Підвищення сейсмічної стійкості мостів з опорами з просвинцованою гумою в Ірані

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Як правило, вважається, що завданням стійких до землетрусів конструкції є передавання сейсмічних навантажень до фундаментів споруди. Ці навантаження розподіляються і переносяться на бічні, спеціально спроектовані опорні елементи. Останнім часом в проектах сейсмічно стійких конструкцій використовуються ізолятори.

З огляду на сейсмічне розташування Ірану і важливість мостів, зокрема на головних артеріях, необхідно розробити нові методи їх проектування. Незважаючи на використання гумових елементів в мостових опорах на території Ірану, просвинцована гума (LRB) – поширена в усьому світі система ізоляції, досі тут не використовувалася. У роботі розглядається ефективність різних LRB на основі параметрів двох мостів (Рис. 1 і 2). Їх прогонові споруди створено і спроектовано на основі збірних бетонних конструкцій з використанням програми Sap2000. Для кращого порівняння, розглядаються моделі трьох різних систем: 1 – з гумовою опорою; 2 – з LRB опорою, вид A; 3 – з LRB опорою, вид B. На наступному етапі проведено аналіз нелінійної часової діаграми та стійкості мостів в умовах сильних рухів землі, що були записані під час двох недавніх землетрусів.

Як вказано на Рис. 4–7, при застосуванні ізоляторів, зсув основи є значно меншим. Відповідно до рисунків, можна зробити висновок, що подовжній і поперечний зсув основи моста є меншим в ізольованій моделі на відповідно 29% і 19%.

Як видно на Рис. 12–14, завдяки використанню LRB A і B зсув в биках моста є меншим на 56% і 64%. При використанні LRB, зниження зміщення в рамових опорах підтверджено для жорстких мостів. Результати дослідження проведені на гнучких мостах є зовсім іншими. Дослідження показало, що гумові опори не дорівнюють під оглядом дисипації енергії мостам з застосуванням ізоляторів. Не є вони також так ефективними для зниження зрушуючих сил. З іншого боку сейсмічні ізолятори можуть балансувати застосовані сейсмічні навантаження на биках і упорах мостів.

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Improving Seismic Behaviour of Bridges with Lead Rubber Bearing in Iran

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Construction of roads in Iran has received a considerable attention during these years. In this issue, the special geographic conditions of this country make bridge structures vital. Because of seismic location of Iran, attention to the reduction of risks is needed. Previous studies on seismic response of bridges prove the effective rules of isolators against the tremendous usage of elastomeric bearings in Iran. Lead rubber bearing (LRB) is one of the isolators that comprised of alternate layers of steel and vulcanized rubber with a central lead core. This paper describes the analytical study on seismic response of two concrete bridges with or without LRB based on a 3D time history nonlinear analysis using Sap2000 program. The models were subjected to strong seismic motions recorded near to the zone. Results show the beneficial effect of the isolation system in comparison with elastomeric bearing system on capability of energy dissipation. Not only, isolators reduce the base shear on bridges but also reduce shear force and bending moment of piers as well. According to this research deck displacement in isolated bridges reduces considerably whereas bent displacement is not effected practically in flexible bridges.

Keywords – Earthquake, Bridge, Base Isolator, Bearing, Time History

I. Introduction

Base Isolation of structures is a method of passive control against earthquake that is used to design and retrofit of modern bridges. According to this method, as an earthquake occurs, the structure separates by creating a flexible level in its base and as a result seismic demands of structure will be reduced. Therefore, an isolated structure will have a better behavior compared to the structure without isolator. The increase of the main period in a bridge structure is one of the effects of isolator utilize. In rigid structures specially general bridges with short piers and abutments, the period is very low and near to the period of earthquake that causes seismic responses. In such circumstances, with the increasing of the period, the applied loads on bridges will be reduced. Hence seismic isolation is a sure way to design resistant bridges against earthquakes.

Regardless of the large number of structures isolated in the world, there is no bridge that built with base isolators in Iran and two of the main impediments for general use of these systems are: first, the demand for regular construction method by focus on a common bearing system and second, the lack of regulation code with specific recommendation rules for the design of base isolated structures.

II. Isolators

Lead Rubber Bearing known as LRB are comprised of alternate layers of steel and vulcanized rubber with a cylindrical lead core. In this type of isolator appropriate dissipative capability provided by lead core. Excremental tests confirm that the force-displacement hysteresis loop of LRB can be reasonably described as a bilinear with an initial elastic stiffness followed by a post yield stiffness much lower than the former. The specifications of two different LRB used in this paper is shown In Table I.

Table I

LRB ISOLATORS SPECIFICATION

LRB Type	G Mpa	Ke KN/mm	Kv Kn/mm
A	0.4	1.95	1160
B	0.6	7.15	5650

III. Analytical Study

Precast concrete girder deck is a common choose in the design of bridges with spans between 15 to 25 meters in Iran. In this research, two bridges that have designed recently are analyzed using Sap2000 program on a 3D time history nonlinear analysis with elastomeric bearing or LRB isolator. In the modeling of isolators, it has been used LINK elements with the type of rubber isolator. The structure of these bridges is upon pinned connection of girders on piers and abutments. Figs. 1 and 2

Sento Bridge - The first bride has a total length of 140 meters and five equal spans, designed with the cast-in-place reinforced concrete piers and abutments, located at the surround of Tabriz-Iran. This bridge will be constructed with a superstructure of six precast girders and a concrete slab that distributes the applied loads on the girders.

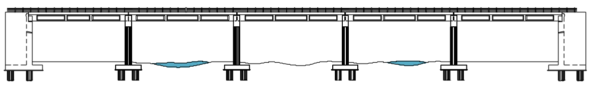

Fig.1 Sento Bridge Elevation

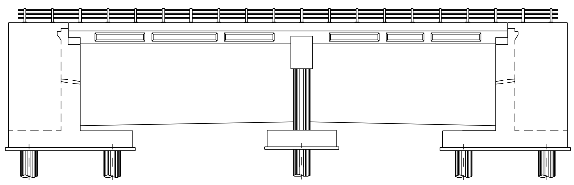

Fig.2 Aflak Bridge Elevation

Aflak Bridge - This bridge is located in downtown of Tabriz with the total length of 36 meters that will be constructed in 2 equal spans. Substructure and superstructure of this bridge are the same with Sento bridge. The distinctions between these two bridges are in the number of girders and the height of piers. In both bridges will be used elastomeric bearing system.

Seismic records of two most important earthquake that was recorded close to the north-west of Iran used in time history analyze. Tabas was recorded during the 16th September 1978 with a maximum longitudinal ground accelarion of 0.836g. Naghan was recorded during the 6th April 1977 with a maximum longitudinal ground accelarion of 0.723g. The longitudinal components of the original ground accelerations were linearly scaled so that their peak ground acceleration (PGAs) are 0.4g. Fig. 2 show seismic response of the Tabas earthquake.

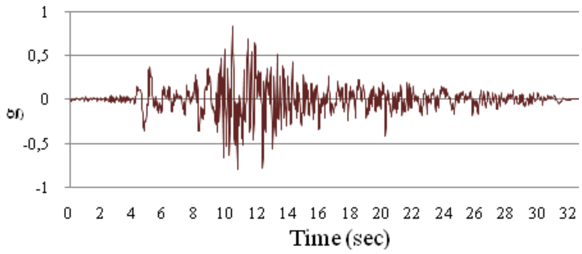

Fig.3 Seismic Response of Tabas Earthquake

IV. Period and Energy Dissipation

Table II shows the main period of bridges in six different cases. As seen in the case of stiff behavior in bridges, the usage of isolators seems vital and by utilizing the stiff isolator B main period of the bridge structures will be reduced.

Table II

MAIN PERIOD OF MODELS

Model	Period (Sec.)
Sento with Elastomeric Bearing	0.42
Sento with LRB A	1.38
Sento with LRB B	1.31
Aflak with Elastomeric Bearing	0.18
Aflak with LRB A	0.56
Aflak with LRB B	0.46

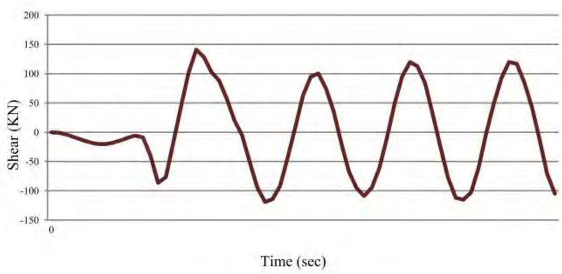

Fig. 4 shows shear of LRB type A on the abutment of Sento and Aflak subjected to Naghan earthquake

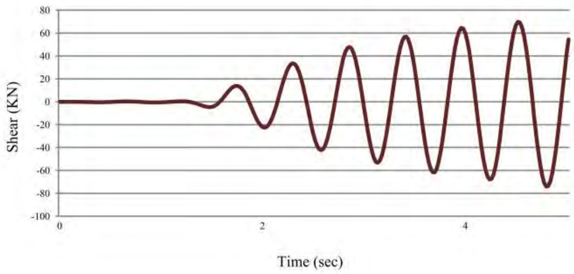

Fig.4 Shear of LRB Type A on the Sento and Aflak

Because of flexible behavior of Sento Bridge, it can be found more increase. Bilinear behaviors of these isolators and their important rules in energy dissipation are clear.

V. Base Shear

As shown in figs. 5 to 7, base shear are strongly reduced when we utilized isolators. For better comparison of the maximum base shear in bridges, six different cases under two kinds of earthquakes are shown in fig. 8.

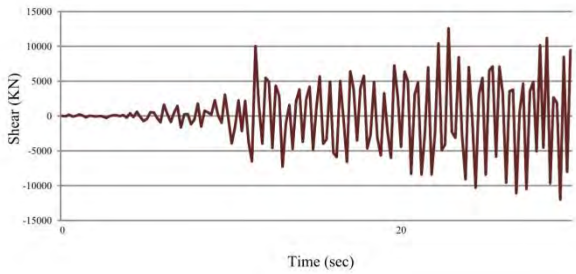

Fig.5 Base Shear in Aflak Bridge without Isolator

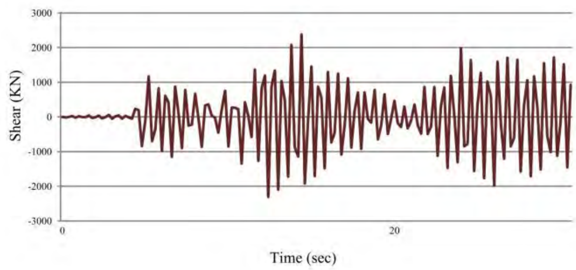

Fig.*6 Base Shear in Aflak Bridge with LRB Type A*

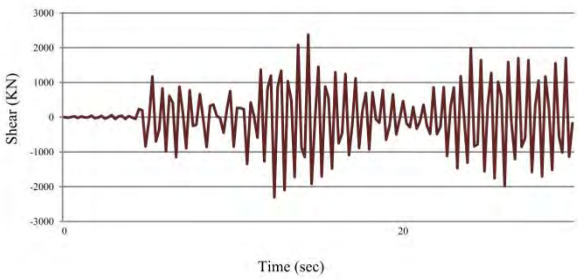

Fig.7 Base Shear in Aflak Bridge with LRB Type B

According to the figures ,it can be concluded that longitudinal base shear of the first bridge is reduced in the isolated model up to 29% subjected Naghan and up to 19% subjected Tabas. On the other hand, in transversal direct it reduced up to 19% in isolated system. As seen for the Aflak bridge reduction is more notable.

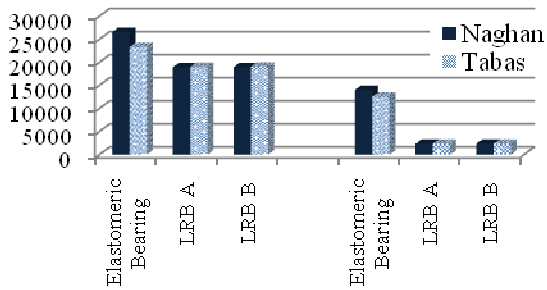

Fig.8Comparison of Base Shear in Six Different Cases

VI. Displacement

Figs. 9 to 11 show displacement for one point in the middle of deck and for another point on the bent of Aflak bridge. These time histories have been processed based on the Tabas earthquake record. The result shows that the maximum deck displacement of the bridge was increased about 11% by using type A isolator. The maximum deck displacement showed a increase of 12% by using type B isolator. By evaluation of results in Sento bridge it was also found that increasing the spans of the bridge would not improve the overall performance of isolators.

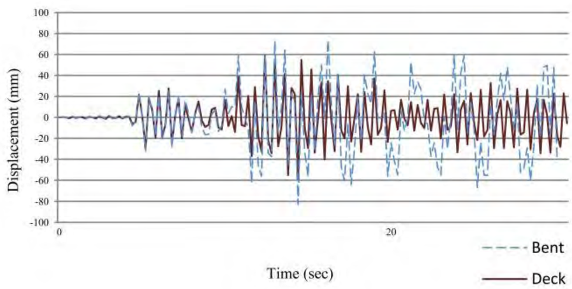

Fig.9 Deck Displacement in Aflak Bridge without Isolator

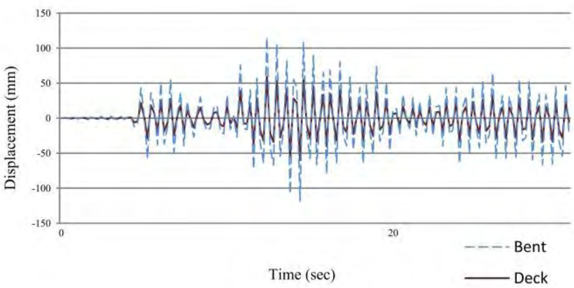

Fig.10 Deck Displacement in Aflak Bridge LRB Type A

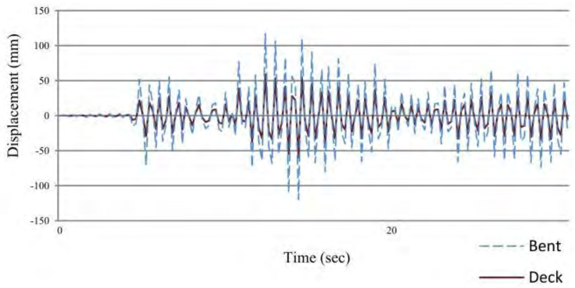

Fig.11 Deck Displacement in Aflak Bridge LRB Type B

In fact, isolation systems will have a better result in the reduction of bridge's displacement with more rigidity. In non-isolated systems with short spans and piers, the distribution of lateral loads is based on the stiffness of elements but in the isolated systems, applied loads on bent is reduced and consequently the displacement is decreased as well. Despite the reduction of seismic loads, bent displacements increase in flexible bridges.

Shear in Piers

Figs.12 to 14 show time histories of the shear forces at the piers for the uncontrolled Aflak bridge and same isolated bridge subjected to Tabas earthquake.

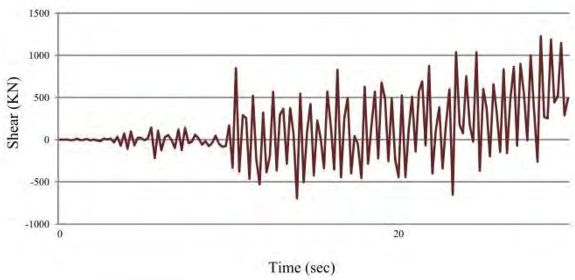

Fig.12 Shear in Piers of Aflak Bridge without isolator

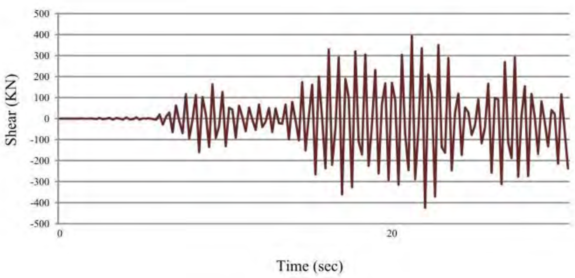

Fig.13 Shear in Piers of Aflak Bridge with LRB type A

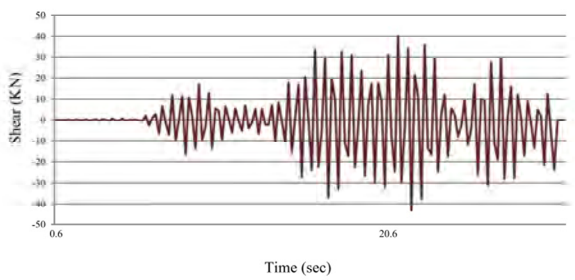

Fig.14 Shear in Piers of Aflak Bridge with LRB type B

Shear force of the piers on isolated Sento bridge has been reduced 49% to 56% whereas in the case of using elastomeric bearing has not decreased. In Aflak bridge with short spans and piers, shear force of the piers in the isolated system has decreased 64%.

Conclusion

In this paper, bridge structures isolated by lead rubber bearing (LRB) based on time history analyze of ground motion are considered. These bridges are located in the regions with high risk of earthquake. The importance of using LRB in bridges was considered through four aspects: First, using of isolator increases period in bridges obviously. This increase is more considerable due to using isolators with more stiffness. Second, Maximum displacements of the bridge with or without isolators are not quite different but it is evident from the graphs the lengthening of the bridge period when isolators are incorporated. According to the use of high stiffness isolators, deck displacement decreases; bent displacement will remain unchanging mostly. Finally, pier shear and bent shears are effected by isolators.

Efficiency of elastomeric bearings is not as well as isolators and don't have enough damping and energy dissipation so can't decrease applied shear force on bridges. Furthermore, there is sensitivity in the response of isolated bridge to ground motion specification such as intensity, duration and frequency content. Thus, site seismic study in the design of isolated bridges seems vital.

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