SEISMIC RESPONSE COMPARISON OF MULTI-STOREY BUILDING WITH ISOLATOR

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ABSTRACT

The purpose of this research is to offer a relative understanding of the seismic response enhancements that a typical eight-storeyed residential steel building can achieve through the implementation of base isolation technology. To reach this understanding, the structures of fixed base building and isolated base building of same size are used, their seismic response is compared. In this study, eight-storeyed residential steel building located in Mandalay is used as the proposed model. The base isolation system that is utilized lead rubber bearing which made up of Myanmar rubber (RSS-1). The sizes of the isolators for RSS-1 before aging and after aging are the same. In this study, base isolation devices are installed under each column between the building and the supporting foundation to support the building and to minimize the damage due to earthquake. Nonlinear time history analysis is done to obtain structural response at design basic earthquake (DBE) and maximum considered earthquake (MCE) levels for Myanmar rubber, RSS-1 (before and after aging).

Keywords *- base isolation, lead rubber bearing, Myanmar rubber, nonlinear time history analysis, seismic response*

I. INTRODUCTION

Buildings are vulnerable to earthquake ground motions. Vulnerability of this kind of structures has been patent after the strong earthquakes and hurricanes that have hit different regions around the world and have caused their collapse with the consequent loss of lives. Civil engineering structures are to be protected from hazardous phenomena like seismic motions. In order to make structures safer against these phenomena, researchers have taken advantage of the fact that, by the principles of energy conservation, damping devices can be added to the structure as protective systems. To help reduce the loss from earthquake events, seismic protective devices emerged in recent decades to improve the performance of building structures against earthquake loads. Seismic isolation and energy dissipating systems are some of the design strategies applied to increase the earthquake resistance of the structures. Base isolation technique is one of the most widely implemented seismic protection systems in earthquake prone areas. The term base refers to the foundation of a structure and isolation refers to reduced interaction between the ground and the structure resting over it. Base isolation is one of the most powerful tools of earthquake engineering pertaining to the passive structural vibration control technologies. The system reduces the structural and non structural damage to a building subjected to seismic forces. Seismic isolation is a process to decrease the response shown to the impacts such as earthquake by separating the superstructure from the ground. In this way, the period and the damping ratio of the structure isolated from the ground are increased. This, in turn, reduces the earthquake forces on the structure. As a result of the use of base isolation, lives and property have been saved.

Myanmar is one of the earthquake prone regions as it is located in the eastern part of Alpide Earthquake Belt, between the eastern end of Himalaya Arc, the collision zone of Indian and Asia Plates, and the northern segments, highly active portions of the Sunda Arc. Therefore, the seismic isolation technique is conducted for the whole of Myanmar and for Mandalay (as pilot area) as well since it is located adjacent to the most active fault in Myanmar, the Sagaing Fault.

Though the application of isolator is going to be very familiar all over the world, there is a lack of proper research to implement the device practically for local buildings in Mandalay especially risk seismicity region, Myanmar as per the local requirements. Many types of isolation system have been developed elsewhere in the world to provide flexibility and damping to a structure in the event of seismic attack. Among the categories, lead rubber bearing is the most commonly used isolator nowadays. The author is very willing to test possibility of using local rubbers as major component of a lead rubber bearing isolator. Therefore, the analysis and design of isolators using Myanmar rubbers for eight-storeyed residential steel building in Mandalay will be investigated.

II. PROPERTIES OF MYANMAR RUBBER

Lead rubber bearings used as Myanmar rubber are expected to be widely used in Myanmar. In this study, the RSS-1 (before and after aging) of Myanmar rubbers are used as major component of lead rubber bearings. The required experimental tests are conducted to determine the properties of the materials in Rubber Research Development Centre. N220 carbon black was used as filler in RSS-1. The aging characteristic for RSS-1 types of rubber are estimated by carrying out heat accelerated aging test in 24 hour at 70°C. The experimental test results of Myanmar rubber properties for different types of specimens are shown in Table I.
RSS-1 Myanmar rubber contains the following chemical properties. They are

- Volatile matter = 1.74%
- Dirt Content = 0.06%
- Ash Content = 0.4%
- Nitrogen Content = 0.63%

RSS-1 Myanmar rubber contains the following physical properties. They are

- Plasticity No = 49.3
- Plasticity Retention index (P.R.I) = 78

TABLE I: Test Results for Properties of Myanmar Rubber

Type	Rubber Hardness IRHD	Young's Modulus E (kip/ft^2)	Shear Modulus G (kip/ft^2)	Elongation at Break (%)
RSS-1	55	75.594	18.84	587.3
	60	90.211	21.489	590
RSS-1 Aging	55	71	17.695	542
	60	87.946	20.95	520

III. COMPARISON OF PERFORMANCE RESULTS FROM NONLINEAR TIME HISTORY ANALYSIS

The Comparisons of average response values of fixed base building and lead rubber isolated base building (RSS-1 before and after aging, Myanmar rubber) from nonlinear time history analysis at DBE and MCE seismic demand levels are presented with the following indicators.

- Storey Drift
- Storey Acceleration
- Storey Displacement

The nonlinear time history analysis at DBE and MCE seismic demand levels results on storey drift, storey acceleration, storey displacement of fixed base and isolated base buildings are compared as shown in Figures 1 to 24.

3.1 Comparison of Storey Drift for Fixed and RSS-1 Base Buildings at DBE Level

The comparisons of storey drift for fixed and RSS-1 buildings at DBE level in X and Y directions are shown in Figure 1 and 2.

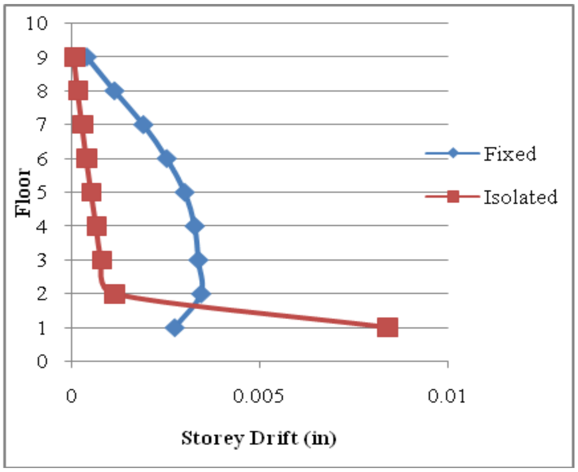

Figure 1. Comparison of Storey Drift for Fixed and RSS-1 Buildings at DBE in X Direction

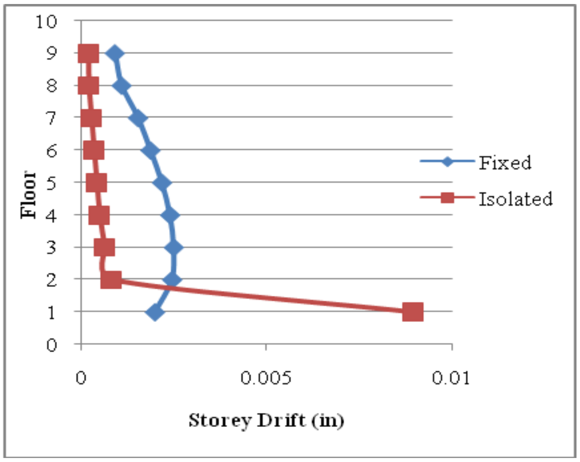

Figure 2. Comparison of Storey Drift for Fixed and RSS-1 Buildings at DBE in Y Direction

It can be seen that the storey drift is higher at lower floors in case of fixed base model and it decreases drastically move to the top floors. Storey drift of fixed base model is comparatively lower in lower floors and higher in upper floors than in case of isolated model. The average reduction in storey drift is 42.58% in X direction while 27.28% in Y direction for isolated base model in comparison with the fixed base model.

3.2 Comparison of Storey Acceleration for Fixed and RSS-1 Base Buildings at DBE Level

The comparisons of storey acceleration for fixed and RSS-1 buildings at DBE level in X and Y directions are shown in Figure 3 and4. It can be seen that in X direction, the reduction in the acceleration at the top floor is 80.61% for isolated model in comparison with fixed base model. While the reduction in the acceleration at the top floor is 87% for isolated model in comparison with fixed base model in Y direction.

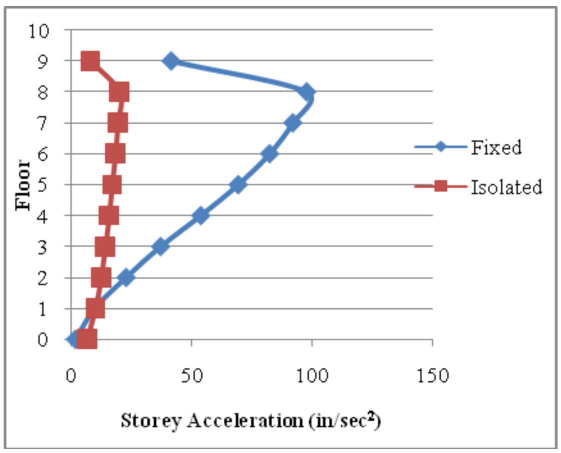

Figure 3. Comparison of Storey Acceleration for Fixed and RSS-1 Buildings at DBE in X Direction

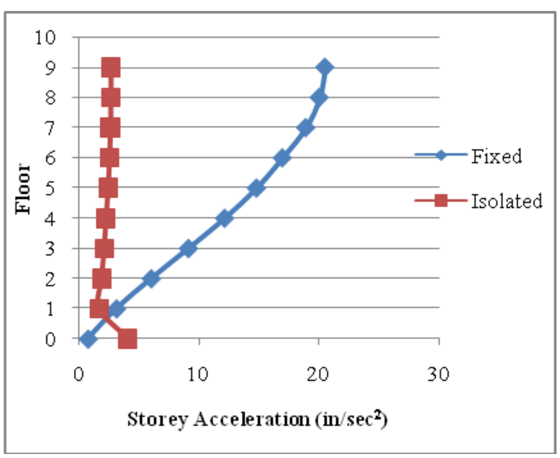

Figure 4. Comparison of Storey Acceleration for Fixed and RSS-1 Buildings at DBE in Y Direction

3.3 Comparison of Storey Displacement for Fixed and RSS-1 Base Buildings at DBE Level

The comparisons of storey displacement for fixed and RSS-1 buildings at DBE level in X and Y directions are shown in Figure 5 and 6. It can be seen that in X and Y direction, the reduction in displacements are 84.021% and 81.761% at the top for isolated model in comparison with the fixed base model.

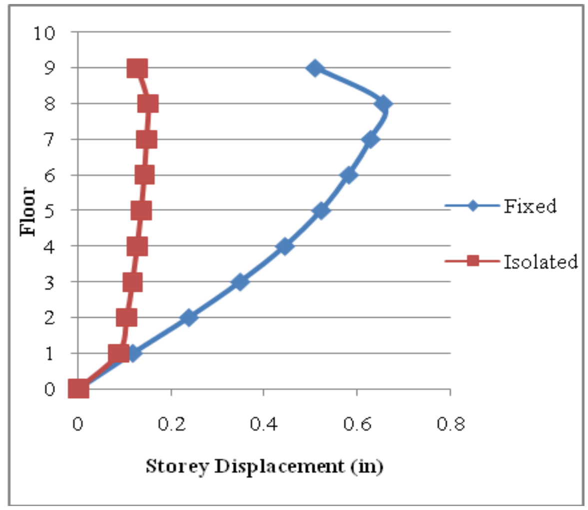

Figure 5. Comparison of Storey Displacement for Fixed and RSS-1 Buildings at DBE in X Direction

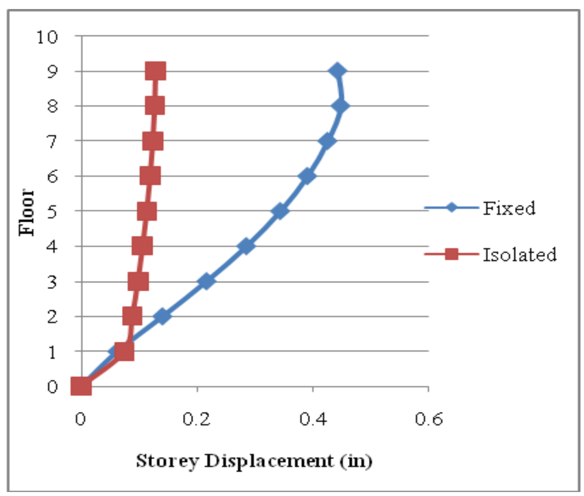

Figure 6. Comparison of Storey Displacement for Fixed and RSS-1 Buildings at DBE in Y Direction

3.4 Comparison of Storey Drift for Fixed and RSS-1 Base Buildings at MCE Level

The comparisons of storey drift for fixed and RSS-1 buildings at MCE level in X and Y directions are shown in Figure 7 and 8. It can be seen that storey drift is comparatively lower in lower floors of fixed base model than in case of isolated model and decreases move to the top floor. The average reduction in storey drift is 41.168% in X direction while 26.856% in Y direction for isolated model in comparison with the fixed base model.

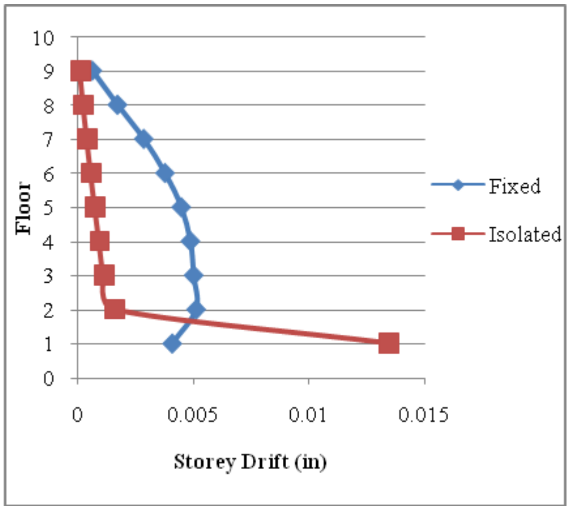

Figure 7. Comparison of Storey Drift for Fixed and RSS-1 Buildings at MCE in X Direction

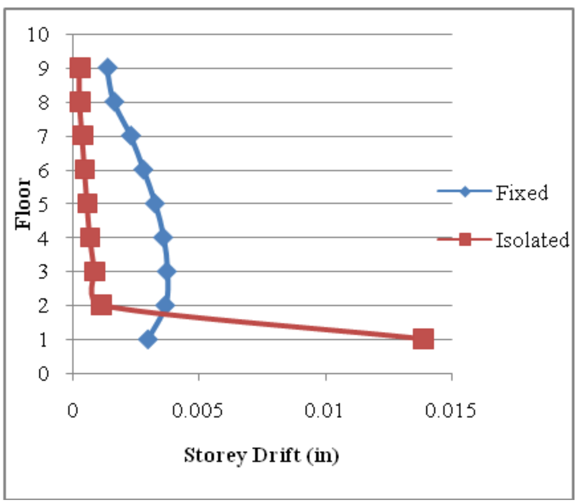

Figure 8. Comparison of Storey Drift for Fixed and RSS-1 Buildings at MCE in Y Direction

3.5 Comparison of Storey Acceleration for Fixed and RSS-1 Base Buildings at MCE Level

The comparisons of storey acceleration for fixed and RSS-1 buildings at MCE level in X and Y directions are shown in Figure 9 and 10. It can be seen that in X direction, the reduction in the acceleration at the top floor is 87.3761% for isolated model compared with fixed base model. While the reduction in the acceleration at the top floor is 88.56% for isolated model compared with fixed base model in Y direction.

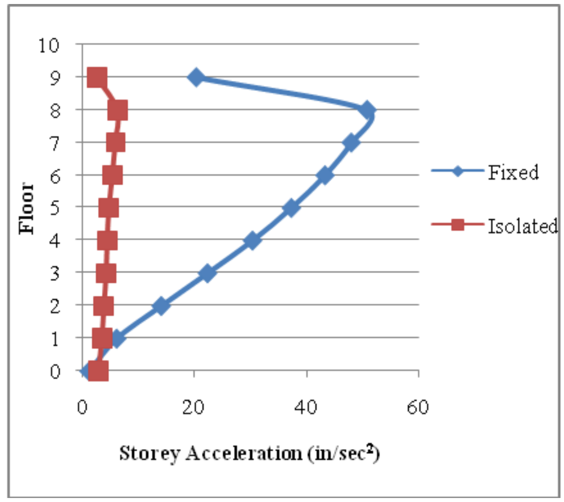

Figure 9. Comparison of Storey Acceleration for Fixed and RSS-1 Buildings at MCE in X Direction

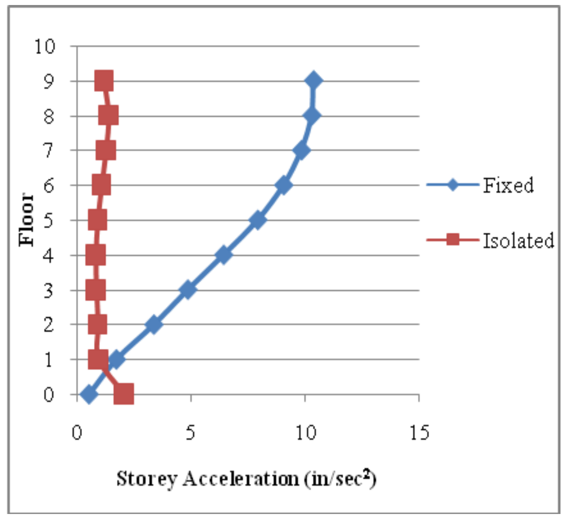

Figure 10. Comparison of Storey Acceleration for Fixed and RSS-1 Buildings at MCE in Y Direction

3.6 Comparison of Storey Displacement for Fixed and RSS-1 Base Buildings at MCE Level

The comparisons of storey displacement for fixed and RSS-1 buildings at MCE level in X and Y directions are shown in Figure 11 and 12. It can be seen that in X and Y directions, the reductions in displacement are 54.139% and 44.155% at the top floor for isolated model in comparison with the top floor for fixed base model.

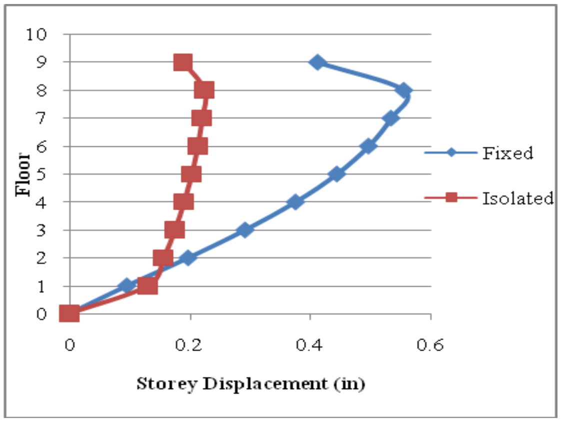

Figure 11. Comparison of Storey Displacement for Fixed and RSS-1 Buildings at MCE in X Direction

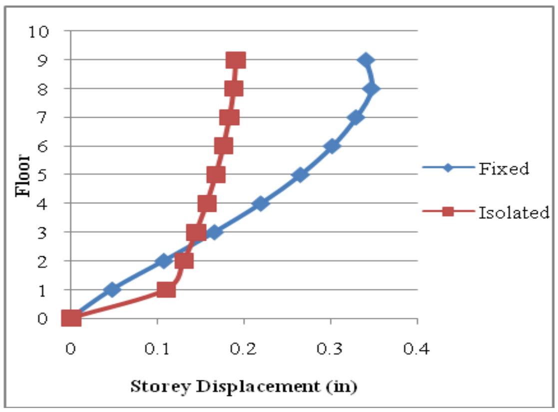

Figure 12. Comparison of Storey Displacement for Fixed and RSS-1 Buildings at MCE in Y Direction

3.7 Comparison of Storey Drift for Fixed and RSS-1 Aging Base buildings at DBE level

The comparisons of storey drift for Fixed and RSS-1 Aging buildings at DBE level in X and Y directions are shown in Figure 13 and 14.

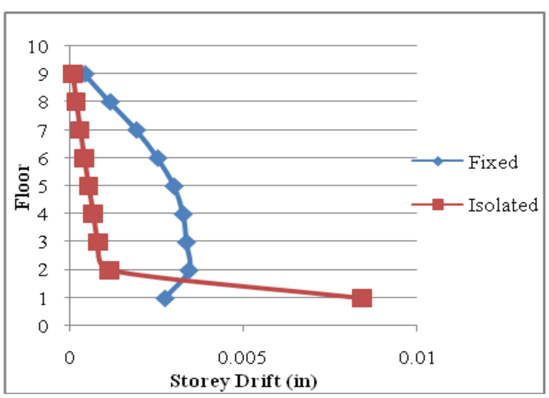

Figure 13. Comparison of Storey Drift for Fixed and RSS-1 Aging Buildings at DBE X Direction

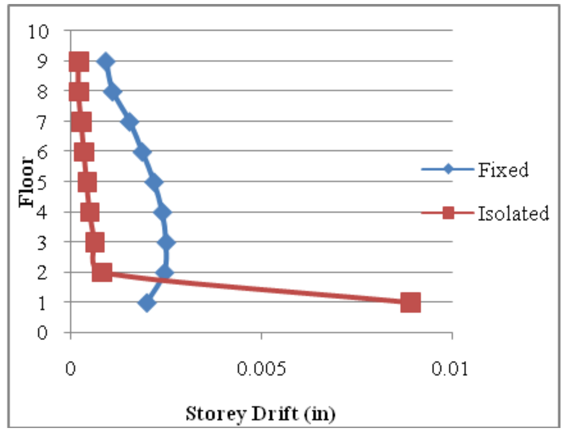

Figure 14. Comparison of Storey Drift for Fixed and RSS-1 Aging Buildings at DBE Y Direction

It can be seen that the average reduction in storey drift is 42.58% in X direction while 27.224% in Y direction for isolated base model in comparison with the fixed base model.

3.8 Comparison of Storey Acceleration for Fixed and RSS-1 Aging Base buildings at DBE level

The comparisons of storey acceleration for Fixed and RSS-1 Aging buildings at DBE level in X and Y directions are shown in Figure 15.and 16. It can be seen that in X direction, the reduction in the acceleration at the top floor is 88.924% for isolated model in comparison with fixed base model. While the reduction in the acceleration at the top floor is 90.052% isolated model in comparison with fixed base model in Y direction.

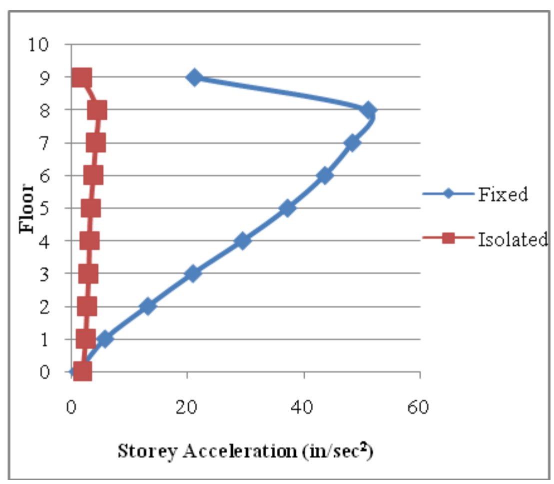

Figure 15. Comparison of Storey Acceleration for Fixed and RSS-1 Aging Buildings at DBE X Direction

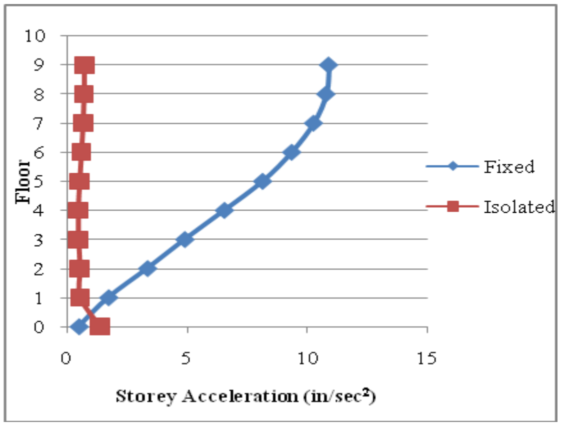

Figure 16. Comparison of Storey Acceleration for Fixed and RSS-1 Aging Buildings at DBE Y Direction

3.9 Comparison of Storey Displacement for Fixed and RSS-1 Aging Base buildings at DBE level

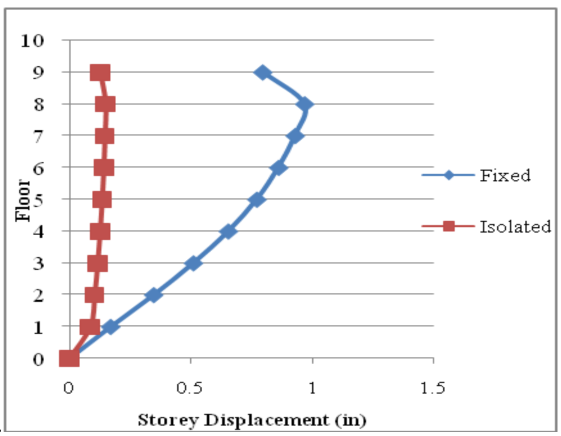

Figure 17. Comparison of Storey Displacement for Fixed and RSS-1 Aging Buildings at DBE X Direction

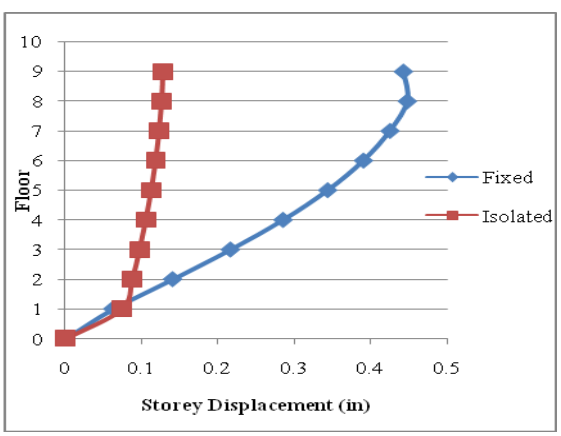

Figure 18. Comparison of Storey Displacement for Fixed and RSS-1 Aging Buildings at DBE Y Direction

The comparisons of storey displacement for Fixed and RSS-1 Aging buildings at DBE level in X and Y directions are shown in Figure 17 and.18. It can be seen that in X and Y directions, the reductions in displacement are 84.017% and 71.014% at the top for isolated model in comparison with the fixed base model.

3.10 Comparison of Storey Drift for Fixed and RSS-1 Aging Base buildings at MCE level

The comparisons of storey drift for Fixed and RSS-1 Aging buildings at MCE level in X and Y directions are shown in Figure 19 and 20. It can be seen that the average reduction in storey drift is 41.141% in X direction while 26.821% in Y direction for isolated model in comparison with the fixed base model.

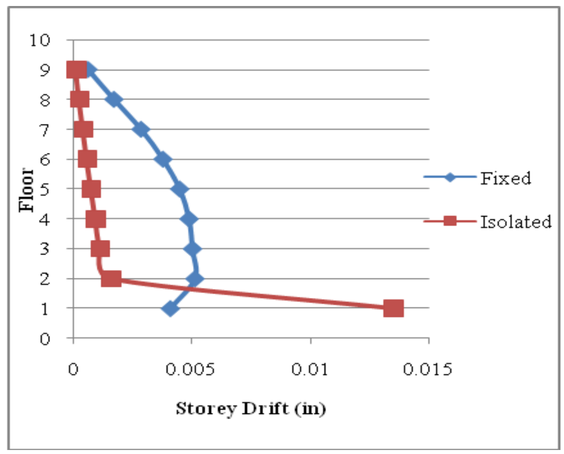

Figure 19. Comparison of Storey Drift for Fixed and RSS-1 Aging Buildings at MCE X Direction

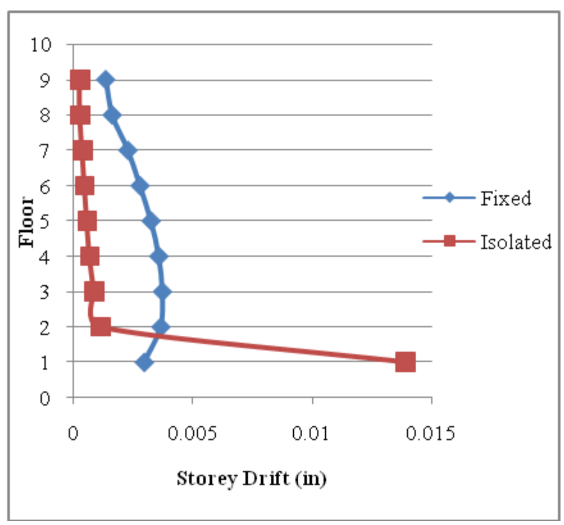

Figure 20. Comparison of Storey Drift for Fixed and RSS-1 Aging Buildings at MCE Y Direction

3.11 Comparison of Storey Acceleration for Fixed and RSS-1 Aging Base buildings at MCE level

The comparisons of storey acceleration for Fixed and RSS-1 Aging buildings at MCE level in X and Y directions are shown in Figure .21 and 22. It can be seen that in X direction, the reduction in the acceleration at the top floor is 83.648% for isolated model in comparison with fixed base model. While the reduction in the acceleration at the top floor is 84.421% isolated model in comparison with fixed base model in Y direction.

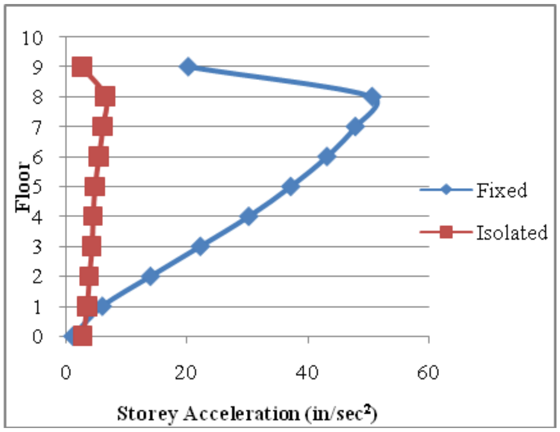

Figure 21. Comparison of Storey Acceleration for Fixed and RSS-1 Aging Buildings at MCE X Direction

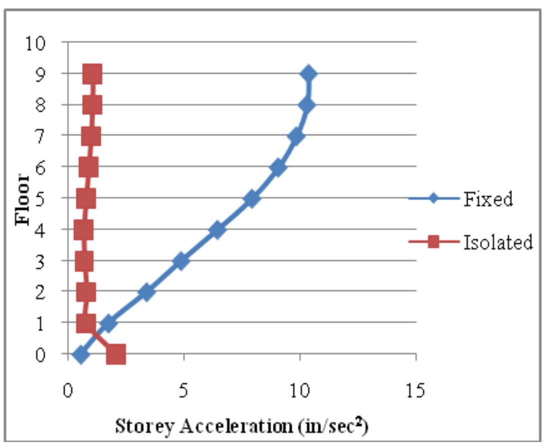

Figure 22. Comparison of Storey Acceleration for Fixed and RSS-1 Aging Buildings at MCE Y Direction

3.12 Comparison of Storey Displacement for Fixed and RSS-1 Aging Base buildings at MCE level

The comparisons of storey displacement for fixed and RSS-1 Aging buildings at MCE level in X and Y directions are shown in Figure 23 and 24. It can be seen that in X and Y directions, the reductions in displacement are 54.123% and 44.138% at the top floor for isolated model in comparison with the top floor for fixed base model

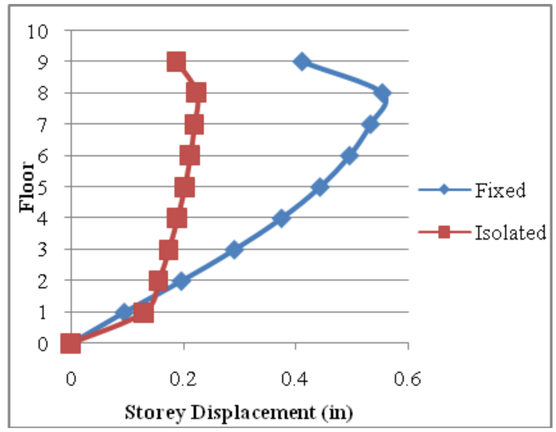

Figure 23. Comparison of Storey Displacement for Fixed and RSS-1 Aging Buildings at MCE X Direction

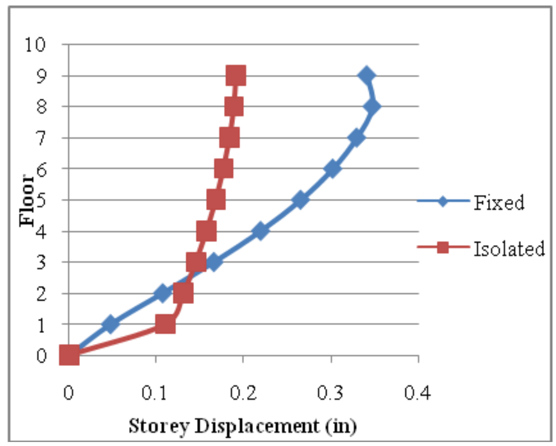

Figure 24. Comparison of Storey Displacement for Fixed and RSS-1 Aging Buildings at MCE Y Direction

IV. CONCLUSION

Ground motion records for time history analysis are obtained from PEER ground motion database web site based on ASCE code spectrum. A set of seven ground motions were used to conduct the nonlinear dynamic time history analyses. After conducting time history analyses with representative ground motion data, the seismic response of the RSS-1 (before and after aging) isolated models were compared to those of the fixed base models in terms of storey accelerations, storey drifts and storey displacements at DBE and MCE seismic demand levels. At DBE seismic demand levels, the average reduction in storey drift is 0.0397% in X direction while 0.1098% in Y direction for RSS-1 before aging isolated model in comparison with the RSS-1 after aging isolated model. In X direction, the storey acceleration is reduced 0.018% in average for before aging and 0.017% in Y direction in comparison with the after aging isolated model. In X and Y directions, the average reductions in displacement are 0.013% and

0.0129% for before aging isolated model in comparison with the after aging isolated model. At MCE seismic demand level, the average reduction in storey drift is 0.039% in X direction while 0.038% in Y direction for before aging isolated model in comparison with the after aging isolated model. In X direction, the storey acceleration is decreased 3.3144 % in average for before aging isolated model in comparison with after aging isolated model and 14.167% in Y direction. In X and Y directions, the average reductions in displacement are 0.013% and 0.019% for before aging isolated model in comparison with after aging isolated model at MCE seismic demand level.

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