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Research Article

A study on seismic isolation of building used LRB

Muhammet Yurdakul [a,*], Mehmet Burak Yıldız [a]

[a] *Department of Civil Engineering, Bayburt University, 69000 Bayburt, Turkey*

ABSTRACT

Base isolation system with lead rubber bearing (LRB) is commonly used to prevent structure against to damage of earthquake. Design of LRB system is detailed in this study. The isolated building with LRB design according to Uniform Building Code (UBC-97) and fixed building were examined. The six-storey building with LRB and fixed building were modelled in SAP2000 with the same dynamic loads. The relative floor displacement and internal forces of the seismic isolated and fixed building are compared. In addition, transverse and longitudinal reinforcement of any axis of seismic isolated and fixed building are compared. Analyse results showed that effectiveness of using seismic isolation system on building. The weight of longitudinal and transverse reinforcement of isolated building is smaller than fixed building about 36%, 40% respectively.

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1. Introduction

Earthquake is inevitable natural disaster which occurs unknown time and place. Detrimental effects of earthquake on building and decreasing these effects are most important issues in the world. There is some way to decrease these effects. Base isolation system is one of them. Use of base isolation system is decrease lateral load of earthquake. This give rise to less internal forces. So, smaller size elements and reinforcement are sufficed.

Base isolation systems basically are separated two types as sliding and rubber isolation system. The laminated rubber bearing system is commonly used isolation system among rubber isolation systems. There are several studies on effectiveness of LRB system in literature. Su et al. (1989) carried out a comparative study of effectiveness of various base isolation systems. One of them is laminated rubber bearing. Analyses results show that base isolators can significantly reduce the acceleration transmitted to the superstructure. Tavakoli et al. (2015) evaluated the effect of LRB system to increase the resistance of structures against progressive collapse. Authors used concrete moment resisting frames in both the fixed and base isolated model structures. The analyses results showed that push down analysis is dependent on location of removal column and floor number of buildings. Liu et al. (2016) carried out a study of seismic isolation performance of prestressed concrete (PC) continuous beam bridge using lead rubber bearings. It was pointed out that use of rubber isolation system can effectively reduce the seismic damage to the bridge. Abadi and Adhami (2016) carried out improving the seismic behaviour of symmetrical steel structures under near field earthquake using a base isolation system with LRB isolator. The analysis results point out a significant reduce in the results of base shear, the acceleration and floors drift in the seismically isolated system in comparison with the fixed base structure. Nakhostin and Poursha (2017) attempted to extend the modal pushover analysis and the extended N2 (EN2) method to medium-rise base-isolated building frames with LRB to account for the effect of higher modes in predicting the seismic demands of these structures. It was observed from analyses results that N2 method with the PSC load distribution gives better estimates of the seismic demands for low rise base isolated frames. Reddy et al. (2017) examined effect of base isolation with LRB in multi-storeyed reinforced concrete building. Analysis results showed that period of the isolated structure longer than that of fixed structure. Base shear is significantly reduced as compared to fixed structure by using the isolators. Wu et al. (2018) conducted a study included compression shear properties of

* *Corresponding author.* Tel.: +90-458-211-1152 ; Fax: +90-458-211-1178 ; E-mail address: myurdakul@bayburt.edu.tr (M. Yurdakul)
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small size seismic isolation rubber bearings. Analyse results show that all the research methods can reveal the fundamental properties of the small size bearings. Tanwer et al. (2018) studied on different types of base isolation system over fixed based. Dynamic behaviour of seismic isolated with LRB and fixed were investigated. Habieb et al. (2019) compared fixed and isolated a masonry building with fiber reinforced elastomeric isolators. The study showed that the isolation system significantly reducing the damage level of the masonry building. Kumar and Petwala (2019) carried out a study included comparing of secondary system of isolated and fixed building. The analyses results showed that the base isolated building gives better performance. Shoaei and Mahsuli (2019) puts forward an approach to seismic design of isolated steel moment frame structures with LRB devices. The proposed approach is showcased for an example steel moment frame structure. Billah and Todorov (2019) evaluated the seismic performance of a base isolated bridge with LRB at subfreezing temperature. Analysis results point out that freezing condition may have a remarkably effect on the component fragility. There is a study to develop software for designing of steel reinforced elastomeric isolator according to American Association for State Highway and Transportation Officials Load and Resistance Factor Design (Atmaca and Ateş, 2017).

In generally, LRB system is used as an isolation device on building to against harmful of earthquake ground motion. There is no detailed study involving the design of LRB isolation system in the literature. This study may able to close this gap. Also, the cost efficiency of LRB system is investigated.

2. Material and Method

LRB bearing system was designed for Uniform Building Code (UBC-97) (Atmaca and Ateş, 2017) and used for seismic isolation system in this study. The UBC-97 regulation is based on the assumption that the displacement remains at the base isolation level and that the superstructure behaves rigidly. Therefore, the first vibration mode is important according to this regulation. UBC-97 is obliged to spectral analysis when the building was constructed on weak ground types of the building, the period of building is longer than 3 sec. under the maximum earthquake load and building height is higher than four floors or higher than 19.8 m. It is assumed that the selected building was built in Istanbul. Response spectrum analyses is carried out in SAP2000 (Atmaca and Ateş, 2017).

2.1. Selecting parameters to be used in UBC-97

Seismic isolator was used in the 1st earthquake zone in UBC-97. Effective ground acceleration, A_o, is 0.4. Therefore, seismic zone factor (Z) is selected as 4 from Table 1. Istanbul is located on zone 4 according to UBC-97.

It is assumed that selected building was built hard rock. The floor profile type is selected as S_A from Table 2.

Table 1. Seismic zone factor (UBC-97).

Zone	1	2A	2B	3	4
Z	0.075	0.15	0.20	0.30	0.40

Table 2. Soil profile type (UBC-97).

Soil Profile Type	Soil Profile Name/Generic Description	Average soil properties for top 100 feet (30 480 Mm) of soil profile		
		Shear Wave Velocity $\bar{v}_s$(m/s) feet/second (m/s)	Standard Penetration Test, $\bar{N}$ [or $\bar{N}_{CH}$ for cohesionless soil layers] (blows/foot)	Undrained Shear Strength $\bar{s}_u$ psf (kPa)
S_A	Hard Rock	>1500	-	-
S_B	Rock	760-1500	-	-
S_C	Very Dense Soil and Soft Rock	360-760	>50	>100
S_D	Stiff Soil Profile	180-360	15-50	50-100
S_E	Soft Soil Profile	<180	<15	<50
S_F	Soil Requiring Site-specific Evaluation.			

In UBC-97, seismic source type is classified as A, B and C according to the seismic risk of the fault lines. It is assumed that selected building was located in the first earthquake zone and close to the faults that may cause major earthquakes. So seismic source type A is selected from Table 3.

Since it is assumed to be distance to seismic source less than 2 km and seismic source type is A, near source factor (N_V) is selected as 2.0 from Table 4.

Seismic zone factor (Z), soil profile type and near source factor are selected as 0.4, S_A and 2, respectively. With these values, $0.32N_V$ is selected from Table 5. Since N_V is equal to 2, seismic coefficient (C_v) is calculated as 0.64.

Isolators with damping ratio of 10% are selected and damping coefficient is determined as 1.2 from Table 6.

Since the structural system of the building to which the isolation is to be applied is the frame system which transfers moment, Coefficient of Structural System Behaviour (R) coefficient is selected from Table 7.

Table 3. Soil source types (UBC-97).

Seismic Source Type	Seismic Source Description	Seismic Source Definition	
		Maximum Moment Magnitude (M)	Slip Rate, SR (mm/year)
A	Faults that are capable of producing large magnitude events and that have a high rate of seismic activity	$M \geq 7.0$	$SR \geq 5$
B	All faults other than Types A and C	$M \geq 7.0$ $M < 7.0$ $M \geq 6.5$	$SR < 5$ $SR > 2$ $SR < 2$
C	Faults that are not capable of producing large magnitude earthquakes and that have a relatively low rate of seismic activity	$M < 6.5$	$SR \leq 2$

Table 4. Near source factor (UBC-97).

Seismic Source Type	Closest Distance to Known Seismic Source			
	≤ 2 km	5 km	10 km	≥ 15 km
A	2.0	1.6	1.2	1.0
B	1.6	1.2	1.0	1.0
C	1.0	1.0	1.0	1.0

Table 5. Seismic coefficient (UBC-97).

Seismic Source Type	Seismic Zone Factor (Z)				
	Z=0.075	Z=0.15	Z=0.2	Z=0.3	Z=0.4
S_A	0.06	0.12	0.16	0.24	0.32 N_V
S_B	0.08	0.15	0.20	0.30	0.40 N_V
S_C	0.13	0.25	0.32	0.45	0.56 N_V
S_D	0.18	0.32	0.40	0.54	0.64 N_V
S_E	0.26	0.50	0.64	0.84	0.96 N_V
S_F	Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients for Soil Profile Type S_F				

Table 6. Damping coefficient (UBC-97).

Effective Damping (β_D, β_M)	(B_D, B_M)
≤ 2	0.8
5	1.0
10	1.2
20	1.5
30	1.7
40	1.9
≥ 50	2.0

Table 7. Coefficient of structural system behaviour (UBC-97).

Structural system	R_1	R
Frame transferred moment	2	8.5
Shear wall	2	5.5
Concentrically braced frame	1.6	5.6
Eccentrically braced frame	2	7

2.2. Building information to be used in design

Selected building to examine is given Fig. 1. The first vibration of the 6-storey building was determined as 0.6 sec. Targeted period is 1.8 sec. Two different LRB isolator are used in this study. These are type A and type B. Type A is supported 680 kN axial load and shear modulus is 0.65 MPa. 16 pieces of type A isolator were used in building. Type B is supported 1150 kN axial load and shear modulus is 1.00 MPa. 8 pieces of type B isolator were used in building. The total weight of the building (g + 0,3q) is 18700 kN.

2.3. Design of LRB

2.3.1. The minimum horizontal stiffness

The minimum horizontal stiffness, k_D, is calculated by Eq. (1) according to UBC-97.

$$k_D = \frac{4\pi^2 \times W}{T_D^{\,2} \times g} \tag{1}$$

where k_D is the minimum horizontal stiffness, W is axial load supported by isolator, T_D is target period and g is gravity acceleration. Minimum horizontal stiffness was calculated as 0.845 MN/m and 1.428 MN/m for type A and type B isolator by Eq. (1).

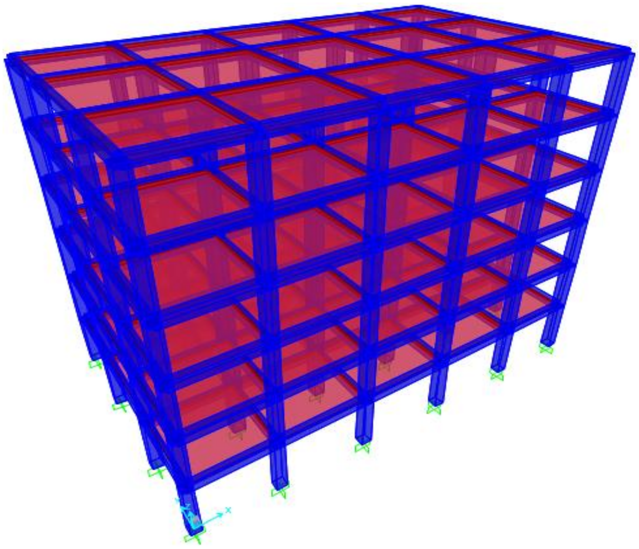

Fig. 1. 3D finite element model of the building used in the study.

2.3.2. Design displacement

The maximum displacement is calculated by Eq. (2).

$$D_D = \frac{g \times C_{vD} \times T_D}{B \times 4\pi^2} \tag{2}$$

where D_D is displacement, C_{VD} is coefficient of seismic and B is damping coefficient of isolator. Maximum displacement was calculated as 0.239 m by Eq. (2).

2.3.3. Calculation of isolator thickness

Isolators can make deformation up to 150% of its thickness. So thickness of isolator is calculated by Eq. (3).

$$t_r = \frac{D_D}{\gamma} \tag{3}$$

where t_r is thickness of isolator and γ is deformation coefficient of isolator. Thickness of isolator was calculated 0.2 m by Eq. (3).

2.3.4. Maximum displacement

It is the maximum displacement of the isolator due to torsion. It is calculated by Eqs. (4-6).

$$E = 0,05 \times e \tag{4}$$

$$D_{total} = D_D\left(1 - \frac{12 \times E}{b^2 + d^2}\right) \tag{5}$$

$$D_{total} \geq D_D \times 1,1 \tag{6}$$

where e is the longest length of the building plan, b and d are the dimensions of the building in the x and y direction. Maximum displacement was calculated as 0.22 by Eqs. (4-6).

2.3.5. Base shear force

Base shear force of the isolated building is calculated by Eqs. (7-9).

$$V_b = K_H \times D_D \tag{7}$$

$$V_s = \frac{K_H \times D_D}{R} \tag{8}$$

$$C_s = \frac{V_S}{W_T} \tag{9}$$

in which V_b is unreduced earthquake force, V_s is base shear force, R is earthquake reduction coefficient and C_s is the ratio of base shear force to building weight. Base shear force was calculated as 3.08 MN by Eqs. (7-8). The ratio of base shear force to building weight was calculated as 16.5% by Eq. (9).

2.3.6. Detail of lead rubber isolator

In UBC-97, a steel plate thickness to be placed between the elastomer layers was made as 2 mm in standards. The thickness of one of the layers in the isolator is calculated by Eq. (10) and the shape factor of the isolator calculated by Eq. (11).

$$\frac{D}{80} \leq t_0 \leq \frac{D}{40} \tag{10}$$

$$S = \frac{\text{Disc area}}{\text{Cross section area}} = \frac{\frac{R \times D^2}{4}}{R \times D \times t} = \frac{D}{4 \times t} \tag{11}$$

where t_0 is the thickness of the rubber between the steel plates and S is the shape factor of the isolator.

The thickness of the elastomer layers between the isolator was calculated as 10 mm by equation 10, the shape factors of type A and type B were calculated as 15 and 16.25, respectively.

The total elastomer thickness was calculated as 200 mm, one-layer elastomer thickness was calculated as 10 mm, and there are 20 layers of elastomer. There are 19 steel plates with a thickness of 2 mm. There are 25 mm steel plates on the top and bottom of the isolators. Total isolators height was calculated as 288 mm. Type A and type B isolators are given Figs. 2 and 3, respectively.

2.3.7. Vertical stiffness

The loading module is calculated by Eq. (12) and vertical stiffness is calculated by Eq. (13).

$$E_C{}^A = \frac{6 \times G_A \times S_A{}^2 \times K}{6 \times G_A \times S_A{}^2 + K} \tag{12}$$

$$K_V{}^A = \frac{E_C{}^A \times A}{t_r} \tag{13}$$

where E_c, K_v *and* K are loading module, vertical stiffness and stiffness of steel plate, respectively. The stiffness of steel plate is 200 MPa. The loading module of type A and type B isolators are calculated as 609.9 MPa and 884.05 MPa respectively. The vertical stiffness of type A and type B isolators are calculated as 863.01 MPa and 1467.53 MPa respectively. Total stiffness of all isolators is calculated by Eq. (14).

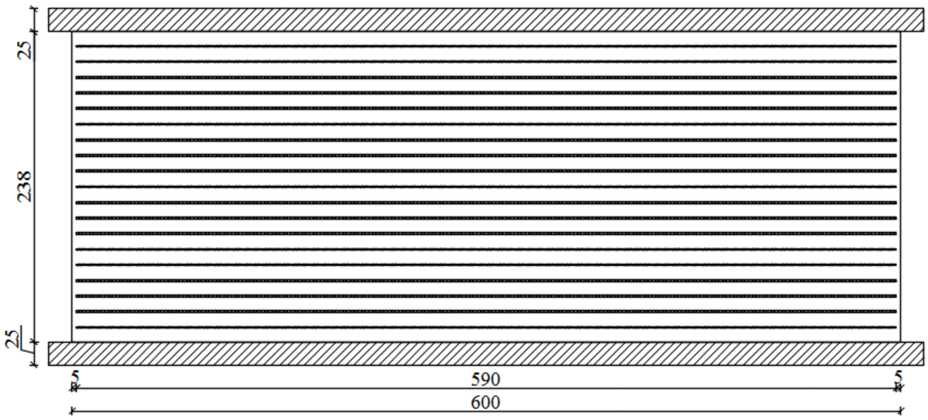

Fig. 2. Detail of type A isolator.

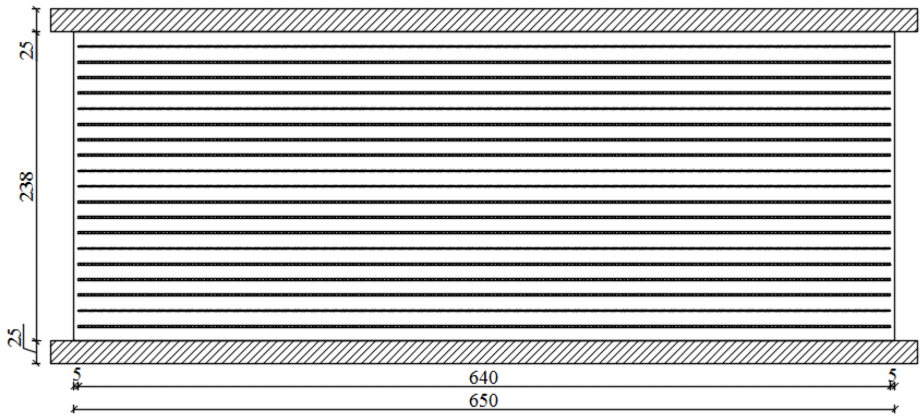

Fig. 3. Detail of type B isolator.

$$\sum K_V = N_A \times N_A{}^V + N_B \times K_B{}^V \tag{14}$$

Total vertical stiffness is calculated as 480829,2 MPa by Eq. (14).

2.3.8. Vertical vibration period

The design displacement of the building is calculated by Eq. (15) and the vertical vibration period is calculated by Eq. (16).

$$\Delta_t = \frac{W_t}{K_V} \tag{15}$$

$$T_V = \frac{T_{DV}}{\sqrt{6S}} \tag{16}$$

where Δ_t is horizontal displacement and T_V is vertical vibration period. The horizontal displacement is calculated as 0.000501 m by Eq. (15) and the vertical vibration period is calculated as 0.17 sec. by Eq. (16).

2.3.9. Control of collapse risk

The inertia of the steel plates of isolator is calculated by Eq. (17) and control of collapse risk is calculated by Eq. (18).

$$I = \frac{\pi \times \left(\frac{D}{2}\right)^2}{4} \tag{17}$$

$$P_{critic} = \frac{\pi}{t_r}\sqrt{\frac{E_C \times I}{3} \times G \times A_S} \tag{18}$$

where P_{critic} is load supported by isolator, I inertia of steel plate. Steel plate inertia for type A and type B isolator is calculated 17 as 0.0059 m^4 and 0.0082 m^4 respectively. P_{critic} for type A and type B isolator is calculated as 7250 kN and 13860 kN respectively. Since the values obtained from calculation are higher than the load supported isolator, there is no collapse risk.

2.3.10. Mechanical properties of isolator

Plastic stiffness is calculated by Eq. (19) and elastic stiffness is calculated by Eq. (20).

$$K_2 = \frac{A \times G}{t_r} \tag{19}$$

$$K_1 = 6 \times K_2 \tag{20}$$

where K_2 is plastic stiffness and K_1 is elastic stiffness. Plastic stiffness for type A and type B is calculated as 0.919 MPa and 1.66 MPa respectively. Elastic stiffness for type A and type B is calculated as 5.514 MPa and 9.96 MPa respectively. Shear force of isolator is calculated by Eq. (21).

$$Q = C_S \times W \tag{21}$$

Shear force of type A and type B is calculated as 0.1122 MPa and 0.1898 MPa respectively.

Yielding displacement is calculated by Eq. (22).

$$D_Y = \frac{Q}{K_1 - K_2} \tag{22}$$

where D_y is yielding displacement. The yielding displacement for type A and type B is calculated as 0,0239m and 0,0229 m respectively.

Effective stiffness is calculated by Eq. (23).

$$K_{eff} = K_1 + \frac{Q}{D} \tag{23}$$

where K_{eff} is equivalent stiffness corresponding to the maximum displacement. K_{eff} for type A and type B is calculated as 1392.04 kN/m and 2475.65 kN/m respectively.

Yielding strength is calculated by Eq. (24).

$$F_y = K_1 \times D_y \tag{24}$$

where F_y is yielding strength. Yielding strength for type A and B is calculated as 129.30 kN and 213.96 kN respectively. Mechanical properties of type A and type B isolator are shown in Table 8.

Table 8. Mechanical properties of isolators.

Direction		LRB			
		Type A (680 kN)		Type B (1150 kN)	
		Linear	Nonlinear	Linear	Nonlinear
U_1 (Vertical)	Stiffness (kN/m)	846612.81	-	1439646.93	-
U_2/U_3 (Horizontal)	Stiffness (kN/m)	1392.4	5409.23	2478	9770.76
	Yielding stiffness (kN)	-	129.3	-	213.96
	K_2 / K_1	-	0.1667	-	0.1667

3. Results

In this study, the internal forces of 6-6 axis of seismic isolated building with LRB and fixed building are compared. As a result of the analyses, the maximum shear forces and moments of the 6-6 axes of the isolated and fixed building are shown in Tables 9-10. 6-6 axis view of the building is shown in Fig. 4.

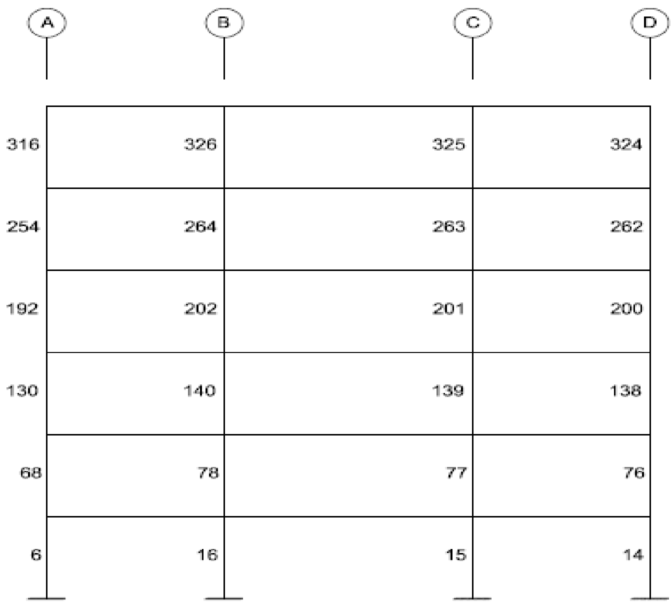

Fig. 4. The view of 6-6 axis of the building.

Table 9. 6-6 Axis column of internal forces of fixed building.

Frame Text	Step Type	V_2 kN	V_3 kN	M_2 kNm	M_3 kNm
6	Max	135.27	126.52	293.09	300.10
6	Min	-126.96	-134.74	-300.98	-292.11
14	Max	135.27	135.27	300.98	300.10
14	Min	-126.96	-126.96	-293.09	-292.11
15	Max	145.22	166.66	331.68	309.66
15	Min	-133.30	-162.58	-327.76	-298.21
16	Max	145.22	162.58	327.76	309.66
16	Min	-133.30	-166.66	-331.68	-298.22

Table 10. 6-6 Axis column of internal forces of isolated building.

Frame Text	Step Type	V_2 kN	V_3 kN	M_2 kNm	M_3 kNm
6	Max	82.13	81.15	245.44	244.42
6	Min	-81.47	-81.81	-243.46	-246.39
14	Max	82.13	82.13	243.47	244.42
14	Min	-81.47	-81.47	-245.44	-246.39
15	Max	82.72	83.92	250.77	245.94
15	Min	-81.98	-83.59	-251.78	-248.16
16	Max	82.72	83.59	251.78	245.94
16	Min	-81.98	-83.93	-250.77	-248.16

The base shear forces of the design earthquakes acting in E_x and E_y directions of the isolated and fixed structure are given in Table 11.

Table 11. Base shear forces of isolated and fixed building.

	Fixed Building	Isolated Building
Ex	4450.65 kN	2542.91 kN
Ey	4420.87 kN	2525.43 kN

The displacement of the floors as a result of the design earthquake affecting the E_x and E_y directions of the fixed and isolated building is given in Table 12.

Table 12. Story displacement of isolated and fixed building.

	Fixed Building (mm)		Isolated Building (mm)	
	E_x	E_y	E_x	E_y
Ground Floor	0.00	0.00	59.52	59.17
1. Floor	4.75	4.79	69.87	69.89
2. Floor	12.23	12.46	75.01	75.46
3. Floor	19.37	19.89	78.70	79.54
4. Floor	25.31	26.13	81.47	82.66
5. Floor	29.64	30.75	83.39	84.89
6. Floor	32.19	33.59	84.53	86.30

As a result of the calculations, the required reinforcement for the 6-6 axis of the fixed and isolated building are shown in Tables 13-14.

As a result of the calculations, the required shear reinforcement for the 6-6 axis of the fixed and isolated building are shown in Tables 15-16.

The longitudinal reinforcement overlap zones and reinforcement passages were not calculated in isolated and fixed building. For the 6-6 axis, approximately 2800 kg of longitudinal reinforcement is required in the fixed structure, while approximately 1800 kg of longitudinal reinforcement is required in the isolated building. Transverse reinforcements were calculated without considering column tightening zones in isolated and fixed building. The transverse reinforcement of fixed and isolated building was calculated as approximately 670 kg and 400 kg, respectively.

4. Conclusions

In this study, the isolated building with LRB and fixed building are examined. LRB isolators used in seismic building were designed according to UBC-97. The floor displacements, internal forces, transverse and longitudinal reinforcement of selected axis of seismic isolated and fixed building are compared.

Comparing the results of this study, the following observations can be made:

- The base shear forces of isolated building are smaller than fixed building nearly about 57%. It means that the isolation system is affected to decrease lateral forces.
- The base shear forces of isolated building are smaller than fixed building about 43%.
- The maximum 6. floor displacement of building increased from 33.59 to 86.3 mm by means of using seismic isolation system. In ground floor, displacement increased from zero to 59 mm. This value is the displacement of the isolator.
- Except first floor, the diameter of required reinforcement used in a seismic isolated building is generally of smaller and greater spacing than the fixed building.
- The diameter of shear reinforcement used in a seismic isolated building is generally of smaller and greater spacing than the fixed building.
- The weight of longitudinal reinforcement of selected axis of isolated building is smaller than fixed building about 36%. It is thought that the cost of reinforcement will decrease considerably if the comparison is made in the whole building.
- The weight of transverse reinforcement of selected axis of isolated building is smaller than fixed building about 40%.

This study demonstrated that using seismically isolated building with LRB decrease required reinforcement and internal forces. So, it is thought that the using LRB decrease cost of reinforcement.

Table 13. Required reinforcement of fixed building.

	A axis	B axis	C axis	D axis
1. Floor	16ϕ25	12ϕ18	12ϕ18	16ϕ25
2. Floor	12ϕ22	12ϕ20	12ϕ20	12ϕ22
3. Floor	12ϕ22	12ϕ22	12ϕ22	12ϕ22
4. Floor	12ϕ20	12ϕ22+8 ϕ14	12ϕ22+8 ϕ14	12ϕ20
5. Floor	12ϕ18	12ϕ22+8 ϕ18	12ϕ22+8 ϕ18	12ϕ18
6. Floor	12ϕ18	12ϕ25+8 ϕ20	12ϕ25+8 ϕ20	12ϕ18

Table 14. Required reinforcement of isolated building.

	A axis	B axis	C axis	D axis
1. Floor	16ϕ22	4ϕ25+12ϕ22	4ϕ25+12ϕ22	16ϕ22
2. Floor	8ϕ20	4ϕ25+12ϕ22	4ϕ25+12ϕ22	8ϕ20
3. Floor	8ϕ20	8ϕ20	8ϕ20	8ϕ20
4. Floor	8ϕ20	8ϕ20	8ϕ20	8ϕ20
5. Floor	8ϕ20	8ϕ20	8ϕ20	8ϕ20
6. Floor	8ϕ20	8ϕ20	8ϕ20	8ϕ20

Table 15. Required shear reinforcement of fixed building.

	A axis	B axis	C axis	D axis
1. Floor	3ϕ8 / 180	4ϕ8 / 150	4ϕ8 / 150	3ϕ8 / 180
2. Floor	3ϕ8 / 180	4ϕ8 / 140	4ϕ8 / 140	3ϕ8 / 180
3. Floor	3ϕ8 / 200	4ϕ8 / 150	4ϕ8 / 150	3ϕ8 / 200
4. Floor	2ϕ8 / 190	4ϕ8 / 190	4ϕ8 / 190	2ϕ8 / 190
5. Floor	2ϕ8 / 190	2ϕ8 / 190	2ϕ8 / 190	2ϕ8 / 190
6. Floor	2ϕ8 / 190	2ϕ8 / 190	2ϕ8 / 190	2ϕ8 / 190

Table 16. Required shear reinforcement of isolated building.

	A axis	B axis	C axis	D axis
1. Floor	2ϕ8 / 200	4ϕ8 / 160	4ϕ8 / 160	2ϕ8 / 200
2. Floor	2ϕ8 / 200	2ϕ8 / 200	2ϕ8 / 200	2ϕ8 / 200
3. Floor	2ϕ8 / 200	2ϕ8 / 200	2ϕ8 / 200	2ϕ8 / 200
4. Floor	2ϕ8 / 200	2ϕ8 / 200	2ϕ8 / 200	2ϕ8 / 200
5. Floor	2ϕ8 / 200	2ϕ8 / 200	2ϕ8 / 200	2ϕ8 / 200
6. Floor	2ϕ8 / 200	2ϕ8 / 200	2ϕ8 / 200	2ϕ8 / 200

Publication Note

This research has previously been presented at the 3rd International Conference on Advanced Engineering Technologies (ICADET'19) held in Bayburt, Turkey, on September 19-21, 2019. Extended version of the research has been submitted to Challenge Journal of Structural Mechanics and has been peer-reviewed prior to the publication.

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