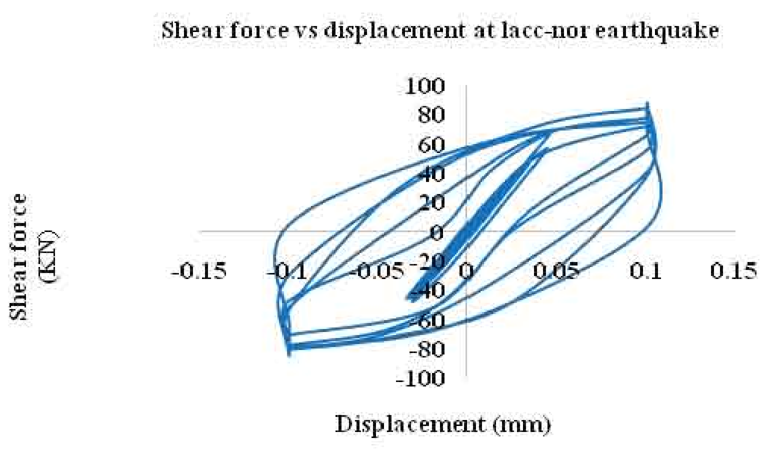


Fig 11 (c): Hysteresis curve of rubber isolator at Lacc-nor earthquake

Figure 4.12 (a), (b), (c) shows the bi- linear hysteresis behavior of isolator at three different earthquake. This graph represents the relationship between shear forces vs. displacement. The highest value or the maximum value of shear force is 75.8 KN at a displacement .069031 mm at Corralit earthquake. At Lacc-Nor earthquake e highest value or the maximum value of shear force is 71.76 KN at a displacement .069543 mm. But the highest shear force is shown in the graph of Holliste earthquake which is 81.10 KN at displacement .093 mm.

4.6 Reduction in energy:

The table 4.5 represents the energy value at different condition of the test building. The aim of using isolator is to dissipate seismic energy. The comparison between the fixed base building and both isolated building shows that energy reduced dramatically. At Corralit earthquake motion the induce energy reduced almost 25% by using rubber isolator and around 29% reduction by using FPS. Energy reduced around 13 % after incorporating Rubber isolator and 22% after using FPS as isolation device at Holliste earthquake motion. At Lacc-Nor earthquake this parameter reduced around 17% for Rubber isolator and 32% for FPS.

Table 4: Comparison in energy reduction of three earthquake

Name of Earthquake	Energy (KN-m)				
	Fixed Base	Rubber Isolator	Reduction (%)	Friction Pendulum	Reduction (%)
Corralit	174.50	131.41	24.69	123.98	28.95
Holliste	167.85	146.21	13.488	132	21.36
Lacc Nor	151.73	126.156	16.85	103	32.12

4.7 Comparison in reduction Energy at fixed base and base isolated structure:

The following graphs represent the huge reduction in Energy after using isolator. Main aim of isolation system is to dissipate the excessive generated energy due to earthquake motion. This graph also indicates that FPS is better than RB.

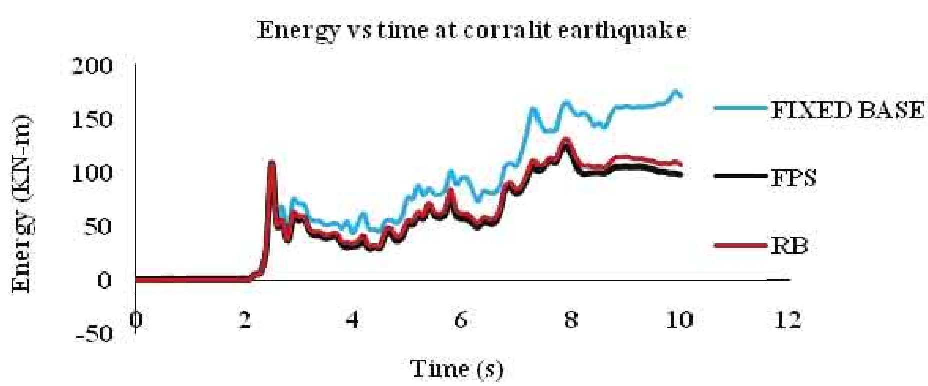


Fig 12 (a): Comparison in energy reduction at corralit earthquake

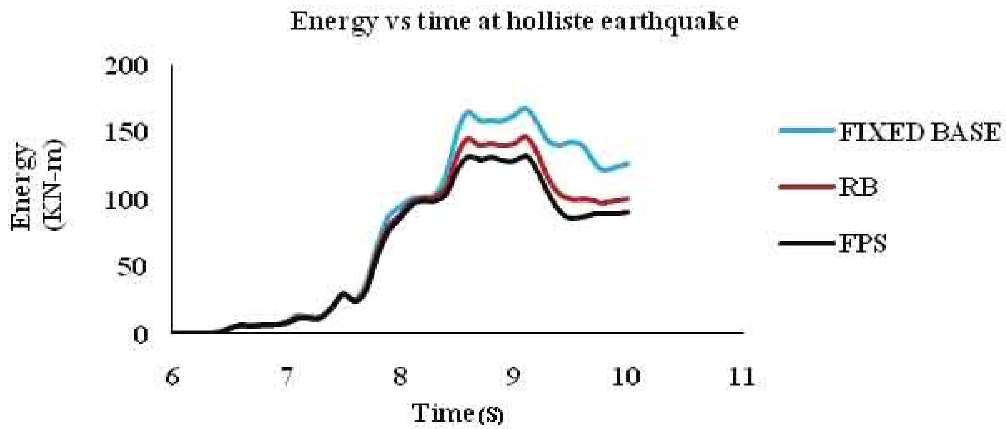


Fig 12 (b): Comparison in energy reduction at holliste earthquake

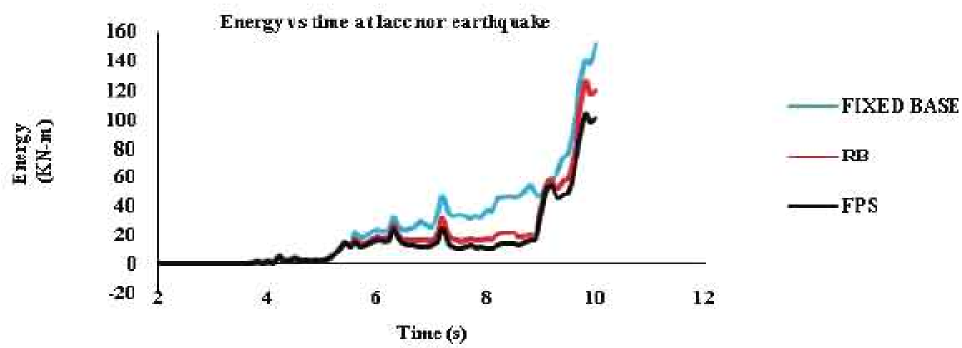


Fig 12 (c): Comparison in energy reduction at lacc nor earthquake

These figures are graphical repsentation of the table. Amoung all three earthquake Holliste earthquake seems severe as the isolators can minimize the energy at lowest pecentage than the other two earthquake. This graphs and table indicates the Friction Pendulum System is more effective in reducing energy thanRubber Isolator.

5.0 CONCLUSION

1. Base isolation technique is one of the most effective way to protect structure from adverse effect of earthquake.

2. Friction pedulum is more effective and suitable for multistorey building as highest amount of base shear and acceration rudeced and displacement increases at every earthquake motion.

3. For Corralit earthquake base shear reduced maximum 17% for rubber isolator and for friction pedulum system this percentage of reduction increases into around 21.1%. Acceleration reduced 3.77 % for rubber isolator and for friction pendulum system this percentage isaround 4.65%. Increment of displacement in rubber isolated structure is 2.08% and for friction pendulum system the increment value is 4.15%.

4. For Holistic earthquake base shear reduced maximum 7.15 % for rubber isolator and for friction pedulum system this percentage of reduction increases into around 7.47%. Acceleration reduced .1 % for rubber isolator and for friction pendulum system this percentage is 1.43%. Increment of displacement in rubber isolated structure is 5.04%and for friction pendulum system5.95%.

5. For Lacc Nor earthquake base shear reduced maximum .1% for rubber isolator and for friction pedulum system this percentage of reduction increases into around 10.2%. Acceleration reduced 2.73 % for rubber isolator and for friction pendulum system this percentage is 3.44%. Increment of displacement in rubber isolated structure is 1%and for friction pendulum system 1.74%.

6. Bilinear hesteriatic behavior of rubber isolator is observed at three different earthquake.

7. Energy reduces maximum 25% after using Rubber Isolator at corralit earthquake motion and 32% after using Friction Pendulum system at laac nor earthquake

References

[1] Dr. T. A. Hussaini, 2014 "Seismic Hazard and Risk Assessment for Bangladesh,"in National Seminar on Engineers Role in Ensuring Safety.

[2] Kelly.T.E., S.E.2001.BASE ISOLATION OF STRUCTURES.

[3] G.O.P, Bakre S.V, Performance of Non-Linear Elastomeric Base-Isolated building structure, 2011.International Journal of Civil and Structural Engineering, ISSN 0976 – 4399, Volume 2,No 1.

[5] Shirule, P. A., Jagtap, L. P., Sonawane, K. R., Patil, T.D., Jadwanir, N., And Sonar, S.K., 2012. Time History Analysis of Base Isolated Multi-Storyed Building,International journal of earth sciences and engineering, ISSN 0974-5904, Volume 05, No. 04. P.P. 809-816.

[6] Parma, V., Hiremath, G.S., 2015. Effect of Base Isolation in Inultistoried RC Irregular Building Using Time History Analysis,International Journal of Research in Engineering and Technology (IJERT), pISSN: 2321-7308. Volume: 04.

[7] Kaptan, K.,2013.Seismic base isolation and energy absorbing devices, European Scientific Journal. ISSN: 1857 – 7881, vol.9, No.18.

[8] Aung, T. M., Win,T. T. AndKyaw, N. M., Analysis and Design of Reinforced Concrete Structures with Spring Base Isolation, MM090011

[9] Warrier, G.A., Balamonica, K., Dr. Kumar, K.S., Dhanalakshmi, 2015.Study on laminated rubber bearing base isolators for seismic protection of structures, International Journal of Research in Engineering and Technology (IJRET), pISSN: 2321-7308.

[10] Dr. AL-Maliki H.N. G., 2013.Analytical Behavior of Multi-Storied Building with Base Isolation Subjected to Earthquake Loading,Journal of Engineering and Development, ISSN 1813- 7822, Vol. 17, No.2.

[11] Nithya,S. E., Dr. Prasanna, P.R., 2012.Moment Resisting Frame with Rubber Base Isolation for Development of Earthquake Resisting Structures,International Journal of Modern Engineering Research (IJMER), ISSN: 2249-6645,Vol.2, Issue.4. pp-2431-2433.

[12] Keerthana,S., Kumar, K.S., Balamonica, K., Jagannathan, D.S.,Seismic Response Control Using Base Isolation Strategy, International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459,Volume 4, Special Issue 4.

[13] Figueiredo. F. R. D., Design of base isolation systems in buildings.

[14] Islam, A. B. M. S., Jameel, M., and Jummat, M.Z., 2011. Study on optimal isolation system and dynamic structural responses in multi-storey buildings, International Journal of the nor earthquake

Physical Sciences,ISSN 1992 – 1950, Vol. 6(9), pp. 2219-2228.

[15] Mr. Katti, G. B., and Dr. Balapgol, B.S., 2014.Seismic Analysis of Multistoried RCC Buildings Due to Mass IrregularityBy Time History Analysis, International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181 .Vol. 3.

[16] Akhare, A.R., Wankhade, T.R., Seismic Performance of RC Structure Using Different Base Isolator, International Journal of Engineering sciences ResearchTechnology (IJERT), ISSN: 2277-9655, 2014.

[17] Analysis Manual, Inelastic Time History Analysis.