Ukrainian Journal of Ecology

Ukrainian Journal of Ecology, 2018, 8(2), 326–333

ORIGINAL ARTICLE

Comparison of drift and energy depreciation in concrete moment frames using HDRB isolators under near-fault earthquakes

Fazel Mirhasani[1], Mostafa Koohsari Nodeh[1], Bashir Yazdani[2]

[1]Master of Structural Civil Engineering, Civil Engineering Department, Islamic Azad University, Gorgan Branch, Iran.
[2]Bachelor of Architecture, Architecture Department, Islamic Azad University, Shahrood Branch, Iran.
E-mail: fazelmirhasani@Yahoo.com, Mostafa.Koohsari@Ymail.com, Yazdanibashir@gmail.com

Received: 22.03.2018. Accepted: 09.04.2018

Seismic Isolator Systems in structures can be constructed for buildings with any height according to the Design Regulations available in Seismic Isolator. On the other hand, the behavior of high structures in the past earthquakes indicates the different behavior of these structures in comparison with short buildings. For this purpose, the main objective of this project is to examine the seismic behavior of short, intermediate and high-order concrete moment building without any isolator and comparison them with isolated buildings using High Damping Rubber Bearing (HDRB). Linear and nonlinear structural analysis methods including static linear and nonlinear modal dynamic analysis methods have been used to achieve the results using the Kobe, Morgan Hill, NewZealand, Loma Prieta, Imperial Valley**,** Northridge, Dinar earthquake records with the help of SAP2000 software.

The effect of isolation on structural behavior has been investigated with the definition of 3 frames with fixed base and 3 frames with isolated base as 3-dimensional model for 3 buildings with heights of 4, 8 and 12 storey, and parameters such as amount of relative displacement and energy depreciation are compared with each other. Generally, it was observed that, the amount of energy depreciation is 65.34%, 59.42% and 53% and amount of drift reduction is 58%, 48.71% and 36.48% in structures with seismic isolator in structures 4, 8 and 12 storey than structures with fixed base, on average, under acceleration of reflection maps, respectively, which the energy depreciation of isolators is higher in structures with less storey. This is due to the acceleration response spectrum shape that the rate of acceleration response drop relative to the increase in period, is less amount than that of lower periods in areas with high periods (higher order structures).

Keywords: High Damping Rubber Bearing (HDRB); linear static analysis; nonlinear dynamic analysis; near-fault earthquake

Introduction

Seismic isolation is a new method for designing buildings against earthquake, which is based on reducing the forces imposed on structure due to earthquake rather than increasing the structure's capacity to withstand lateral loads. The basis of this method is the reduction of responses by increasing the period of time and the appropriate damping in the structure. Also, the application of this method usually causes deformations of the structure to remain in the elastic range, which this matter will add to the structural safety level. Isolation will allow us to design based on the smaller amount of earthquake forces for the same level of safety in the conventional corresponding structures that have not been isolated. The idea of protecting buildings against the devastating effects of the earthquake is a topic that had been considered for more than a century. The philosophy of using seismic isolation is affected to the fact that the isolation of the structure from the earth and its protection against devastating earthquake effects is possible and can be applied and is created and becoming pervasive more and more. An extra softness is often provided in the wake of the building in order to achieve this result while retaining the ability to exploit the structure and, a way is considered to increase the damping in addition, in place of the isolator to control the displacement.

Research background

Although the first recorded operation in the field of base isolator dates back to the 1800s, the first structural separator can be found in the early 1900 (the Tokyo Imperial Hotel), which is basically considered as a base isolation system before the 1970. Isolation on bridges had been also common before the 1970. In the early 1980, advances in rubber technology were achieved, that, new rubber parts called "high-damping rubber bearing" or HDRB (Skinner, 2004) were obtained in results of them. In a paper titled "Effect of vertical component of near-fault earthquakes on structures isolated on a base with high-damping rubber bearing isolations" has been published by Tavakoli et al. The response of the frames in a fixed and isolation base state was compared with an HDRB isolator under far and near earthquake with orientation. Vertical component of earthquakes has the most effect on vertical responses. The compressive response of the 8-storey frame base, in fixed and separation base state, has decreased by about 40% and 60%, respectively. Seismic far and near needs are different and in longer frames are more serious and require more investigation (Yousefi, 2015). In another paper entitled "Comparative Study of Seismic Performance of Concrete Frames with Seismic Isolator " by Dhawade, S.M during investigation of a Seismic Performance of a 14-story concrete frame structure isolated on a base with high-damping rubber bearings and the fixed base compared, and understood that the inferiority of the overturning and shear of the storey in the isolated structure decreases in the base , and the internal forces of the beams and columns will also be reduced because of the relative movement reduction of the storey (Dhawade, 2014).

The concept of vibrating isolator

The phrase isolation the base from the word isolator in its sense means the act of isolation, and the base is meant to be part of the supporter of the end part of the structure or foundation. As the lexical concept shows, the structure is separated from its foundation. Logically, the separation of the structure from the ground to prevent earthquake damages is very wise. In an earthquake, the earth moves, and this movement causes the most damages to the structure. The only way to stay stable the structure under gravity loads is to stay on the ground. Isolation is not compatible with the fact how to separate a structure from the earth and still can bear gravity loads. Therefore, the material stated here is not related to ideal systems, but also is about isolated practical systems and systems that have been isolated due to encountering with power and destructive effects of the earthquake. When a new concept is explained, it is useful to compare it with the previous concept. Seismic isolation is a new conception of the concept of reducing seismic demand on the structure.

The base separation topic is included in the inactive power dissipation group and includes in-structural damping. In-structural damping has been made of equipment that, wastes the energy by addition the damping inside the structure, but does not prevent the base location change in the building. Active control is another model of earthquake reduction demand, which actually isolator and / or energy dissipation equipment is used using electric power to provide optimal efficiency (Skinner, 2004).

New buildings contain highly sensitive and expensive equipment that have vital importance in business, commerce, education and health care. Hospitals, mass communication centers, emergency centers, police office and fire stations should be able to serve at a time when they are needed, that is, after the earthquake. A typical building can cause very high accelerations in the storey of the hard buildings and the displacement of adjacent places between the big storey in flexible structures. These two factors create a problem in ensuring the safety of building components and its contents.

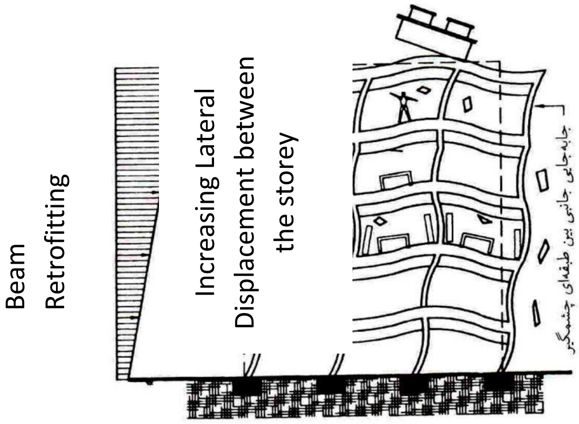

Figure 1. Normal structure.

In the last few years, other ways have been created other than unreasonable response to the force of nature that has come to a stage, although it has no result, at least is more practical. This new concept is now called seismic isolation, which responds to the criteria of classical technological innovation. As shown in Figure 1 and Figure 2, building buildings on an isolator system reduces the horizontal movement transfer of the Earth to the building. This action leads to a sharp reduction in the accelerations of the storey and the inter-storey lateral displacements, thus protecting the contents and components of the building.

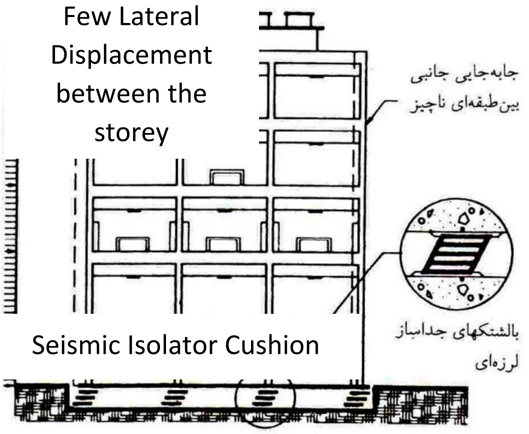

Figure 2. Structure with isolated storey.

The seismic isolation principle is based on creating flexibility in the foundation of the building on the horizontal plane, while at the same time using depreciable components to limit the range of motion caused by the earthquake. The benefits of seismic isolation are the ability to remove or reduce structural and non - structural severe damages and enhance the safety of building contents and architectural views and facades and reduce the forces of the earthquake. Reducing five to ten times the elastic force, as a result of the seismic isolation can be expressed as a magnitude reduction of an earthquake of eight magnitudes to a range of five to six magnitudes (Anderson & Christopher, 2009).

The effects and features of near-earthquakes

Near-earthquakes include critical energy pulses. However, these earthquakes may have small magnitudes or smaller range, but they have high damaging potential. Also, speed pulses that are caused by rapid slip of fault were first recognized by Bolt by studying the recorded movements of the San Ferando earthquake. In total, these earthquakes have features such as pulse time history with long and almost big periods and sometimes (vPG / aPG) the maximum speed to maximum acceleration are large permanent changes in the earth. These features are caused by the effect of many phenomena near the seismic spring (Davoudi, Feizi & Hadiani, 2010).

Maximum acceleration of near-earthquake mapping

The studying about sudden movements known as earthquake has a long history. The magnitude of the damage caused by the earthquake depends on many factors, including collapse mechanism, fault-to-place distance, soil type, and earthquake record characteristics, including frequency content, movement time and amplitude, as well as the dynamic characteristics of the structure. In 2004, In Kil Chuy and colleagues examined the effect of near-fault earthquakes on the range of Korea's nuclear power plant design, which concluded that the spectrum of the plan of regulations in the medium and high frequency range was consistent with the near-fault spectrum, but within the range with a low frequency, the near-fault spectrum allocates more values to itself. In this study, it was found that the fault near effects on the response spectrum is seen within 10 kilometers of the fault. The results show that in the period of 0.2 to 0.5 s, the horizontal component effect, perpendicular to the fault, is about 30% higher than the horizontal component parallel of the fault due to the effects of orientation. In 2004, Bolt pointed out to this point that in the near-fault range in sites that have a effect of orientation, they have a larger response spectrum for a period more than 0.5 seconds. He also has showed that the effect of the horizontal component perpendicular to the fault has a greater effect on periods larger than 0.6 seconds compared to the horizontal component parallel to the fault, which this subject depends to the magnitude of the earthquake, the distance and the collapse direction (Khosravani, 2013).

Since the objective is to investigate the behavior of structure in near-earthquakes that we use the recommended records in accordance with FEMA P695 regulation for near-earthquakes (FEMA, 2009). These records were extracted from the PEER database (PEER, 1997). The selection of each of the stations and records is based on the shear wave velocity (speed) of the soil. So that the most suitable record of the near area was considered to be a record in the most similar site to the hypothetical building site. In this way, according to Table 4 of Standard 2800, fourth edition, records were selected that the shear wave velocity at their registration site to be between 175 and 375 m/s so that the soil associated with the desired record can be considered type III (Housing and Urban Development Research Center, 2015).

After selecting the records, we divide each of the horizontal and vertical records into the maximum value of each record so that each of the records is scaled to one. Since the records available in the PEER base are all multiplied by g, we multiply the records that have been scaled to 1 in 981 to convert them into centimeters per second. The spectrum associated with each record is plotted in horizontal directions in the next step, using the SEISMOSIGNAL software. In the next step, we multiply the spectra values by 981 to convert the spectra to cm / s. Then we divide each of the spectra by the maximum acceleration value of the acceleration map of that spectrum. We now obtain the sum of squares of the modified spectra. 3 or 7 pairs of acceleration mapping can be used to analyze the history of time. In the case that three acceleration pairs of mapping to be used, the maximum pair wise acceleration values of mappings is used and, if 7 of the acceleration pairs of mapping to be used, the average values of the acceleration pairs of mappings are used. The result should be scaled in a way that is not less than 1.3 times the standard design spectrum at 0.2T to 1.5T. The standard design spectrum is obtained from the product of multiplication B at the ground acceleration g (equal to 981). The final scale is the product of the multiplication of the scale that sets the above condition in the ratio of the base acceleration of the design, in the coefficient of importance of the building, divided by the behavior coefficient of the building. The final scale for the 4 storey structure is obtained equal to 0.486, for the 8 storey structure is obtained equal to 0.486 and for the 12th storey structure is obtained equal to 0.565. Table 1 shows the maximum acceleration amount and maximum velocity can be observed in Imperial Valley, Morgan Hill, Loma Prieta, North Ridge, Kobe, Dinar and New Zealand earthquake acceleration maps.

Table 1. Acceleration Rate and Records velocity.

Records	max accel	max velocity
Imperial Valley	0.287	34.93
Morgan Hill	0.212	12.74
Loma Prieta	0.285	43.38
Northridge	0.34	41.07
Kobe	0.326	44.91
Dinar Turkey	0.326	45.31
New Zealand	0.228	20.34

Design details of structures

Considered structures are all of the seismic resistant system of concrete moment (bending) frame with special ductility. The height of the storey has been considered as a type and equal to 3 meters. The building storeying system was considered as block joists slab. The soil of the studied site is Gorgan and Type III. The studied structures are residential uses with 4, 8 and 12 storey. The plan of the studied structures studied has been shown in Figure 3. In addition, in this study Guideline for Design and Practice of Base Isolation Systems in Buildings No. 523 journal has been used to design HDRB isolator (Skinner, 2004).

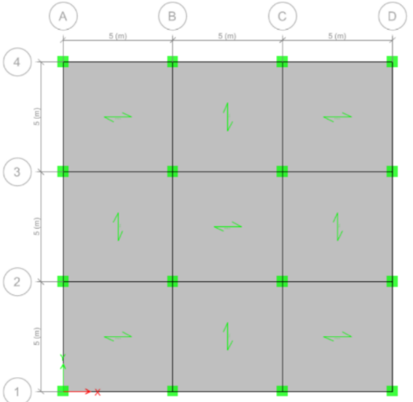

Figure 3. Studied Structural Plan.

In tables (2) and (3) and (4), the specifications of the sections of beam and columns used in this study are as follows.

Table 2. 4-storey structure specifications table.

beam	column	4 storey structure
B50X40	C50X50-12f20	Ground storey
B50X40	C50X50-12f20	First storey
B45X40	C45X45-12f18	Second storey
B40X40	C40X40-8f16	Third storey
	C40X40-10f16	

Table 3. 8-storey structure specifications table.

beam	**column**	**8 storey structure**
B55X50	C55X55-16f20	Ground storey
B55X50	C55X55-16f20	First storey
B50X40	C50X50-14f20	Second storey
B50X40	C50X50-14f20	Third storey
B50X40	C50X50-12f20	Fourth storey
B45X40	C45X45-10f20	Fifth storey
B45X40	C45X45-10f18	Sixth storey
B40X40	C40X40-10f16	Seventh storey

Table 4. 12-storey structure specifications table.

beam	column	12 storey structure
B65X55	C65X65-20f20	Ground storey
B65X55	C65X65-20f20	First storey
B60X50	C60X60-18f20	Second storey
B60X50	C60X60-18f20	Third storey
B55X50	C55X55-16f20	Fourth storey
B55X50	C55X55-16f20	Fifth storey
B50X40	C50X50-14f20	Sixth storey
B50X40	C50X50-14f20	Seventh storey
B50X40	C50X50-12f20	Eighth storey
B45X40	C45X45-12f18	Ninth storey
B40X40	C40X40-10f18	Tenth storey
B35X35	C35X35-8f16	Eleventh storey

Comparison of the structure drift response for the structures with anchored and isolated bearing

As it can be shown in diagram (1), seismic isolators play an important role in reducing the structural storey drift. Since one of the collapse criteria is the storey drift, so the use of seismic isolators can greatly contribute to the stability of the structure in large earthquakes with a long return period.

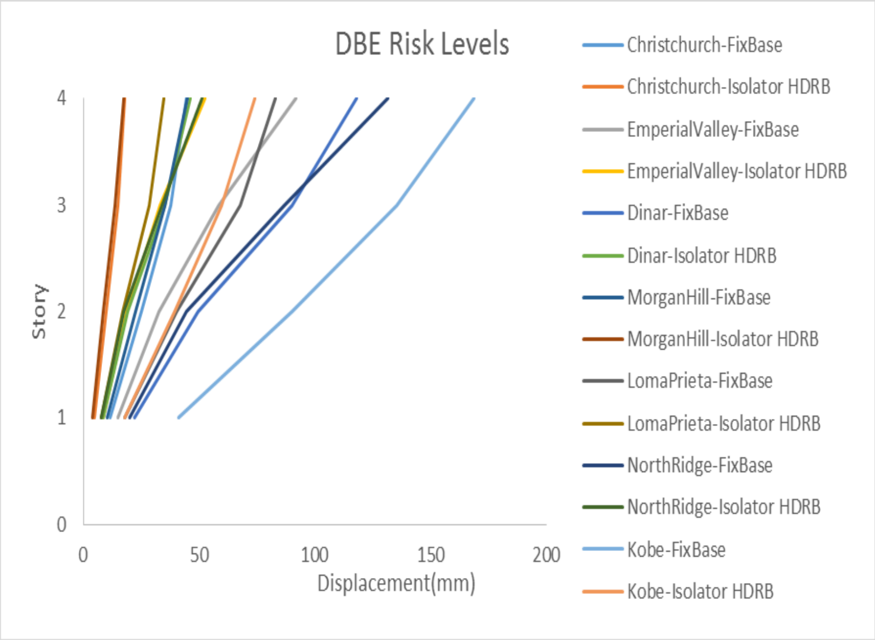

Diagram 1. Displacement of 4 storey structure in state with seismic isolator and without isolator.

As it can be observed in diagram (2), seismic isolators play an important role in reducing the structural storey drift. Since one of the collapse criteria is the storey drift, so the use of seismic isolators can greatly contribute to the stability of the structure in large earthquakes with a long return period.

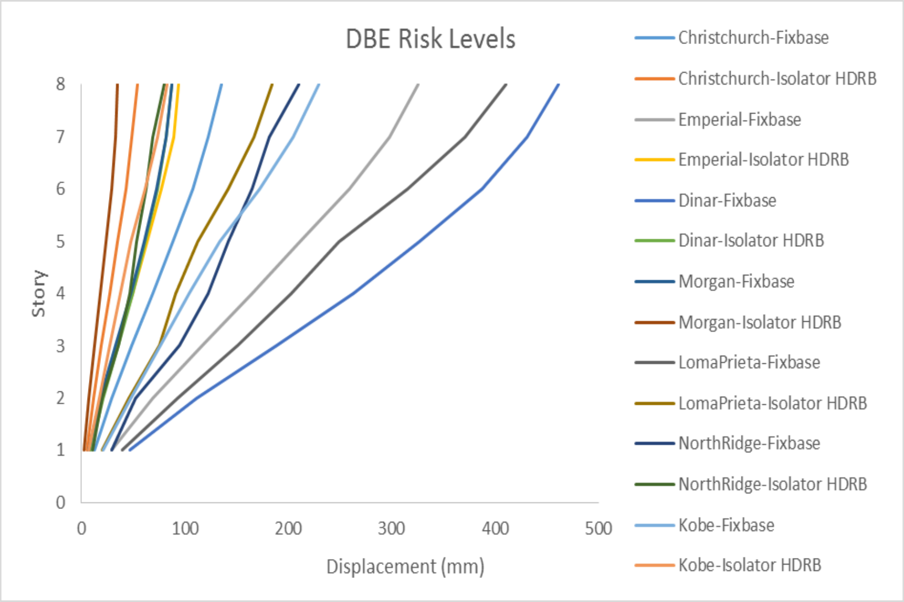

Diagram 2. displacement of 8 storey structure in state with seismic isolator and without isolator.

As it can be observed in diagram (3), isolator performance is not evident in reducing the storey drift in a 12-storey building as short buildings. This matter can be explained due to the response spectrum, and the longer the period, by increasing the period, we have less amount of reduction in response of acceleration.

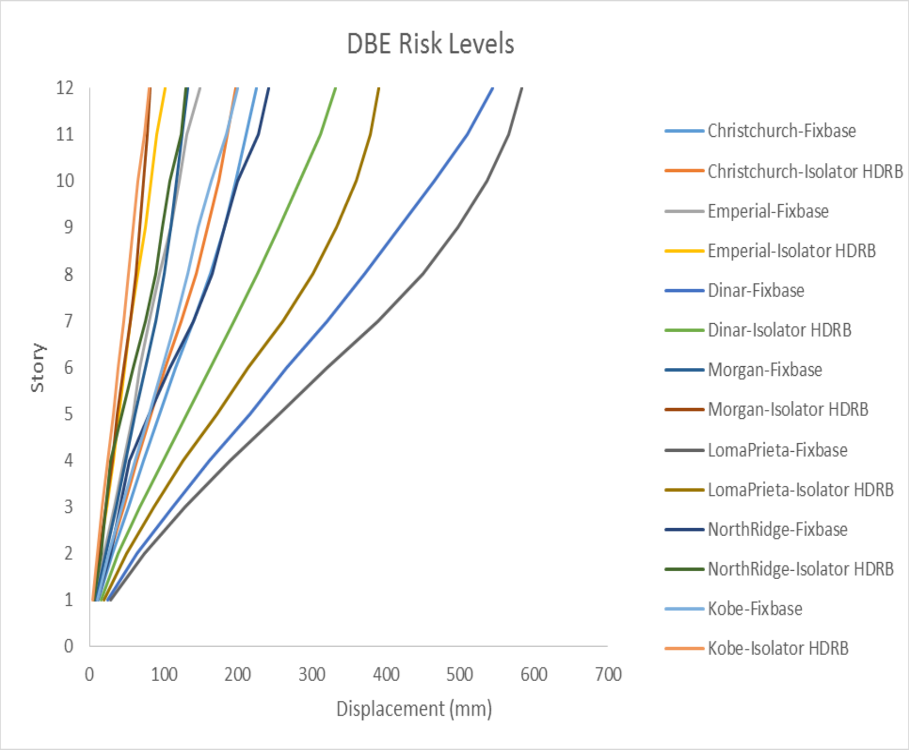

Diagram 3. Displacement the 12-storey structural storey in with isolator and without isolator state.

Studying energy input into structures

As it can be observed in diagrams 4, 5 and 6, seismic isolator in the DBE surface earthquakes exhibits a more efficient performance and absorbs a larger share of the energy input of the earthquake. Additionally, seismic separators reduce the energy produced by structural component's deformations at the DBE level. Due to the energy absorption capacity of the structure before collapse, the non-collapse of the structure can be ensured. Also, as it can be observed, in lower-storey structures, the amount of energy depletion of isolators is greater. This matter returns to the acceleration response spectrum that in high period regions (higher order structures), the rate of acceleration response drop relative to the increase ratio of the period, is less than that of low periods.

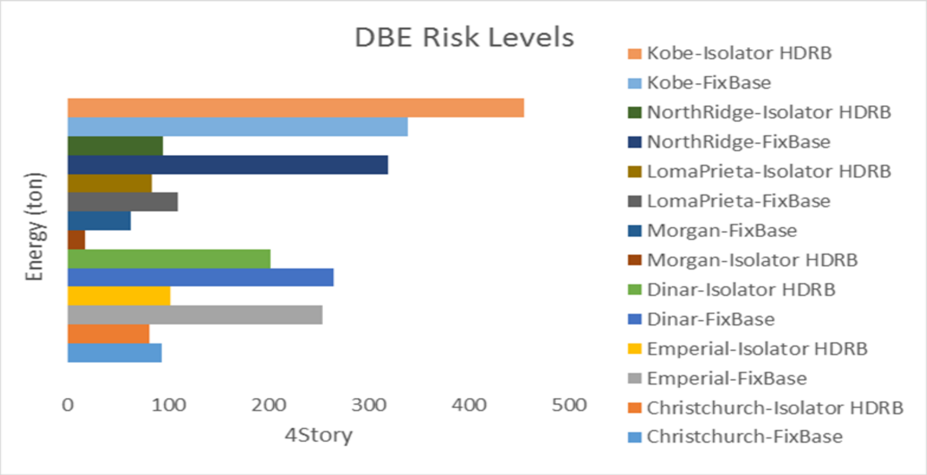

Diagram 4. Input energy to the 4-storey structure with isolator and without isolator.

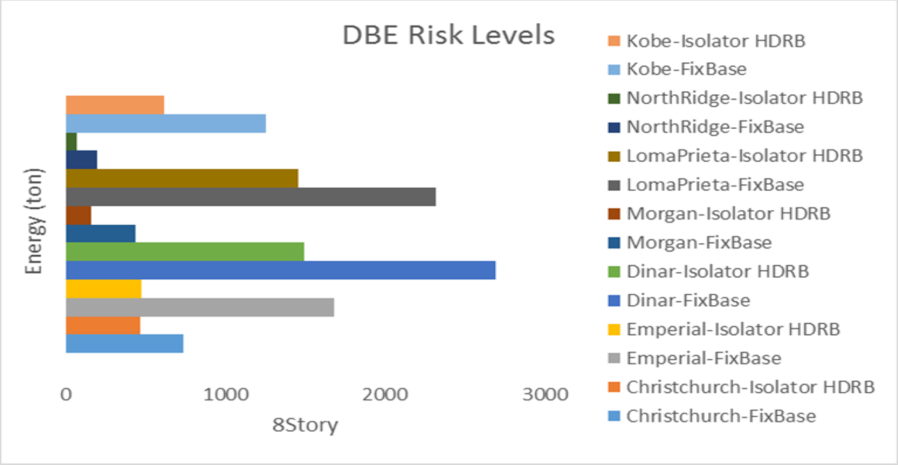

Diagram 5. Input energy to the 8-storey structure with isolator and without isolator.

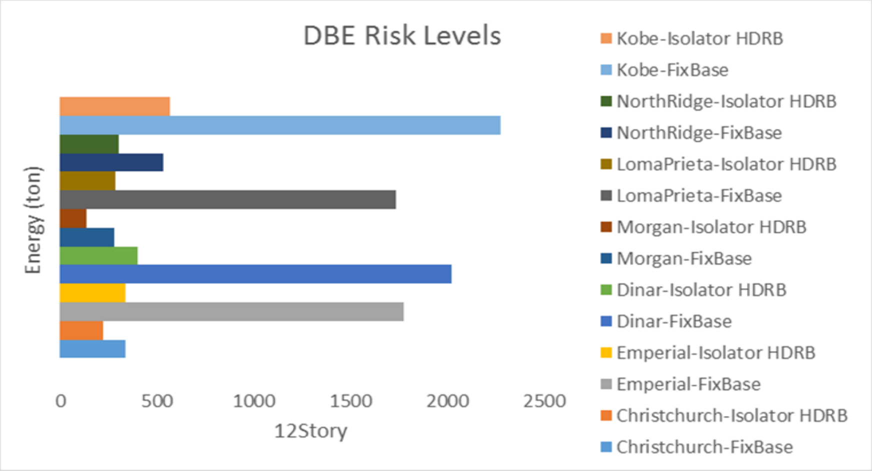

Diagram 6. Input energy to the 12-storey structure with isolator and without isolator.

Conclusion

In this study, the following results are obtained by examining and analyzing the desired data and comparing the dynamic responses of three concrete buildings with 4, 8 and 12 storey of moment frames with a special ductility in two clamping base state and seismic isolator of high-damping isolators under seismic ranges of near fault zone:

- Since one of the collapse criteria is the class drift, therefore, it can be ensured the stability of the structure in large earthquakes with a long return period using seismic isolator. In structures with 4, 8 and 12 storey, the reduction in drift rates in seismic isolators' structures is on average 58%, 48.71% and 36.48%, respectively, relative to fixed base structures under acceleration of reflected mappings.
- The amount of energy depreciated at DBE hazard level shows effective performance compared to fix base structures in isolated structures using seismic isolator (HDRB). In addition to seismic isolators, reduces the energy resulting from structural component's deformation. Due to the energy absorption capacity of the structure before collapse,

the lack of collapse of the structure can be ensured. Also, as it can be observed, in lower-storey structures, the energy depreciation of isolators is greater. The reason of this matter returns to the acceleration response spectrum in zones with high periods (higher order structures), the rate of acceleration response drop than that period increasing is less amount relative to the low periods. In structures 4, 8, and 12, energy depreciation storey in seismic isolator structures have been obtained on average 65.34%, 59.42% and 53%, respectively, relative to fix base structures that are under reflected acceleration mappings.

References

Skinner, R. (2004). Design and implementation of seismic separation of applications in buildings, bridges and other structures along with modeling. In ETABS and SAP2000, translation of Alireza Salehin and Hassan Mohammadi, Tehran: Farahmand University of Publication: Adena.

Yousefi, R., Tavakoli, H., & Bani Hashem, M., (2015). The Effect of Vertical Component of Near-Earthquakes on Structures Isolated on Base with High-Damping Rubber Separator, Second International Conference and Sixth National Conference on Earthquake and Structures, Kerman, University of Kerman.

Dhawade, S. M. (2014). Comparative study for seismic performance of base isolated and fixed base RC frame structure. International Journal of Civil Engineering Research, 5, 183-190.

Anderson, J., & Christopher, A. (2009). Design of Seismic Structures 2, Center for Academic Publishing.

Davoudi, M., Feizi, R., & Hadiani N., (2010). Investigating the effect of far and near-earthquakes on seismic behavior of several types. Various types of earthquakes, Seismology and earthquake engineering, 13th year, Number three and four.

Khosravani, M. A. (2013). Collected leaflet of near-earthquakes.

Federal Emergency Management Agency (FEMA). (2009). Quantization of Building Seismic Performance Factors, p:695.

The Pacific Earthquake Engineering Research Center (PEER). (1997). A research and education center with headquarters at the University of California, Berkeley.

Housing and Urban Development Research Center, Building Design Regulations against Earthquake, Standard 2800, Fourth Edition, 2015.

Citation: Fazel, M., Mostafa, K. N., & Bashir, Y. (2018). Comparison of drift and energy depreciation in concrete moment frames using HDRB isolators under near-fault earthquakes. Ukrainian Journal of Ecology, *8*(2): 326-333.