Seismic Performance Comparison of Fixed Base and Isolated Base Steel Multi-Storey Building

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Abstract

This study presents the comparative study on seismic performance of with and without isolation in eight-storeyed hypothetic steel building located in Mandalay. The base isolation system that is utilized lead rubber bearing which made with Japan rubber and Myanmar rubbers (RSS-1 and RSS-3). 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. In this study, comparative advantages for using lead rubber bearing isolation systems with various types of rubber are mainly investigated by performing response spectrum and nonlinear time history analyses. The comparison process has been carried out on performance of the structure with storey displacement, storey acceleration, and storey drift. In the analysis phase, nonlinear time history analyses at DBE and MCE levels are conducted in ETABS to obtain the related floor accelerations, interstorey drifts and storey displacement. In performance assessment phase, probable damage cost, repair time and rate of injuries are computed using fragility curves and FEMA P-58 methodology in Performance Assessment Calculation Tool (PACT). Damage cost, repair time and rate of injuries are computed for each building at seismic demand level and the results are compared. According to investigation conducted, it can be inferred that RSS-3 is more effective than RSS-1 at DBE while RSS-1 is better than RSS-3 at MCE levels.

Keywords: lead rubber bearing; Japan rubber; Myanmar rubber; response spectrum and nonlinear time history analyses; ETABS; FEMA P-58; PACT.

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1. Introduction

As it is known earthquakes uncontrollably occur. As soon as a seismic activity begins, the ground starts to vibrate and thereby release high amounts of energy, some of which absorbed by the structure. This absorbed energy when exceeds the elastic limit of structure causes inevitable occurrence of damages. Therefore, the demand should be accepted and made sure that the capacity surpasses it. However, the internal forces in the structure depend on the building mass and ground acceleration. When the ground acceleration increases, the strength of the building must be raised in order to reduce the structural damages [1]. To mitigate the response of earthquake on the structure many engineers and architects trying to find out the best applicable method to reduce the response given to ground motion by the structures. Base isolation is one of the best alternatives for this issue. During earthquake the conventional structure without seismic isolation is subjected to substantial storey drifts, which may lead to damage or even collapse of the building. Whereas the isolated structure vibrates almost like a rigid body with large displacement due to the presence of isolators at the base of structures. In the base isolation technique, the flexible interface is introduced between the foundation and the base of the superstructure from earthquake ground motion there by increasing the fundamental time period of the structure [2]. In traditional dealings, the building design of is based upon an increased resistance (strengthening) of the structures. This ideology duly increases the structural cost of multi-storey construction subjected to huge lateral loading in seismic excitation. Alternatively, incorporation of seismic base isolation is aimed at a momentous lessening of dynamic loads induced by the earthquake at the base of the structures themselves [3]. The seismic forces on the structures can be reduced if the fundamental period of the structure is lengthened or the energy dissipating capability is increased. Therefore, the seismic isolation is a promising alternative for earthquake resistant design of structures [4]. A range of isolation devices including elastomeric bearing, lead rubber bearing, frictional/sliding bearings have been developed and used in design of buildings and bridges during the last 20 years in many countries such as New Zealand, Japan, USA and UK, etc [5]. The lead rubber bearing is most commonly used base isolation system. The bearing is very stiff and strong in the vertical direction, but flexible in the horizontal direction. These bearings are multilayered, laminated elastomeric bearings that have one or more circular holes. Lead plugs are inserted into these holes to add damping to the isolation system. Several researchers have attempted to study the performance and most favorable design parameter for seismic isolated strictures with different isolators [6]. 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. Preliminary exploration for suitability of incorporating isolator has been done with equivalent static analysis. The dynamic analysis has been performed to satisfy the structural limitation executing different comparative contribution. The analysis and design of isolators for eight-storeyed residential steel building in Mandalay are performed first. Design parameters of isolators for this building have been evaluated. Base shear, storey drift, story displacement and storey acceleration are also compared for the cases. Finally, damage cost savings through using isolators for the buildings have been evaluated. The specific objectives of the study are (i) to evaluate the effect of the isolators based on various of rubber properties, (ii) to compare the seismic performance of structures with fixed

base and isolated bases at design basic earthquake (DBE) and maximum considered earthquake (MCE) events, (iii) to describe the feasibility and damage cost effectives of implementing base isolation based on the benefits of implementing base isolation.

2. Types of Myanmar rubber

Type description for ribbed smoked sheet rubber grades are:

1. RSS-1. Standard Quality Ribbed Smoked Sheets
2. RSS-2. Good Fair Average Quality Ribbed Smoked Sheets
3. RSS-3. Fair Average Quality Ribbed Smoked Sheets
4. RSS-4. Low Fair Average Quality Ribbed Smoked Sheets
5. RSS-5. Inferior Fair Average Quality Ribbed Smoked Sheets

2.1. RSS-1. Standard quality ribbed smoked sheets

The rubber must be dry, clean, strong, sound and free from blemishes, resinous matter (rust) blisters, sand and other foreign matter, small pinhead bubbles, if scattered are permissible. Oxidized sports or streaks, weak, heated, under cured, over-smoked, opaque and burnt sheets are not permissible.

2.2. RSS-2. Good fair average quality ribbed smoked sheets

The rubber must be dry, clean, strong, sound and free from blemishes, blisters and sand, dirty packing and all other foreign matters other than that specified below. Slight rust and slight amount of dry mould not more than 5% of the bales sampled are permissible. Small bubbles and slight specks of bark, if scattered are permissible. Oxidized spots or streaks, weak, heated, under cured, over smoked, opaque and burnt sheets are not permissible.

2.3. RSS-3. Fair average quality ribbed smoked sheets

The rubber is dry, clean, strong, sound and free from blemishes, blisters and sand, dirty packing and all other foreign matters, except to the extent specified below. Slight rust and slight amount of dry mould not more than 10% of the bales sampled are permissible. Slight blemishes in colour, small bubbles and small specks of bark may be present. Oxidized spots or streaks, weak, heated, under curved, over smoked, opaque and burnt sheets are not permissible.

2.4. RSS-4. Low fair average quality ribbed smoked sheets

The rubber is dry, clean, strong, sound and free from blemishes, blisters and sand, dirty packing and all other foreign matters, except to the extent specified below. Slight rust and slight amount of dry mould not more than 20% of the bales sampled are permissible. Medium sized bark particles, bubbles, translucent stains, slightly sticky and slightly over-smoked rubber are permissible but would not be evident to a marked degree. Oxidized spots or streaks, weak, heated, under curved, over smoked, opaque and burnt sheets are not permissible.

2.5. RSS-5. Inferior fair average quality ribbed smoked sheets

The rubber is dry, clean, firm and free from blemishes, blisters and sand, dirty packing and all other foreign matters, except to the extent specified below. Slight rust and slight amount of dry mould not more than 30% of the bales sampled are permissible. Large bark particles, bubbles and small blisters, stains, small blemishes, over-smoked and slightly sticky rubber are permissible but would not be present to a marked degree. Slightly under curved rubber is also permissible. Oxidized spots or streaks, weak, heated, under curved, over smoked, opaque and burnt sheets are not permissible.

Myanmar lead rubber bearings are expected to be widely used in Myanmar. In this study, the RSS-1and RSS-3 types Myanmar lead rubber bearings are studied. The required experimental tests are conducted to determine the properties of the materials in Rubber Research Development Centre. The Japan rubber properties for different types of specimens are shown in table 1. The experimental test results of Myanmar rubber properties for different types of specimens are shown in table 2.

Table 1: Properties of Japan rubber

Type	Rubber IRHD	Hardness	Young's Modulus E (kip/ft^2)	Shear Modulus G (kip/ft^2)	Elongation at Break (%)
Japan	55		67.868	16.915	500
	60		92.927	22.136	400

Table 2: Test results for properties of Myanmar rubber

Type	Rubber IRHD	Hardness	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-3	55		23.492	5.855	463
	60		39.154	9.327	412

3. Structural model

A model of 96 ft length and 60 ft width eight-storeyed building is created with steel columns and beams as represented in figure 1. The steel superstructure has a lateral system of special moment frames (SMF) in both the transverse and longitudinal directions, and that structural system is used for the fixed base and isolated base buildings designed for this study. Building is assumed to be located in Mandalay area, and to be subjected to a 10% probability of exceedance in 50 years (10% in 50 years) seismic hazard corresponding to design basic earthquake (DBE) and a 2% probability of exceedance in 50 years (2% in 50 years) seismic hazard corresponding to maximum consider earthquake (MCE). According to Myanmar National Building Code

(MNBC), the mapped spectral accelerations for 0.2- and 1-s periods are taken as 2.01 g and 0.8 g, respectively. The response modification factors are taken as the value of 8 consistent with special moment frames structure. For all the buildings dynamic analysis for both response spectrum and nonlinear time history analysis have been performed.
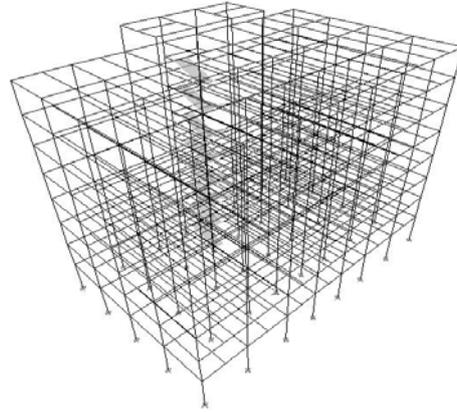

Figure 1: 3Dview of the proposed building

3.1. Design of isolators

The reaction loads obtained from the static analysis of fixed base building are divided into three groups. One isolator is designed of the most critical column load in buildings. The properties of the designed isolators are shown in the table 3, table 4 and table 5. The main parameters are the vertical stiffness (K_v), effective stiffness (K_{eff}), effective damping (D_{eff}), isolator diameter (D_i), lead core diameter (d), height of the isolator (H) and the number of layers (n).

Table 3: Properties of the designed lead rubber bearing (Japan Rubber)

Japan (JRB)	K_v (k/in)	K_{eff} (k/in)	D_{eff} (%)	D_i (in)	d (in)	H (in)	n
LBR1	2342.27	5.56532	18.982	16	3.5	25.4087	54
LBR2	3302.97	8.01205	18.982	19	3.5	22.7557	45
LBR3	5270.12	11.0421	18.982	24	3.5	20.6186	36

Table 4: Properties of the designed lead rubber bearing for RSS-1 (Myanmar Rubber)

RSS-1	K_v (k/in)	K_{eff} (k/in)	D_{eff} (%)	D_i (in)	d (in)	H (in)	n
LBR1	2273.82	5.56532	18.982	16	3.5	25.4087	54
LBR2	3206.44	8.01205	18.982	19	3.5	22.7557	45
LBR3	5116.09	11.0421	18.982	24	3.5	20.6186	36

Table 5: Properties of the designed lead rubber bearing for RSS-3 (Myanmar Rubber)

| RSS-3	K_v (k/in)	K_{eff} (k/in)	D_{eff} (%)	D_i (in)	d (in)	H (in)	n
LBR1	2409.42	5.56532	18.982	25	3.5	19.3033	35
LBR2	3469.56	8.01205	18.982	30	3.5	18.74	29
LBR3	4722.46	11.0421	18.982	35	3.5	18.5033	25

Diameters of RSS-3 are greater 1.53 times than diameters of JRB while diameters of RSS-1 and JRB are the same in the case of IRHD 60 are shown in table 3, table 4 and table 5. Size of bearing depends on the variability of rubber properties. Size of bearing also changes especially vertical stiffness of bearing but remaining unchanged the analysis properties of bearing.

4. Analysis phase results and discussions.

The response spectrum analysis results on base shear, storey drift, storey acceleration, structural period of fixed base and isolated base buildings are compared as shown in figure 2 to 4 and table 6. 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 figure 5 to 16.

4.1. Comparison of base shear for different types of base condition

Figure 2 shows comparison of base shear for different types of building, both X and Y direction respectively.
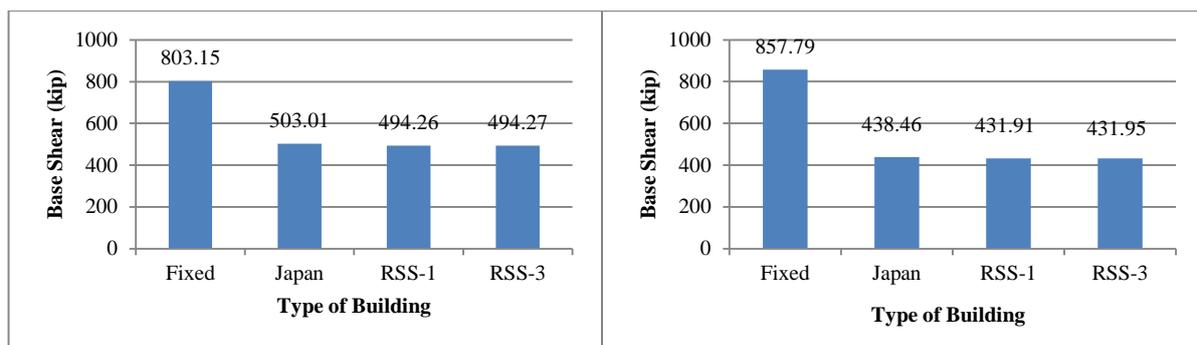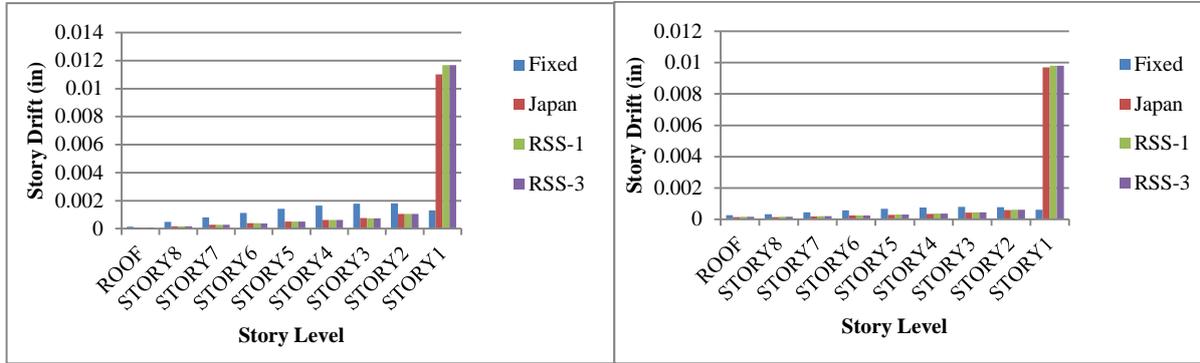

(a) X direction (b) Y direction

Figure 2: comparison of base shear for Fixed, Japan, RSS-1 and RSS-3

From the comparison above figure 2, it can be seen that the reduction of base shear is 300.14 kip for JRB, 308.89 kip for RSS-1 and 308.88 kip for RSS-3 in X direction and 419.33 for JRB, 425.88 kip for RSS-1 and 425.84 kip for RSS-3 in Y direction than fixed base.

4.2. Comparison of storey drift for different types of base condition

Figure 3 shows comparison of storey drift for different types of building, both X and Y direction respectively.
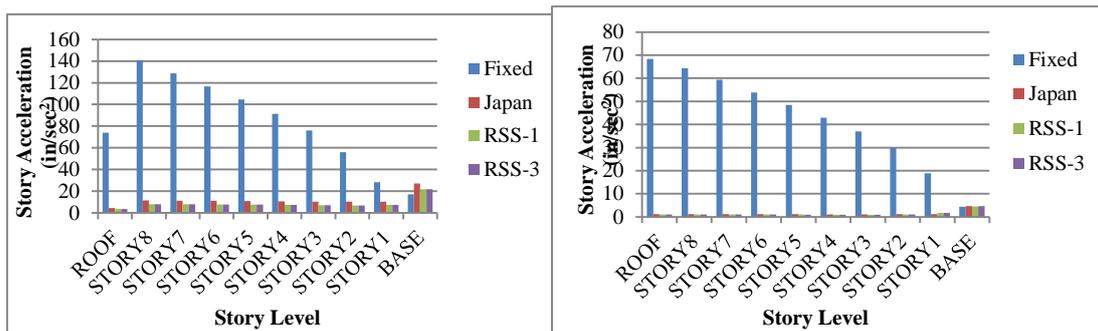

(a) X direction

(b) Y direction

Figure 3: comparison of story drift for Fixed, Japan, RSS-1 and RSS-3

From the above figure 3, it is shown that the story drift in X and Y direction at the top floor are reduced 49.65%, 50.74% for JRB isolated modal, 48.252 %, 41.852% for RSS-1 isolated modal and 48.252 %, 42.222% for RSS-3 isolated modal than fixed base model.

4.3. Comparison of storey acceleration for different types of base condition

Figure 4 shows comparison of storey acceleration for different types of building, both X and Y direction respectively.

(a) X direction

(b) Y direction

Figure 4: comparison of story acceleration for Fixed, Japan, RSS-1 and RSS-3

From the above figure 4, it can be seen that the acceleration in X and Y direction at the top floor are reduced 93.0843%, 98.333% for JRB isolated model in comparison with the fixed base model and the same are 95.179%, 98.525% for RSS-1 isolated model, 95.215%, 98.551% for RSS-3 isolated model in comparison with the fixed base model.

354

4.4. Comparison of structural period for different types of base condition

Structural period of fixed base and base isolated structure using lead rubber bearing are compared. Structural period for all cases is compared and shown in table 6. Structural period increases in the base isolated structures.

Table 6: Comparison of structural period for JRB, RSS-1, RSS-3 and Fixed base condition

Fixed(second)	JRB(second)	RSS-1(second)	RSS-3(second)
0.6376	1.4455	1.4595	1.4593

The structural period more increases 0.82079 seconds in JRB, 0.8219 seconds in RSS-1 and 0.8217 seconds in RSS-3 in comparison with the fixed base condition. The structural period more increases 0.014 seconds in RSS-1 and 0.0138 seconds in RSS-3 than JRB isolated modal is shown in table 6.

4.5. Overview of performance results for various isolators (Response spectrum analysis)

The base shears of RSS-1 and RSS-3 isolated model are 1.7395% and 1.7375% in X direction and 1.4938 % and 1.4847 % in Y direction less than that of JRB isolated model. In X direction, the reduction in the story drift at the top floor is 2.703% for JRB isolated model in comparison with either RSS-1 and RSS-3 isolated model, otherwise the bottom floors are 5.674% and 5.69% for JRB isolated model in comparison with RSS-1 and RSS-3 isolated model. In Y direction, the reduction in story drift are 15.287% and 14.744% at the top floor for JRB isolated modal and 1.07% and 1.06% at bottom floor for JRB isolated modal in comparison with RSS-1 and RSS-3 isolated modal. The story acceleration of JRB isolated model is greater than RSS-1and RSS-3 isolated model in X and Y direction. The increasing of structural period is 0.97% for RSS-1 and 0.95% for RSS-3 in comparison with JRB isolated modal.

4.6. Comparison of story drift for different ground motion (DBE) of Fixed and RSS-1

Figure 5 shows storey drift for different ground motion at DBE level for different types of base condition both X and Y direction respectively.
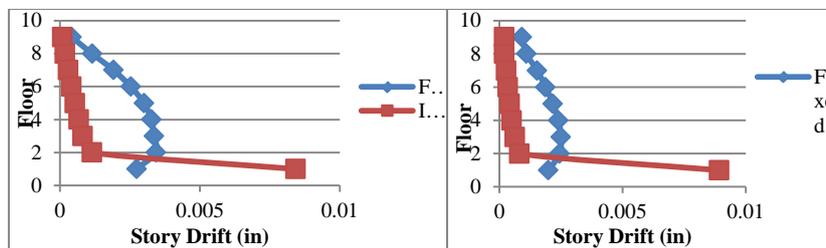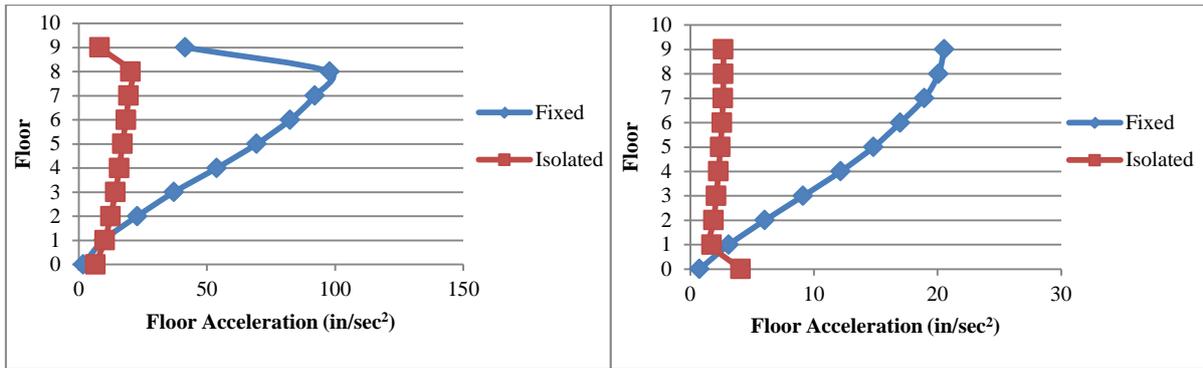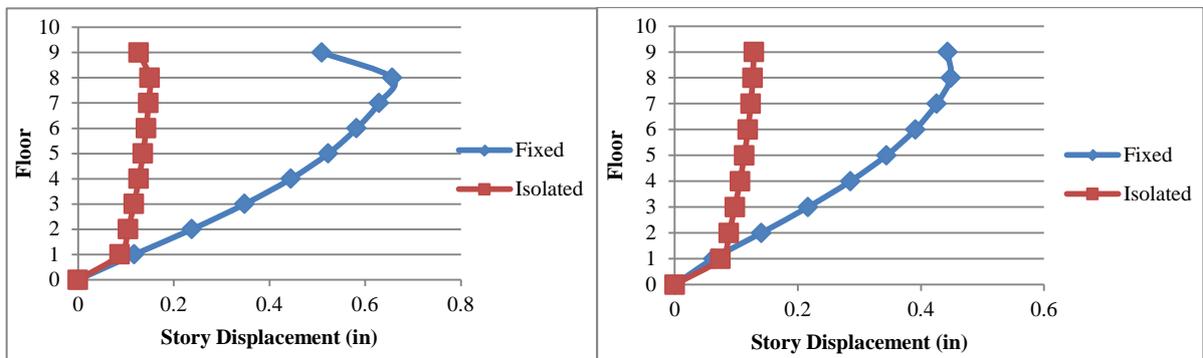

(a) X direction   (b) Y direction

Figure 5: comparison of story drift for Fixed and RSS-1

From the above figure 5, it can be seen that 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.

4.7. Comparison of story acceleration for different ground motion (DBE) of Fixed and RSS-1

Figure 6 shows storey acceleration for different ground motion at DBE level for different types of base condition both X and Y direction respectively.

(a) X direction   (b) Y direction

Figure 6: comparison of story acceleration for Fixed and RSS-1

From the above figure 6, 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% isolated model in comparison with fixed base model in Y direction.

4.8. Comparison of story displacement for different ground motion (DBE) of Fixed and RSS-1

Figure 7 shows storey displacement for different ground motion at DBE level for different types of base condition both X and Y direction respectively.

(a) X direction   (b) Y direction

Figure 7: comparison of story displacement for Fixed and RSS-1

From the above figure 7, 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.

4.9. Comparison of story drift for different ground motion (MCE) of Fixed and RSS-1

Figure 8 shows storey drift for different ground motion at MCE level for different types of base condition both X and Y direction respectively.
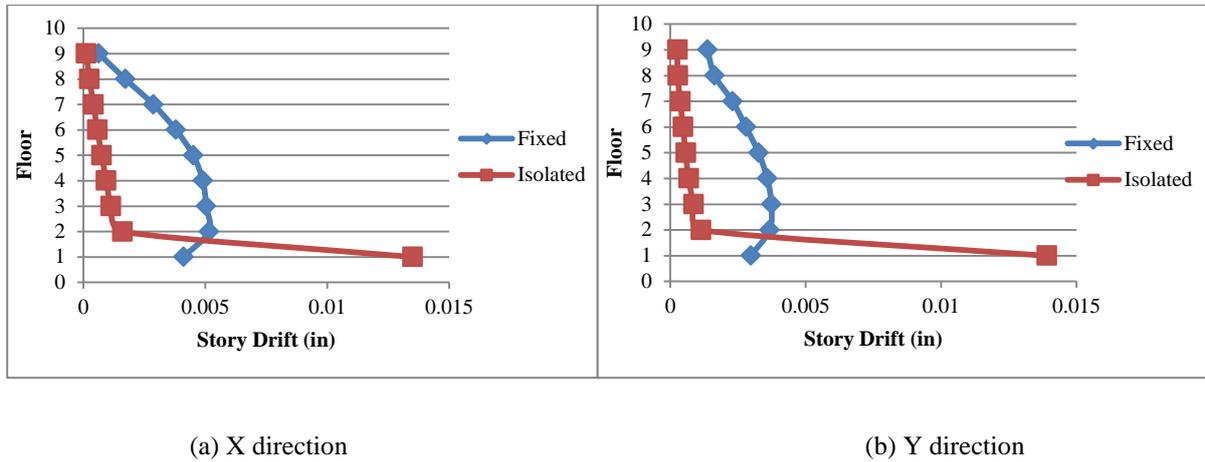

(a) X direction   (b) Y direction

Figure 8: comparison of story drift for Fixed and RSS-1

From the above figure 8, it can be seen that 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.

4.10. Comparison of story acceleration for different ground motion (MCE) of Fixed and RSS-1

Figure 9 shows storey acceleration for different ground motion at MCE level for different types of base condition both X and Y direction respectively.
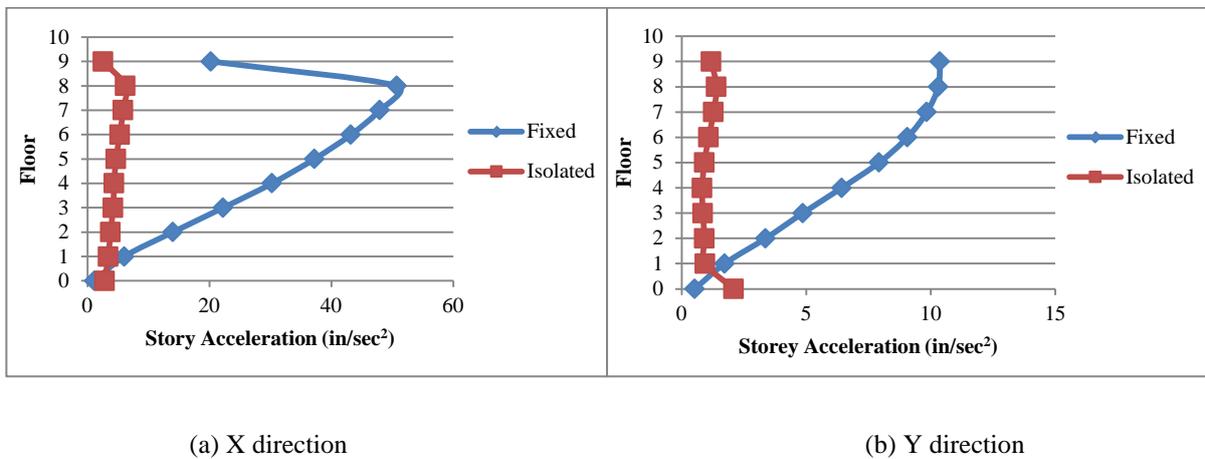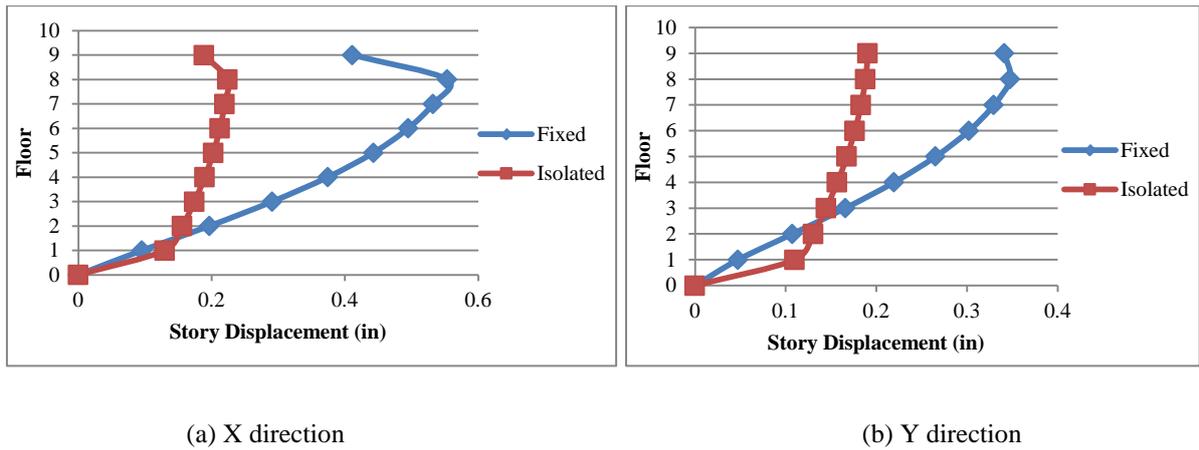

(a) X direction   (b) Y direction

Figure 9: comparison of story acceleration for Fixed and RSS-1

From the above figure 9, it can be seen that in X direction, the reduction in the acceleration at the top floor is 87.3761% for isolated model in comparison with fixed base model. While the reduction in the acceleration at the top floor is 88.56% isolated model in comparison with fixed base model in Y direction.

4.11. Comparison of story displacement for different ground motion (MCE) of Fixed and RSS-1

Figure 10 shows storey displacement for different ground motion at MCE level for different types of base condition both X and Y direction respectively.

(a) X direction   (b) Y direction

Figure 10: comparison of story displacement for Fixed and RSS-1

From the above figure 10, it can be seen that in X and Y direction, the reduction in displacements are 54.139% and 44.155% at the top floor for isolated model in comparison with the top floor for fixed base model.

4.12. Comparison of story drift for different ground motion (DBE) of Fixed and RSS-3

Figure 11 shows storey drift for different ground motion at DBE level for different types of base condition both X and Y direction respectively.
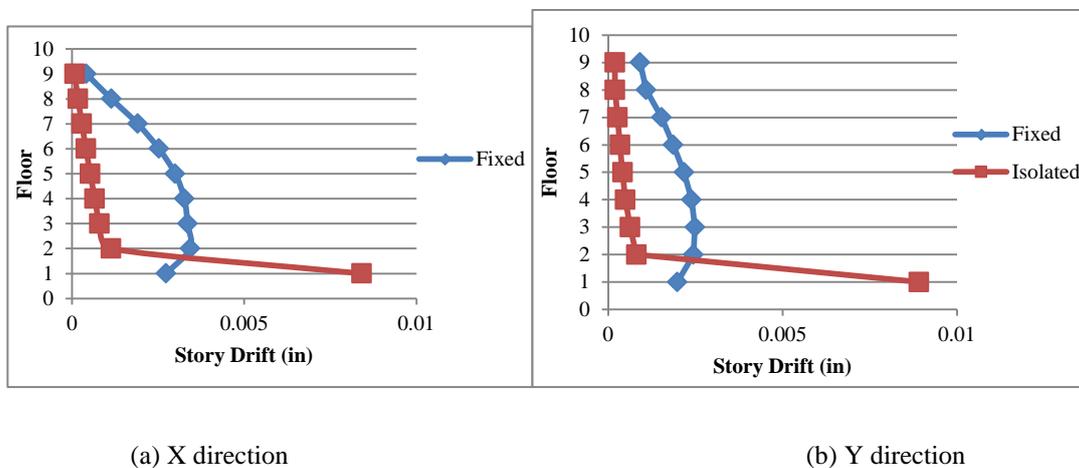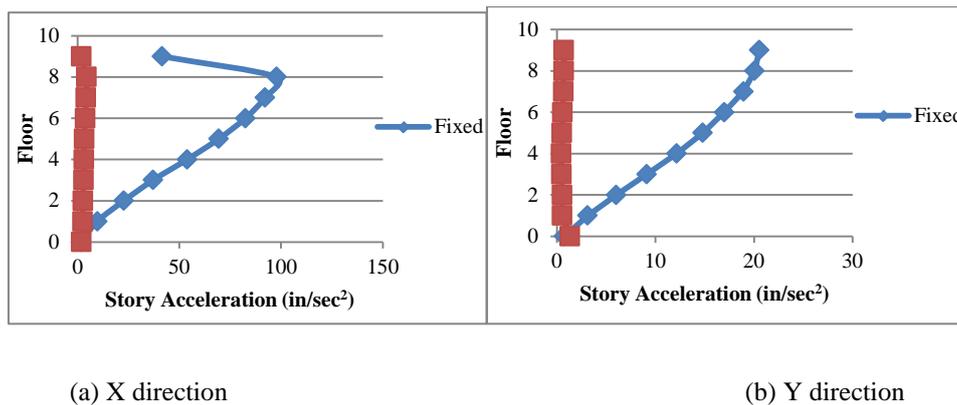

(a) X direction   (b) Y direction

Figure 11: comparison of story drift for Fixed and RSS-3

From the above figure 11, 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 floors. The average reduction in storey drift is 42.662% in X direction while 27.491% in Y direction for isolated model in comparison with the fixed base model.

4.13. Comparison of story acceleration for different ground motion (DBE) of Fixed and RSS-3

Figure 12 shows storey acceleration for different ground motion at DBE level for different types of base condition both X and Y direction respectively.

(a) X direction   (b) Y direction

Figure 12: comparison of story acceleration for Fixed and RSS-3

From the above figure 12, it can be seen that in X direction, the reduction in the acceleration at the top floor is 95.73% for isolated model in comparison with fixed base model. While the reduction in the storey acceleration at the top floor is 96.516% isolated model in comparison with fixed base model in Y direction.

4.14. Comparison of story displacement for different ground motion (DBE) of Fixed and RSS-3

Figure 13 shows storey displacement for different ground motion at DBE level for different types of base condition both X and Y direction respectively.
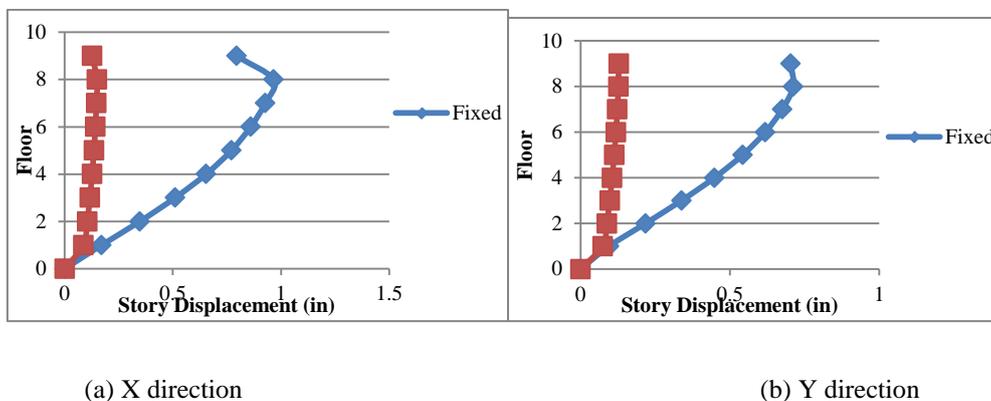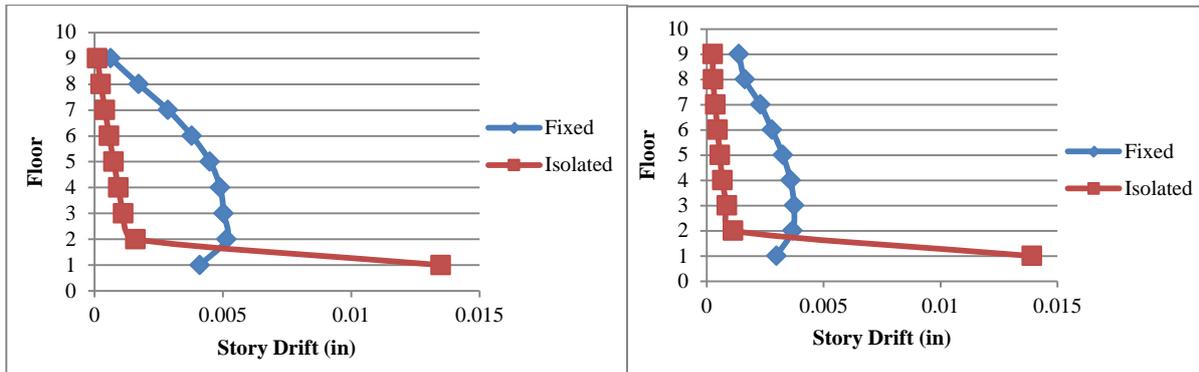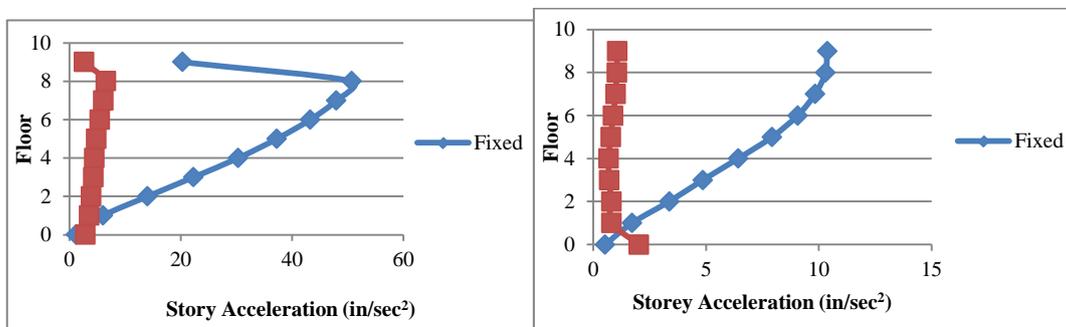

(a) X direction   (b) Y direction
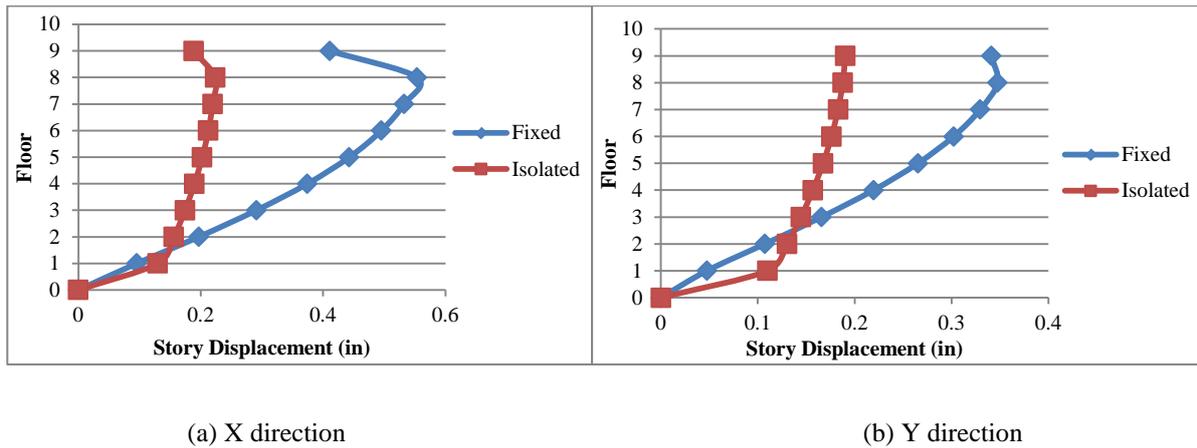
Figure 13: comparison of story displacement for Fixed and RSS-3

From the above figure 13, it can be seen that in X and Y direction, the reduction in displacements are 84.027% and 81.788% at the top floor for isolated model in comparison with top floor for the fixed base model.

4.15. Comparison of story drift for different ground motion (MCE) of Fixed and RSS-3

Figure 14 shows storey drift for different ground motion at MCE level for different types of base condition both X and Y direction respectively.

(a) X direction   (b) Y direction

Figure 14: comparison of story drift for Fixed and RSS-3

From the above figure 14, 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 floors. The average reduction in storey drift is 41.223% in X direction while 26.963% in Y direction for isolated model in comparison with the fixed base model.

4.16. Comparison of story acceleration for different ground motion (MCE) of Fixed and RSS-3

Figure 15 shows storey acceleration for different ground motion at MCE level for different types of base condition both X and Y direction respectively.

(a) X direction   (b) Y direction

Figure 15: comparison of story acceleration for Fixed and RSS-3

From the above figure 15, it can be seen that in X direction, the reduction in the acceleration at the top floor is 86.98% for isolated model in comparison with fixed base model. While the reduction in the storey acceleration at the top floor is 89.709% isolated model in comparison with fixed base model in Y direction.

4.17. Comparison of story displacement for different ground motion (MCE) of Fixed and RSS-3

Figure 16 shows storey displacement for different ground motion at MCE level for different types of base condition both X and Y direction respectively.

(a) X direction   (b) Y direction

Figure 16: comparison of story displacement for Fixed and RSS-3

From the above figure 16, it can be seen that in X and Y direction, the reduction in displacements are 54.161% and 44.241% at the top floor for isolated model in comparison with the top floor for fixed base model.

4.18. Overview of performance results for RSS-1 and RSS-3 (Nonlinear Time History Analysis)

The average reduction in storey drift is 0.1224% in X direction while 0.1233% in Y direction for RSS-3 isolated model in comparison with the RSS-1 isolated model at DBE seismic demand levels. In X direction, the storey acceleration is average reduced 0.2149% for RSS-3 and 2.3082% in Y direction in comparison with the RSS-1 isolated model. In X and Y direction, the average reduction in displacements are 0.0341% and 0.0574% for RSS-3 isolated model in comparison with the RSS-1 isolated model. The average reduction in storey drift is 0.0937% in X direction while 0.1457% in Y direction for RSS-3 isolated model in comparison with the RSS-1 isolated model at MCE seismic demand levels. In X direction, the storey acceleration is average increased 3.0868 % for RSS-3 isolated model in comparison with the RSS-1 isolated model and 14.8963% in Y direction. In X and Y direction, the average reduction in displacements are 0.0361% and 0.0609% for RSS-3 isolated model in comparison with the RSS-1 isolated model.

5. Performance phase results and discussions

In the performance assessment phase, the floor accelerations and interstorey drifts obtained from the nonlinear time history analyses in the analysis phase are used to assess the seismic performance of the structures via

fragility cures and FEMA P-58 (Federal Emergency Management Agency) are used to compute probable damage costs, repaired time and rate of injuries for each base condition and seismic demand level and the results are compared.

5.1. Comparison of damage cost for DBE Fixed Base and RSS-1 Isolated Base

The figure 17 shows damage cost for different types of base condition at DBE level of seismic demands.
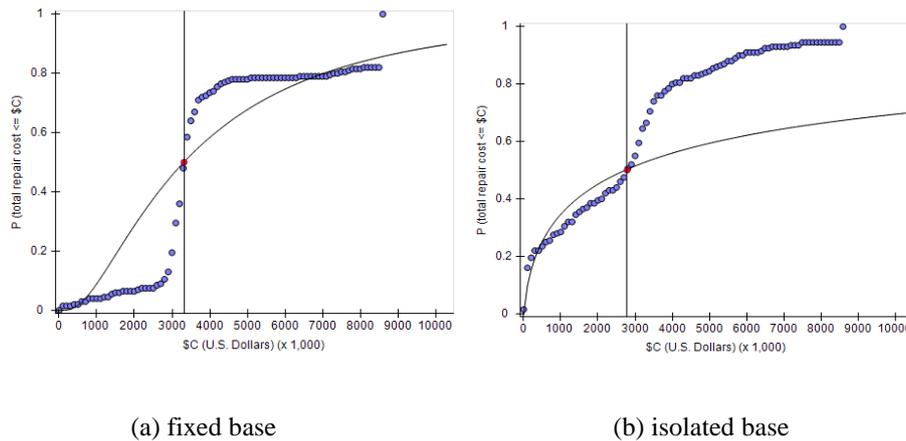

(a) fixed base   (b) isolated base

Figure 17: damage cost result for DBE Fixed and RSS-1

Figure 17 illustrates the probability of the fixed base and RSS-1 isolated base apartment buildings incurring damage costs for DBE level seismic events. The X-axis shows the damage costs inthousands of dollars and the Y-axis gives the probability of repair costs not surpassing the given damage costs. Accordingly, the fixed base and the isolated base buildings have 50% probability of incurring $3.2 million and $2.78 million in damage costs when subjected to DBE level seismic events.

5.2. Comparison of repair time for DBE Fixed Base and RSS-1 Isolated Base

The figure 18 shows repair time for different types of base condition at DBE level of seismic demands.
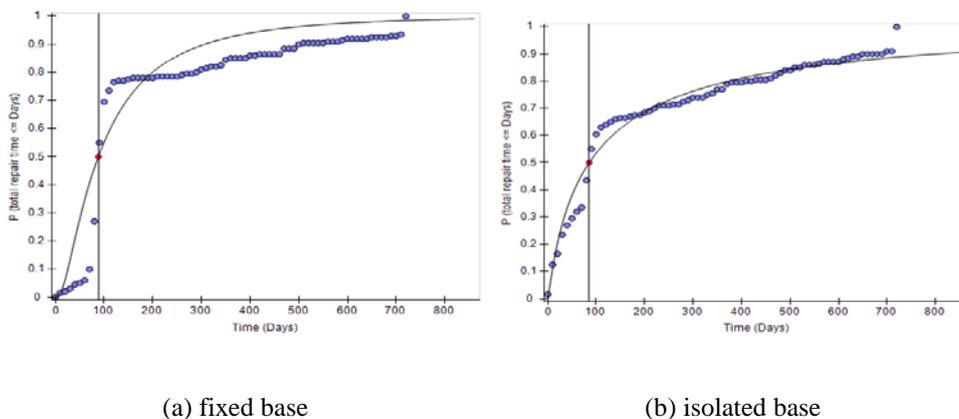

(a) fixed base   (b) isolated base

Figure 18: repair time result for DBE Fixed and RSS-1

The probability of repair time being incurred for the fixed base and the isolated base buildings subjected to DBE level of seismic demands are 89 and 86 days as shown in figure 18.

5.3. Comparison of injuries for DBE Fixed Base and RSS-1 Isolated Base

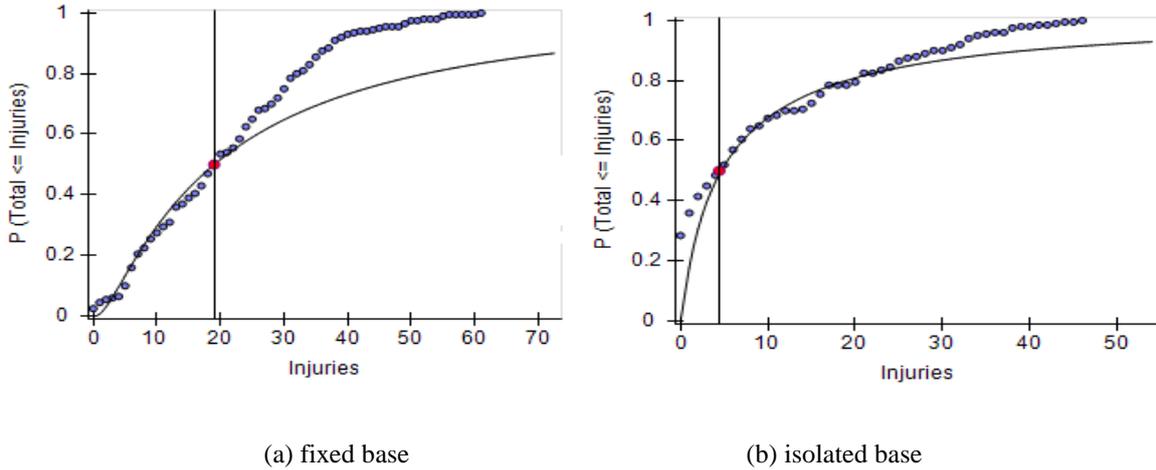The figure 19 shows injuries for different types of base condition at DBE level of seismic demands.

(a) fixed base   (b) isolated base

Figure 19: injuries result for DBE Fixed and RSS-1

When subject to DBE level seismic events, the fixed base and the isolated base apartment building have 50% probability of incurring 19 and 5 injuries respectively as shown in figure 19.

5.4. Comparison of damage cost for MCE Fixed Base and RSS-1 Isolated Base

The figure 20 shows damage cost for different types of base condition at MCE level of seismic demands.
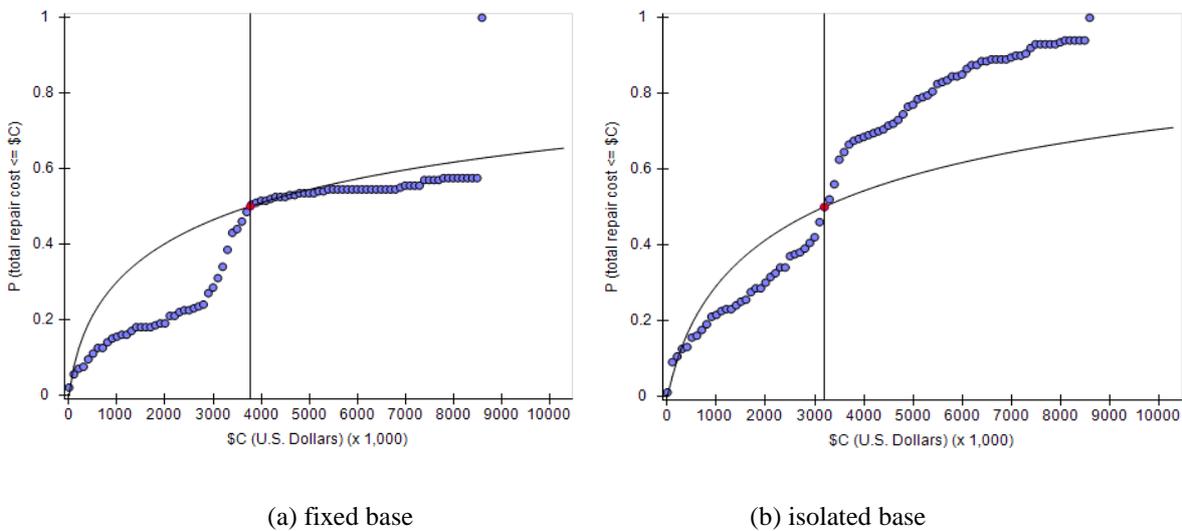

(a) fixed base   (b) isolated base

Figure 20: damage cost result for MCE Fixed and RSS-1

The fixed base and the isolated base buildings have a 50% probability of incurring $3.78 million and $3.13 million in damage costs when subjected to MCE level seismic events as shown in figure 20.

5.5. Comparison of repair time for MCE Fixed Base and RSS-1 Isolated Base

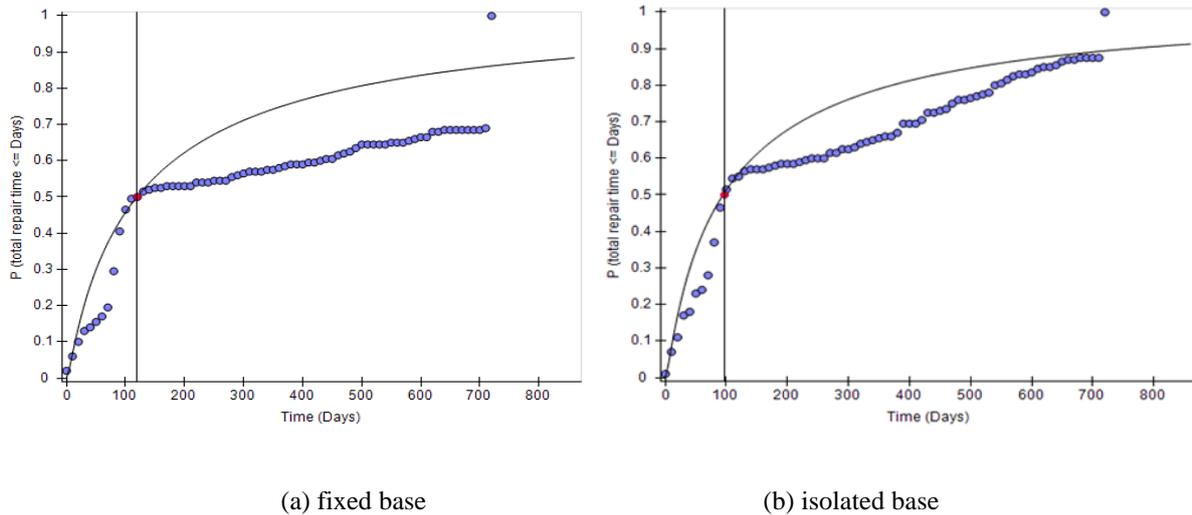The figure 21 shows repair time for different types of base condition at MCE level of seismic demands.

(a) fixed base   (b) isolated base

Figure 21: repair time result for MCE Fixed and RSS-1

The probability of repair time being incurred for the fixed base and the isolated base buildings subjected to MCE level of seismic demands are 120 and 97 days.as shown in figure 21.

5.6. Comparison of injuries for MCE Fixed Base and RSS-1 Isolated Base

The figure 22 shows repair time for different types of base condition at MCE level of seismic demands.

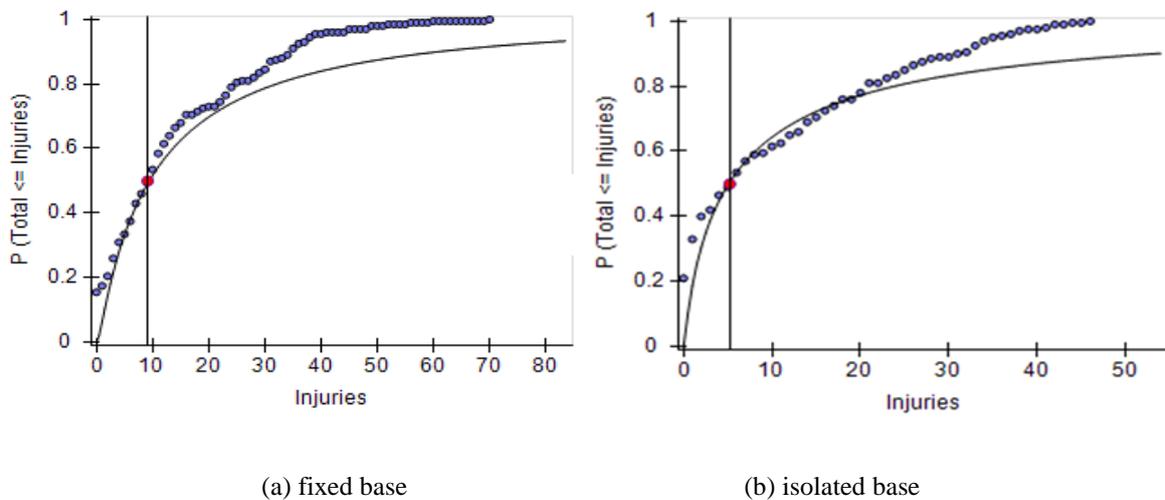(a) fixed base   (b) isolated base

Figure 22: injuries result for MCE Fixed and RSS-1

When subject to MCE level seismic events, the fixed base and the isolated base apartment building have 50% probability of incurring 10 and 6 injuries respectively as shown in figure 22**.**

5.7. Comparison of damage cost for DBE Fixed Base and RSS-3 Isolated Base

The figure 23 shows damage cost for different types of base condition at DBE level of seismic demands.
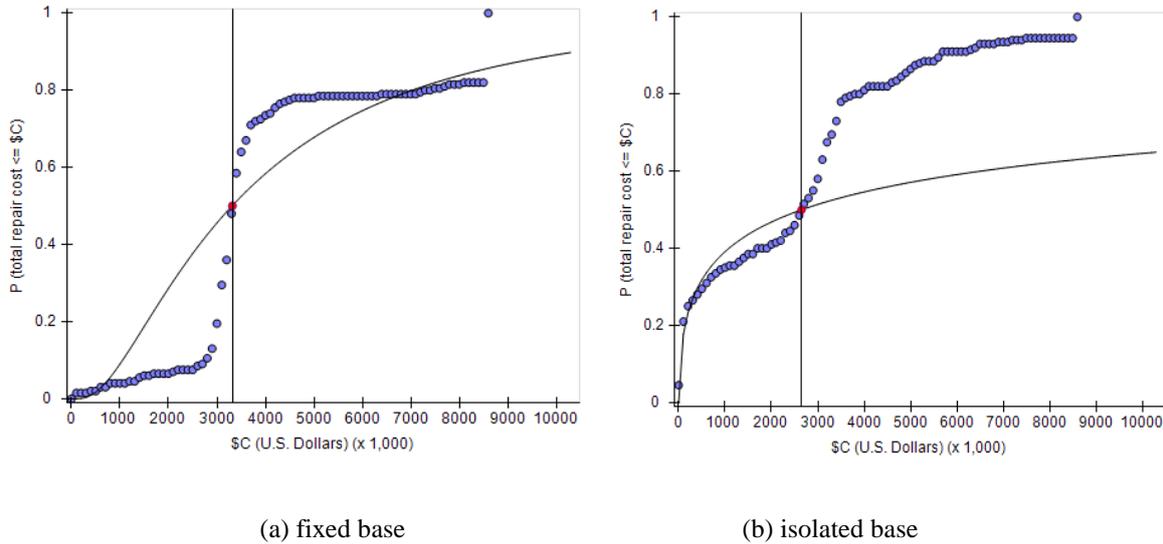

(a) fixed base   (b) isolated base

Figure 23: damage cost result for DBE Fixed and RSS-3

The fixed base and the isolated base buildings have a 50% probability of incurring $3.32 million and $2.65 million in damage costs when subjected to DBE level seismic events are shown in figure 23.

5.8. Comparison of repair time for DBE Fixed Base and RSS-3 Isolated Base

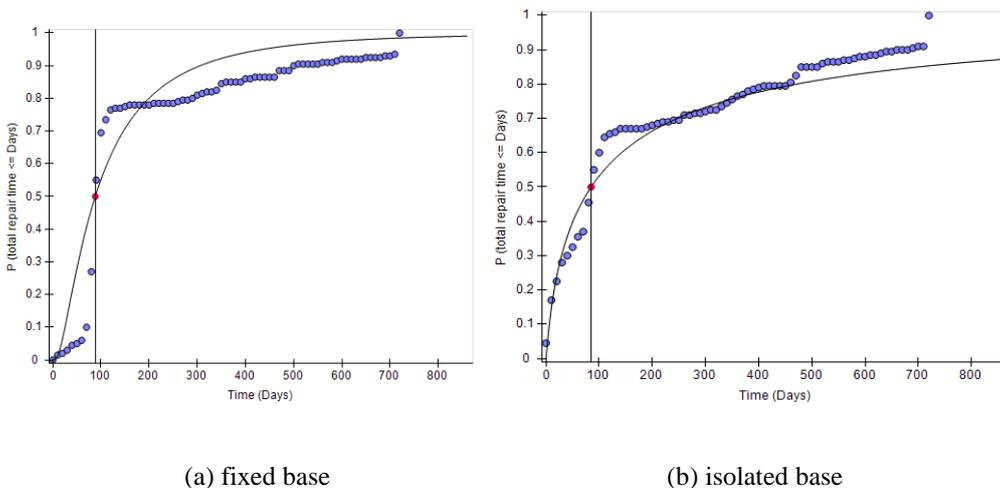The figure 24 shows repair time for different types of base condition at DBE level of seismic demands.

(a) fixed base   (b) isolated base

Figure 24: repair time result for DBE Fixed and RSS-3

The probability of repair time being incurred for the fixed base and the isolated base buildings subjected to DBE level of seismic demands are 89 days and 85 days as shown in figure 24.

5.9. Comparison of injuries for DBE Fixed Base and RSS-3 Isolated Base

The figure 25 shows injuries for different types of base condition at DBE level of seismic demands.
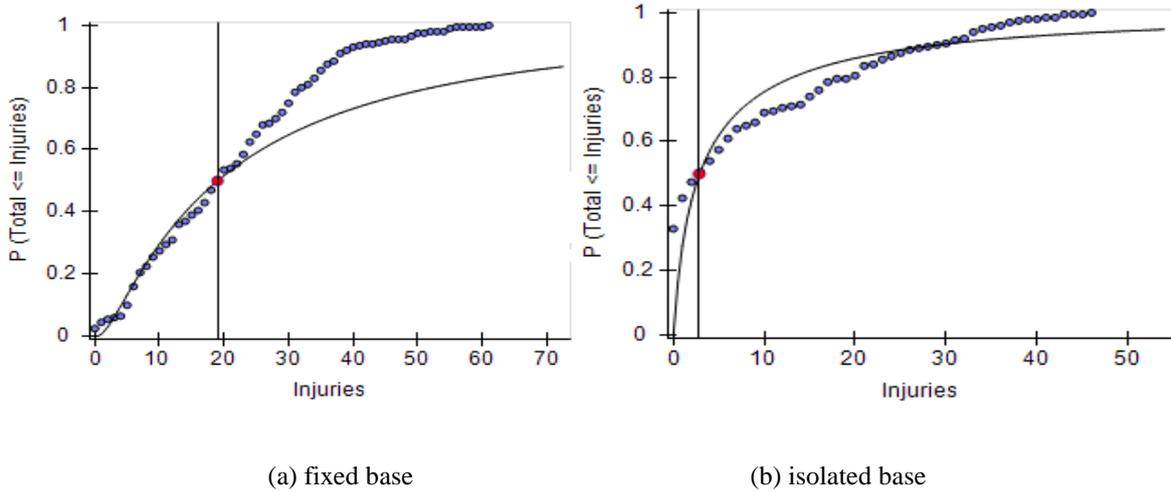

(a) fixed base   (b) isolated base

Figure 25: injuries result for DBE Fixed and RSS-3

When subject to DBE level seismic events, the fixed-base and the isolated base apartment building have 50% probability of incurring 19 and 3 injuries respectively are shown in figure 25.

5.10. Comparison of damage cost for MCE Fixed Base and RSS-3 Isolated Base

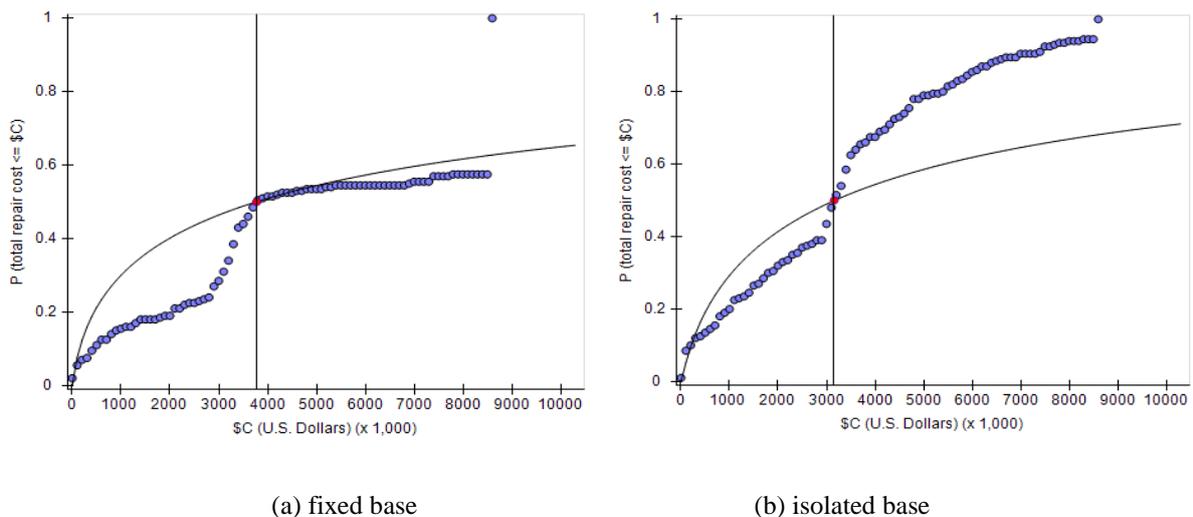The figure 26 shows damage cost for different types of base conditionatMCE level of seismic demands.

(a) fixed base   (b) isolated base

Figure 26: damage cost result for MCE Fixed and RSS-3

The fixed base and the isolated base buildings have a 50% probability of incurring $3.78 million and $3.17 million in damage costs when subjected to MCE level seismic events are shown in figure 26.

5.11. Comparison of repair time for MCE Fixed Base and RSS-3 Isolated Base

The figure 27 shows repair time for different types of base condition at MCE level of seismic demands.
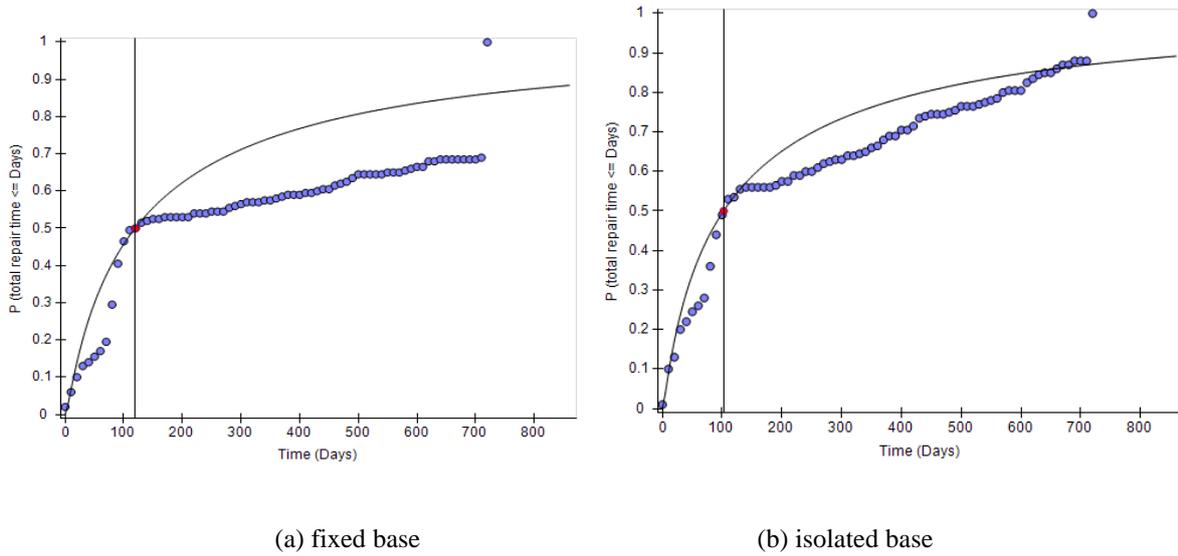

(a) fixed base   (b) isolated base

Figure 27: repair time result for MCE Fixed and RSS-3

The probability of repair time being incurred for the fixed base and the isolated base buildings subjected to MCE level of seismic demands are 120 and 103 days as shown in figure 27.

5.12. Comparison of injuries for MCE Fixed Base and RSS-3 Isolated Base

The figure 28 shows injuries for different types of base condition at MCE level of seismic demands.
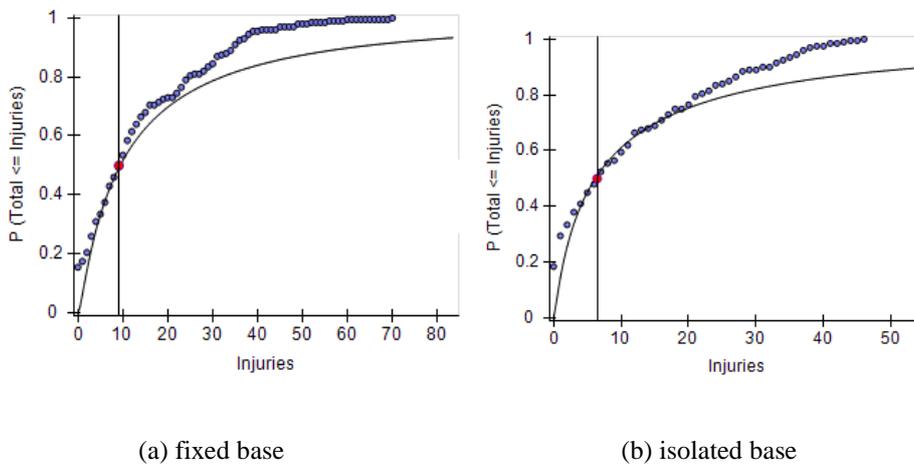

(a) fixed base   (b) isolated base

Figure 28: injuries result for MCE Fixed and RSS-3

367

When subject to MCE level seismic events, the fixed base and the isolated base apartment building have 50% probability of incurring 10 and 7 injuries respectively are shown in figure 28.

The damage cost results of each building at seismic demand level for RSS-1and RSS-3 are summarized in the table 7 and table 8.

Table 7: Damage cost saving results for RSS-1

	DBE damage cost ($ Million)	MCE damage cost ($ Million)
Fixed	3.32	3.78
Isolated base	2.78	3.13
Saving	0.54	0.65

Table 8: Damage cost saving results for RSS-3

	DBE damage cost ($ Million)	MCE damage cost ($ Million)
Fixed	3.32	3.78
Isolated base	2.65	3.17
Saving	0.67	0.61

5.13. Comparison of damage cost, repair time and injuries for RSS-1 and RSS-3

RSS-1 isolated building occurred 16.27% reduction in damage cost at DBE levels and 17.2% reduction in damage cost at MCE levels than fixed base building. RSS- 3 isolated building occurred 20.18% reduction in damage cost at DBE levels and 16.4% reduction in damage cost at MCE levels than fixed base building. At DBE levels, the reduction in repair time is 3.37% in RSS-1 and 4.49% in RSS-3 while 19.17 in RSS-1 and 14.58% in RSS-3 isolated base structures compared with the fixed base structure at MCE levels. For the rate of injuries, RSS-1 reduces 73.68% while RSS-3 reduces 84.21% than that of fixed base structure. In comparison with the fixed base structure, RSS-1 and RSS-3 isolated structures reduces 42.773% and 26.94% in the rate of injuries at MCE levels.

There are five types of Myanmar rubber that can be used as major components of isolator. Among these types of rubber, RSS-1 and RSS-3 are used in this study. Other three types of Myanmar rubber should be used to resist earthquake.

6. Conclusion

In this research, the analysis and design of fixed base and isolated base (LRB) for eight-storyed steel buildings

in risk seismicity region has been carried out. The response spectrum analysis and time history analysis are used to evaluate structural responses of fixed base and isolated base buildings. Ground motion records for time history analysis are obtained from PEER ground motion database web site based on ASCE code spectrum. Size of RSS-3 are greater 1.533 times than size of RSS-1 according to the rubber properties. The saving in damage costs reported in this study are underestimated due to the number of components and fragility curves available in PACT. From the results of this study, the following conclusion can be drawn out;

1. As the structural responses of building using local rubber RSS-1 and RSS-3 are approximately equal to the responses of Japan rubber, they can be used major component of isolators.

2. RSS-3 isolated building provides lower damage cost than RSS-1 isolated building at DBE seismic demand levels.

3. RSS-3 reduces repair time and rate of injuries than RSS-1 at DBE seismic demand levels.

4. At MCE seismic demand levels, damage cost, repair time and rate of injuries are more reduced in RSS-1 than RSS-3.

5. Base isolation (Myanmar rubber) is found significantly effective mitigating and preventing for seismic performance of proposed building.

In comparison results, although at DBE levels, RSS-3 isolated model is reduced structural response than RSS-1 isolated model, at MCE levels, RSS-1 isolated model is more reduced storey acceleration than RSS-3 isolated model, depending on the size of isolators with rubber properties. Therefore, it can be clearly see that RSS-1 is more suitable for MCE seismic demand levels.

It is recommended that other types of lateral resisting system such as combine damping devices for superstructure and base isolators should be used to obtain the better structural performance of the structure.

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