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Effect of seismic isolation on the Dynamic behavior and in casting cost of reinforced concrete moment frame building

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Abstract

In this study a 10-storey building of reinforced concrete moment frame is designed as isolated and fixed-base. Lead-rubber bearing (LRB) is used as an isolation system. In order to consider the actual behavier of structure , Nonlinear behavior of both isolation system and structure are considered in the modeling. The behaviors of designed models under dynamic loads are analyzed using SAP2000 software. At the end of analysis, period, storey acceleration, inter-storey drifts, base shear forces, volume of concrete and weight of rebards are compared for isolated and fixed-base structures.

Keywords: Lead-rubber bearing; Dynamic analysis; isolation system; Reinforced concrete structure

1. Introduction

With the advancement of science and technology in recent years, increasing the safety and performance of buildings in the event of a strong earthquake, is increasingly important. In conventional systems with fixed base, the seismic ground motion is transmitted to the upper structure to provide lateral load-bearing capacity of the elasto-plastic (ductility) structural elements use(Fig. 1-a). In general, there are two fundamental problems in seismic design of these systems. The earthquake caused large accelerations values at storeies in stiff buildings and caused large Inter-storeies drifts values in soft buildings.In The seismic rehabilitation of structures, instead of increasing the bearing capacity of the structure under lateral forces, the forces acting on them can be reduced. In this method the structure Isolated of its support and is placed on the supports that have large lateral deformation. In this situation, in the event of an earthquake, major deformations occurred in the support and the structure vibrate as a rigid body with small deformation (Fig. 1 – b).

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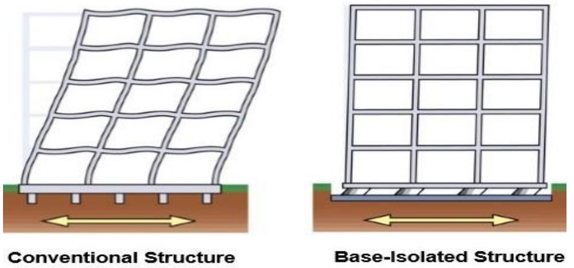
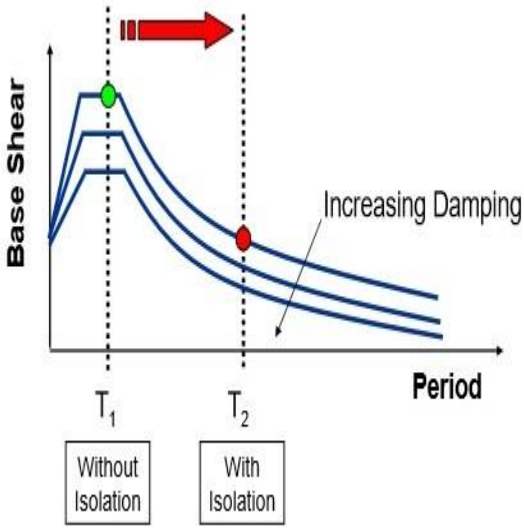


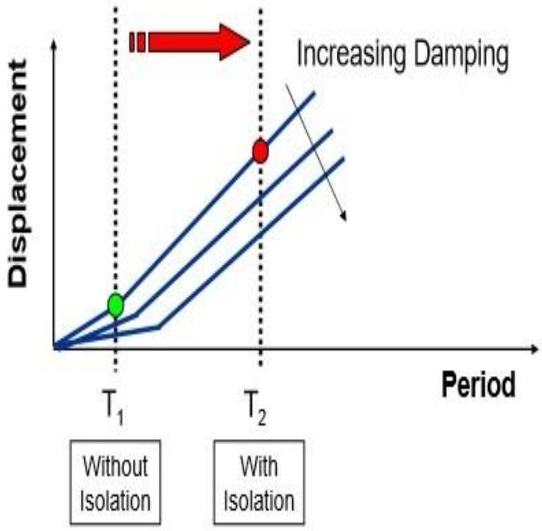
(a) (b)

Fig.1 behavior of structure (a) fixed- base structure and use of ductility (b) base- isolated structure[1].

this method based on reducing responses by increasing Period and damping structure. Seismic isolation caused increasing period, damping, reducing



base shear (Fig. 2-a), and increasing displacement at the base and stories (Fig.2-b).[1-5].



(a) (b

Fig 2. effect of Seismic isolation on the structural parameters [1].

2. Lead rubber bearing base isolator

Lead-rubber bearing (LRB) were invented in 1975 in New Zealand and is widely used in New Zealand, Japan and the United States of America have been used. Lead-rubber bearing isolation system with softening under severe seismic loads, optimal performance in terms of controlling both mild and strong earthquakes have shown. this seismic isolation as shown in Figure 3 , has one or more lead core that are located in the holes. Lead core isolation with yielding At the time of vibration , increases damping of 3% of critical damping to more than 10%. Lead crystal structure changes with displacement, but immediately with returning displacement, returns to the initial state and so Consecutive yielding under Dynamic loads, does not cause fatigue in the lead. Under shear force The relatively low stresses at around 8 to 10 MPa, lead to the yield is , therefore it demonstrated sustained hysteresis behavior and destroys significant amounts of energy in a relatively large earthquake.[3-1]

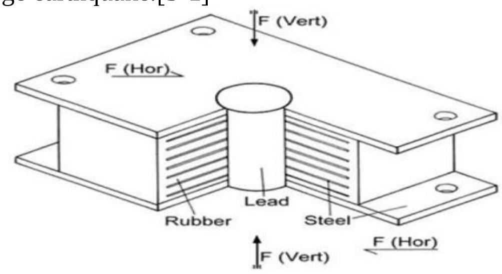


Fig 3. Lead rubber bearing base isolator [2]

3. Bilinear Model of Lead-rubber bearing System

physical deformation occurs in the Lead cores of this isolations in shear flow of about 10 Mpa And cause a bilinear response in the isolations. the Lead core with rubber sector stiffness Which is very low compared to the stiffness of the lead , provides Initial stiffness required in the curve of force – displacement of this isolations . With increasing load, this sector limit yields and shows very little stiffness against The lateral load. This stiffness with rubber sector stiffness of isolation , shows Secondary stiffness in the curve of force – displacement. The LRB isolation modeled As a bilinear model based on three parameters including K_e (elastic stiffness) , K_p (stiffness after yielding) and Q (characteristic strength)(Fig.4). K_e can be defined as a multiple of K_p. K_p value can be obtain accurately with the shear modulus of the rubber and seat design. Q based on the yield stress of lead and lead core area is determined precisely. effective stiffness based on the slope Secant , up to the maximum (the maximum in a positive direction to peak in a negative direction) is defined [1-3].

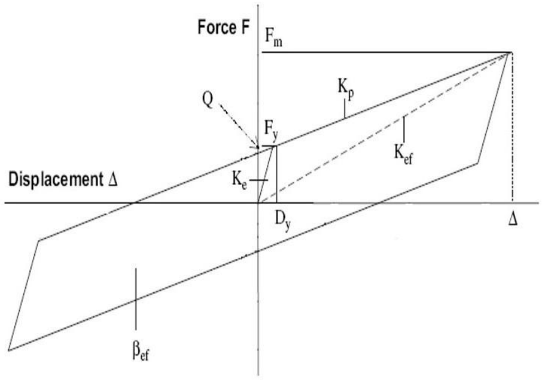
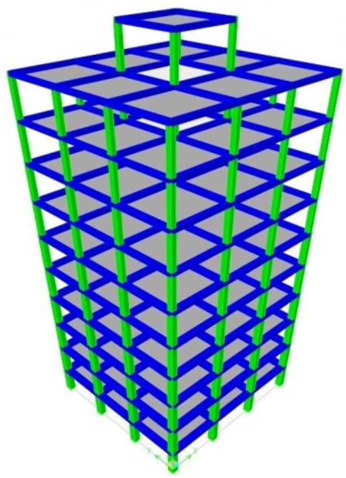


Fig 4. Bininear model of isolator unit.[2]

4. Modeling of Superstructure and isolation system

In this case study a 10-storey building of reinforced concrete moment frame , including three spans of 4.5 m in the X direction and three spans of 4.3 m in the Y direction is studied. the inter-storey height is 3 m , while total height is about 30 m for 10-storey. Structures is assumed in first-degree seismic zone (very high seismically) , 2-type soil and Residential . structure designed according to Iranian Earthquake 2800 Code [6] is considered as shown in Figure 5.

(a)



(b)

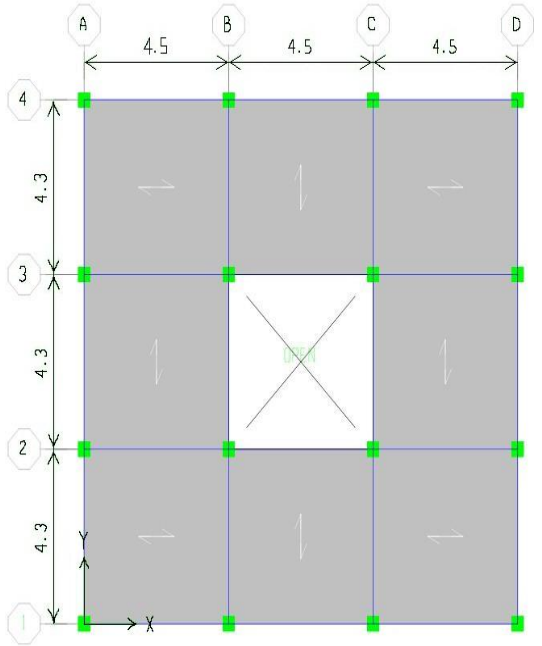


Fig 5. (a) Typical plan of the building model, (b) 3D view of SAP model

the structure was modeled and designed by SAP2000.V14.00 software . Also the response nonlinear dynamic time history analysis used for analyzing and designing of structure. In this structure , there were 16 columns . so , 16 Lead-rubber bearing are used under each column. The isolatore was modeled as a robber isolatore link in SAP 2000 software. The Lead-rubber bearing was designed according to Publication No. 513 [7]. At the time of analysis, three earthquake acceleration records have been used [8]as input excitations in the simulation as mentioned in 2800 code [6]. The detailed information about these three earthquake records are given in table 1.

Table 1. Accelerograms for nonlinear dynamic time history analysis

Earthquake	Station	PGA
Northridge 1994	Newhall	0.5864
Capemendocino 1992	Rio Dell over pass	0.549
Chichi 1999	TCUO57	0.118

5. Resultes and discussion

First four periods of isolated and fixed-base structure is given in Table 2. Analysis showed that the first period of base-isolated structure is 2.775 times bigger than that of fixed-base for the 10-storey structur . Hence, isolation has the effect of lengthening the structural period so it reduces the risk of being in resonance.

Table 2 : priods for isolated and fixed – base structure for various mode

Storey	Support case	Mode			
		1	2	3	4
10	Fixed	1.393 (s)	1.36 (s)	1.157 (s)	0.446 (s)
	LRB	3.865 (s)	3.377 (s)	3.065 (s)	0.736 (s)

In base-isolated structure, the acceleration values at storeys, are decreased while increasing the periods. The acceleration values of structures having both the base-isolated and the fixed-base are given in Table 7 for 10-storey structure. Table 3 show that transmitted ground accelerations has been decreased at the base isolated system according to fixed base system. The ratio of top storey accelerations proportioned to ground accelerations for 10-storey structure are obtained in fixed and LRB conditions as 397% and 111%, respectively.

Table 3. Acceleration values of base-isolated and fixed-base for the 10-storey structure

Support case	$Absolute\ Max.Acceleration(^{m}/_{s^2})$										
	storey										
	base	1	2	3	4	5	6	7	8	9	10
Fixed	0	0.326	0.664	1	1.306	1.373	1.43	1.418	1.339	1.306	1.294
LRB	0.8	0.8	0.788	0.765	0.742	0.698	0.664	0.72	0.765	0.833	0.889

Table 4. Base Shear force of base-isolated and fixed-base condition for the 10-storey structure

Storey	Support case	V(ton)	
		X	Y
10	Fixed	525.417	527.372
	LRB	309.706	307.66

Table 5 :maximum displacement of base-isolated and fixed-base condition for the 10-storey structure

Support case	Displacement (cm)										
	story										
	base	1	2	3	4	5	6	7	8	9	10
Fixed	0	0.895	2.4	3.95	5.386	6.66	7.7	8.53	9.174	9.65	10.01
LRB	35	35.33	36.293	37.27	38.156	38.948	39.531	39.98	40.274	40.498	40.683

The base shear force of isolated and fixed-base structure is given in Table 4. As seen in table 4 , base shear force of base-isolated structure is highly decreased according to base shear force of fixed-base structure. The base shear force acting on the base-isolated system is decreased as a result of decreasing storey acceleration values . The base shear force of structure with LRB is 58.3%, of fixed-base system at the 10-storey structure.

Storey displacements of isolated and fixed-base structures based on storey numbers were given in table 5. As seen in table 5 , Displacement on the base level was increased because of increment in period of base-isolated structure.

Inter-storey drift of isolated and fixed-base structure based on storey was given in Tables 6. inter-storey drift of base-isolated structure was lower than that of fixed-base structure. In fixed-base 10-storey structure, the maximum inter-storey drift ratio was 0.52%, at the 3st storey . In base-isolated structure, the maximum inter-storey drift ratio was 0.33%, at the 3nd storey . This behavior of isolation system provides the minimum damage occurrences in structural members during an earthquake.

Table 6. Inter-storey drifts of base-isolated and fixed-base condition for the 10-storey structure

Support case	. Inter-storey drift× 10^{-3}									
	story									
	1	2	3	4	5	6	7	8	9	10
Fixed	2.982	5.01	5.151	4.787	4.252	3.473	2.785	2.146	1.58	1.2
LRB	1.91	3.211	3.251	2.958	2.639	1.943	1.5	0.9786	0.7498	0.6156

Table 8. comparison of weight of rebar and volume of concrete for the 10-storey structure

Storey	Support case	Weight of rebards (ton)	Volume of concrete (m^3)
10	Fixed	50.37	322
	LRB	43.3	274.7

After designing the new model, due to the base isolator dimension of beams and columns decreases. The volume of concrete for building by isolator decreased about 14.7% for beams and columns in comparison of the fixed-base building. Furthermore, the weight of rebar decreased about 14% . Table 8 exhibit the differences of casting materials, including steel weight and volume of concrete .

6. CONCLUSION

In this study, nonlinear dynamic analyse of 10 storey reinforced concrete moment frame building as isolated and fixed-base type is performed. LRB is used as an isolation system . In base – isolated structure large reduction is observed in acceleration value , base shear force and relative storey displacement with respect to conventional structure. As a result of decreasing relative storey displacement, the acceleration acting on superstructure is damped at base level and the internal forces in superstructure are reduced. On the other hand, the displacement and period of base-isolated structure is increased comparing with fixed-base structure.Also In this study the effect of the base isolator investigated in casting cost of a 10 storey residential building. The results show that using base isolator could decrease the weight of rebar and volume of concrete about 14% in a concrete moment frame. However , the cost of isolators are not considered, But in design of structures , drift and base shear force are the most important parameter, which Using seismic isolation have decreased , As a result , the damage of structure will be decreased.

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