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A Comparative Study on Seismic Response of Bridge with Elastomeric Bearing and Elastomeric Isolator

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Abstract: **The aim of study is to investigate the effect of seismic isolation on the seismic response of bridge components. In this study, first existing bridge with Elastomeric bridge bearing is modelled and analysed to get the seismic response of bridge components and then this results are compared with Elastomeric isolator in place of elastomeric bearing. Modelling and analysis of Highway Bridge is done with help of Structural Analysis and Program 2000 Software. Time history analysis of bridge is conducted for 1940 Imperial Valley earthquake ground motion record. It is found from analysis results that significant reduction in seismic response of bridge components can be achieved by replacing elastomeric bearing with elastomeric isolator.**

1. INTRODUCTION

Conventional idea of designing an earthquake resistant structure is having stiff and strong enough structural components to accommodate foreseeable lateral forces induced due to earthquake. The drawback of conventional approach lies in absorbing all lateral forces induced due to earthquake. This resulted into increase in cost of construction of earthquake resistant structure. Somewhere around 1900 idea of base or seismic isolation came into theory and become practically viable in 1970 for earthquake resistant design of structure. The concept of seismic isolation consists of installation of support mechanism, which decouples structure from earthquake induced ground motion. Seismic isolation reduces fundamental frequency of structural vibration to a value lower than predominant energy-containing frequencies of earthquake.

Also it provides a means energy dissipation, which dissipates energy transmitted to structure. In other words seismic isolation is a strategy that attempts to reduce seismic forces to or near elastic capacity of structural member, thereby eliminating or reducing inelastic deformations. In short, in conventional approach capacity of structural elements is increased and in seismic isolation approach, demand arising due to earthquake is reduced.

Laminated elastomeric bearing, High damping rubber bearing, Lead-Rubber bearing, Friction pendulum bearing are common types of isolation bearing and it can be applied to a variety of structures like buildings, bridges, nuclear reactors, water tanks etc. At first, the idea of seismic isolation is used for construction of building (Imperial hotel, Tokyo) by Frank Lloyd Wright in 1921. In it he used two layers of soil (fairly good soil and soft mud) as seismic isolation to relieve the terrible shocks [1]. In the late twenties and thirties concept of first storey as soft storey was proposed. It reduced the acceleration of upper levels but resulted into concentrated deformation in first storey column due to low damping and consequently disturbing the stability of column and structure finally. Later on many types of roller bearings developed and patented but the problem with this bearing is low damping, no restoring force and no inherent resistance to wind [1].

The first use of rubber for protecting structure from earthquake is done in 1969 for construction of elementary school building (Yugoslavia). The building is three- storied concrete structure rest on large blocks of natural rubber. As natural rubber blocks are unreinforced, it bulged sideways due to weight of structure. To avoid this lateral bulging of rubber block, steel plates are added to it, called as laminated rubber bearing [1]. Laminated rubber bearing being stiff in vertical direction and flexible in horizontal direction, it reduced horizontal component of earthquake acceleration transmitted to structure but increased deformation at the level of rubber bearing due to low damping in it. A. Ghobarah and H.M. Ali studied seismic response of highway bridges in 1987 and concluded that use of lead plug in isolation devices is very efficient energy dissipation system; it reduced shear force transmitted to pier but increased displacement of bridge deck [2]. Kyu-Sik park, Hyung-Jo Jung and In-Won Lee compared seismic performance of three span continuous bridge with various base isolation systems like pure-friction, laminated rubber bearing, lead rubber bearing etc. and concluded that peak responses of bridge with friction type bearing are less sensitive to substantial variations in frequency range and intensity of ground excitation than those with rubber type bearing [3]. Muhammad Chaudhary, Masato Abe and Yojo Fujino investigated seismic response of bridge for moderate to small earthquakes, observed that some of transverse side-stoppers obstructed the movement of isolation bearings and found that malfunctioning of base-isolation bearings at one pier resulted in substantially unequal lateral load distribution to the substructure [4]. Under the parametric study of base- isolated structure by R.S. Jangid, found that effects of viscous damping are insignificant when the additional damping in the isolation system in the form of such as hysteretic (due to yielding of lead-core) or friction is present [5]. Gordon P. Warn, Andrew S. Whittaker investigated the performance of seismically isolated bridge structures subjected to earthquake excitation. In it performance is assessed by maximum isolator displacement and energy demand imposed on individual seismic isolators. He found that Maximum isolator displacements determined from bidirectional seismic excitation are significantly larger than those considering unidirectional seismic excitation [6]. Murat Dicleli, Mohamed Y. Mansour and Michael C. Constantinou studied the efficiency of seismic isolation for seismic retrofitting of bridges with light superstructures and heavy substructures.

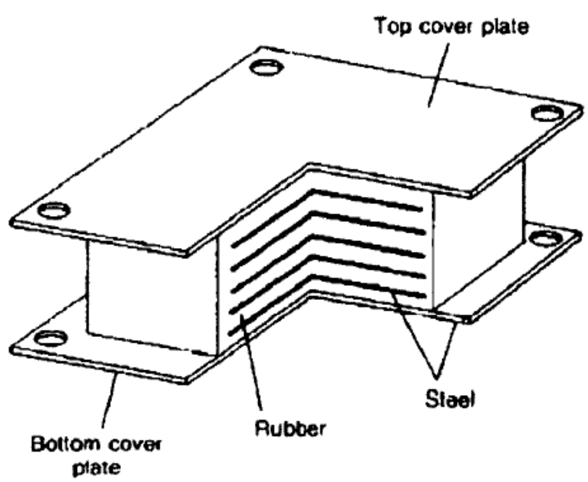

Fig. 1. Typical Elastomeric Bearing

He found that seismic isolation bearings effectively mitigated the seismic forces and eliminated the need for retrofitting of the substructures [7]. Murat Dicleli and Srikanth Buddaram studied the effect of isolator properties as well as the frequency characteristics and intensity of the ground motion on the performance of seismic-isolated bridges. He concluded that seismically isolated bridge response is a function of the peak ground acceleration to peak ground velocity ratio of the ground motion. Furthermore, the isolator post-elastic stiffness is found to have a notable effect on the response of seismically isolated bridge [8]. Murat Dicleli investigated the efficiency of providing supplemental elastic stiffness to seismic-isolated bridges for reducing the isolator displacements while keeping the substructure forces in reasonable ranges. He confirmed that supplemental elastic devices may be used to reduce the displacement of isolators while keeping the substructure base shear forces in reasonable ranges for seismically isolated bridges located in near fault zones [9]. Gordon P. Warn, Andrew S. Whittaker and Michael C. Constantinou summarised an experimental study investigating the influence of lateral displacement on the vertical stiffness of elastomeric and lead–rubber seismic isolation bearings. He found that vertical stiffness decreases with increasing lateral displacement for each bearing tested [10].

2. DESCRIPTION OF BRIDGE AND BRIDGE MODELING

Existing bridge is located in Beed, on the National Highway No. 211 across Bindusara River. The bridge is 42 m long and 7.95 m wide and consists of three span continuous reinforced concrete girder. Superstructure consists of 300 mm deep reinforced concrete deck slab supported by three reinforced concrete girders of 1100 mm depth. Solid piers of 4.0 m width and 1.0 m thick of rest on firm soil strata. In modelling of bridge, deck is modelled as thin shell element. Girders and Pier are modelled as Frame element. Elastomeric bearing is modelled as linear type link and elastomeric isolator is modelled as rubber isolator type link element. Fig 1 shows model of bridge analysed using SAP 2000.

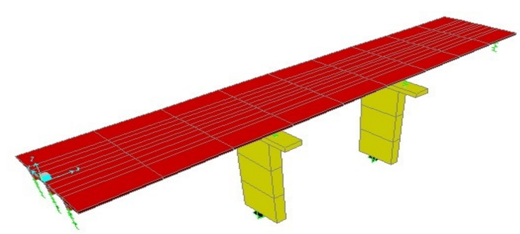

Fig. 2. Bridge model in SAP 2000

In present study, first bridge is modelled and analysed with conventional elastomeric bridge bearing and results found then this bearings are replaced with elastomeric isolation bearing and analysis is made and results compared. The difference between conventional elastomeric and elastomeric isolation bearing is that elastomeric isolation bearing are more flexible in horizontal direction than that of conventional elastomeric bearing and same vertical stiffness. The horizontal flexibility and damping characteristics of the bearing provide the desired isolation effects in the system .The horizontal flexibility transmits relatively limited earthquake forces from the piers to the superstructure. On the other hand, the damping of the bearing dissipates the seismic energy, thereby reducing the design displacement of the bridge. The following assumptions are made for the earthquake analysis of the isolated bridges under consideration.

1. The bridge superstructure and piers are assumed to remain in the elastic state during the earthquake excitation. This is a reasonable assumption, as the isolation attempts to reduce the earthquake response in such a way that the structure remains within the elastic range.

2. The deck of bridge is straight. Deck and abutments of bridge are assumed to be rigid.

3. The bridge piers are assumed to be rigidly fixed at the foundation level.

4. The bridge is founded on firm soil or rock and soil-structure interaction effect is ignored.

5. The bearings provided at abutment and pier has same dynamic properties.

Seismic response of bridge is found by time history analysis. Imperial Valley earthquake ground motion record is used for time history analysis of bridge. This bridge is then modelled and analysed with conventional elastomeric bridge bearing and then this elastomeric bearing replaced with elastomeric isolator. Stiffness properties of elastomeric bearing and elastomeric isolator used in analysis of bridge are as follows:

TABLE 1. Stiffness values of Elastomeric bearing and isolator

	K_V (kN/m)	K_H (kN/m)	K_L (kN/m)
Elastomeric Bearing	457000	7500	7500
Elastomeric Isolator	67000	300	300

3. INPUT GROUND MOTION

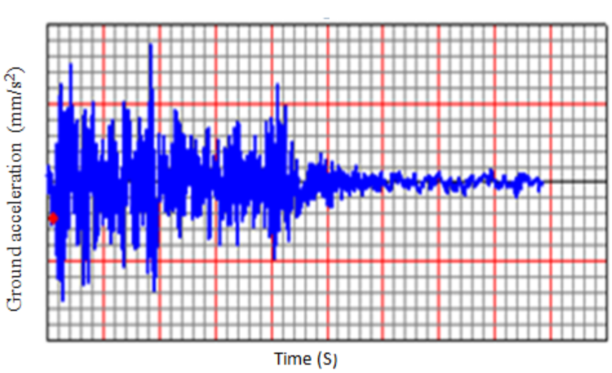

Fig. 3. Ground acceleration Vs. Time record of Imperial Valley earthquake

Ground motion records of 180° component recorded at EL-Centro during May 18, 1940 Imperial Valley earthquake were obtained and used in study.

4. RESULTS AND DISCUSSION

After performing time history analysis of bridge, seismic response of bridge is scrutinized and compiled results are presented in following Table 2, Table 3 and Table 4

TABLE 2: Results of Time period, acceleration and base shear

	Fundamental Time Period (s)	Absolute Deck Acceleration (g)	Base Shear (F_x in kN)
Elastomeric Bearing	0.5	0.6896	7116
Elastomeric Isolator	2.023	0.2234	1283

In above Table 2 Significant increase in fundamental time period is observed due to horizontal flexibility of elastomeric isolator and resultant change in seismic response is reduction in absolute acceleration of deck and base shear in pier values.

TABLE 3: Results of Deformation in Bearing and Isolator

	Deformation (mm)			
	Abutment		Pier	
	U_3	U_2	U_3	U_2
Elastomeric Bearing	41.19	7.393E-03	14.329	0.2184
Elastomeric Isolator	226.9	1.875E-03	211	0.0228

In above Table 3. U3 and U_2 show deformation in longitudinal and transverse direction respectively. From Table 3. It is found that with use of elastomeric isolator, increase in longitudinal deformation takes place with negligible effect on transverse deformation. So special care is to be taken to arrest this increased deformation in longitudinal like add damping to laminated elastomeric isolator or providing supplemental energy dissipating devices.

TABLE 4: Results of Joint displacement

	Joint Displacement (mm)			
	Abutment		Pier	
	U_3	U_2	U_3	U_2
Elastomeric Bearing	50.324	96.123	52.85	53.178
Elastomeric Isolator	227.24	88.608	227.24	52.574

From above Table 4. It is cleared that joint displacement also shows the same behavior as that of bearing and isolator deformation.

5. CONCLUSION

From the study it is concluded that elastomeric bearing can be replaced with elastomeric isolator as it reduces significant amount of the base shear coming on pier. So the reduction in size and amount of reinforcement in pier and foundation can be achieved and ultimately economy of structure. But the limitation is that special care is to be taken to arrest the increased deformation of elastomeric isolator.

REFERENCES

[1] James M. Kelly, "Aseismic base isolation: review and bibliography ", *Soil Dynamics and Earthquake Engineering*, 1986, Vol.5, no.3, pp. 202-216.

[2] A. Ghobarah and H. M. Ali, "Seismic performance of highway bridges ", *Engineering Structures*, 1988, Vol.10, pp. 157-166.

[3] Kyu-Sik Park, Hyung-Jo Jung, In-Won Lee , "A comparative study on aseismic performances of base isolation systems for multi-span continuous bridge ", *Engineering Structures*,2002, Vol.24, pp. 1001-1013.

[4] Muhammad Tariq Amin Chaudhary, Masato Abe, Yozo Fujino, "Investigation of atypical seismic response of a base-isolated bridge ", *Engineering Structures*, 2002, Vol. 24, pp.945-953.

[5] R.S. Jangid, "Parametric Study of Base-Isolated Structures ", *Advances in Structural Engineering*", 2002, Vol. 5, no. 2, pp. 113-122.

[6] Gordon P. warn, Andrew S. Whittaker, "Performance estimates in seismically isolated bridge structures ", *Engineering Structure*", 2004, Vol. 26, pp. 1261-1278.

[7] Murat Dicleli, Mohmad Y. Monsour, "Efficiency of seismic isolation for seismic retrofitting of heavy substructured bridges ", *Journal of Bridge Engineering* ", July 1 2005, Vol. 10, no. 4, pp. 429-441.

[8] Murat Dicleli, Srikanth Buddaram, "Effect of isolator and ground motion characteristics on the performance of seismic-isolated bridges", *Earthquake Engineering and Structural Dynamics* ", 2006, Vol. 35, pp. 233-250.

[9] Murat Dicleli,"Supplementale lastic stiffness to reduce isolator displacements for seismic isolated bridge in near-fault zones ", *Engineering structure* ", 2007, Vol. 29, pp. 763-775.

[10] Gordon P. warn, Andrew S. Whittaker and Michael C. Constantania, "Vertical stiffness of elastomeric and lead- rubber seismic isolation bearings", *Journal of Structural engineering* , Sep 1 2007, Vol. 133, no. 9, pp. 1227-1236.

[11] M.C. Kunde, R.S. Jangid, "Seismic behavior of isolated bridges: A-state-of-the-art review ", *Electronic journal of Structural Engineering*, 2003, Vol.3, pp. 140-170.

[12] R.S. Jangid, "Seismic response of isolated bridges ", *Journal of Bridge Engineering* ", March/April 2004, Vol. 9, no. 2, pp. 156-166.

[13] Mohd Zamri Ramli, "Response Of Existing Rubber Bearing And Designed Base Isolator For Malaysian Highway Bridges ", *Proceedings of the 6th Asia-Pacific Structural Engineering and Construction Conference* ", 5-6 Sep. 2006, Kuala Lumpur, Malaysia.

[14] Georgios Kampas and Nicos Makris, "Transverse versus Longitudinal Eigenperiods of Multispan Seismically Isolated Bridges ", *Journal of Structural engineering*", Feb 1 2012, Vol. 138, no. 2, pp. 193-204.

[15] Atushi Mori, Peter J. Moss, "The behavior of bearings used for seismic isolation under shear and axial load", *Earthquake Spectra* ", May 1999, Vol. 15, no. 3, pp. 1001-1113