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SEISMIC RESPONSE OF CURVED CONTINUOUS BRIDGE ISOLATION WITH TRIPLE FRICTION PENDULUM SYSTEM (TFPS)

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ABSTRACT

In past earthquakes, most of the damages of the bridges occurred due to the failure of the bearings and substructure. Selection of isolation bearings for a curved bridge is a challenging task because of the complexity involved in curved bridges compare to straight bridges. In the present study a simplified lumped mass modal of curved continuous bridge is used foe investigation. The seismic response of the curved bridge with friction pendulum bearing (FPS) and Triple friction pendulum bearing (TFPS) is investigated under near fault ground motions. The response quantities of interest are the base shear, deck acceleration, bearing displacement and Hysteresis behavior. In order to verify the efficiency of FPS and TFPS in the curved bridge, comparison between responses of curved bridge isolated with FPS and TFPS and Non-isolated bridge has been made. The dynamic analysis has been carried out by using SAP2000 software. From the study, it is observed that the TFPS is more effective as compared to FPS in curved bridge subjected to near fault ground motions.

Keywords: Curved Bridge, Friction Pendulum System, Seismic Isolation, Triple Friction Pendulum System.

I. INTRODUCTION

The use of horizontally curved bridges is very important now days, especially to avoid congested traffic and also to solve the limited space requirement in urban traffic conditions. The only problem with these types of bridges is the significant amount of torsion which makes it difficult for design. From the study of damages caused by past earthquakes, it has been found that the performance of bridges is generally governed by the performance of bearings and substructure. Efficiency of isolation bearings, especially in case of curved bridges is important and selecting a proper isolation bearing is also an important task. This paper presents a study of the seismic response of a seven-span continuous curved bridge [1] with two types of isolation bearings that is FPS and Triple friction Pendulum System (TFPS). From the literature survey, it is concluded that there is lack of research is found particularly in seismic analysis of curved continuous bridge with TFPS. The objectives of the study are:

1. To investigate the behavior of TFPS in curved continuous bridge under the near field ground motions and

2. To compare the response of curved continuous bridge with FPS and TFPS in order to verify efficiency of the TFPS.
3. To compare the response of non-isolated bridge and isolated bridge in order to show the effectiveness of base isolation devices.

II. ISOLATION DEVICES

Different types of isolators are now available. However, the present study is limited to a comparative assessment of the seismic performance of the two types of devices viz. FPS [2]and TFPB [3].

The FPS is a sliding-based seismic isolator [4] with a restoring mechanism. The FPS provides resistance to service load by friction. Once the coefficient of friction is overcome an articulated slider moves over a spherical surface which causes the supported mass to rise and provides the restoring force for the system. Friction between the articulated slider and the spherical surface generates damping. The Coulomb damping generated through sliding friction provides energy dissipation in the bearings.

Single Pendulum Bearing
Cross Section

Single Pendulum Bearing
Maximum Credible Earthquake

Triple Pendulum Bearing
Cross Section

Triple Pendulum Bearing
Service Level Earthquake

Triple Pendulum Bearing
Design Base Earthquake

Triple Pendulum Bearing
Maximum Credible Earthquake

Figure 1. The possible position of FPS and TFPS bearing

The Triple Friction Pendulum bearing offers better seismic performance, lower bearing costs, and lower construction costs as compared to conventional seismic isolation technology. The properties of each of the bearing's three pendulums are chosen to become sequentially active at different earthquake strengths. As the ground motions become stronger, the bearing displacements increase. At greater displacements, the effective pendulum length and the effective damping increase, resulting in lower seismic forces and bearing displacements.

Series models and new element for TFPS is available in structural analysis programs SAP2000. In present study special element is used for modelling triple friction pendulum bearing. Series models of FPS for modelling TFPS also give appropriate overview of behaviour of TFPS [5]. This was observed in experimental testing and is also predicted analytically [6]. Sliding on the inner spherical recess of the slide plate occurs in the initial stage of motion, then stops when sliding begins at the outer sliding interface, and subsequently starts again when the slide plate contacts the displacement restrainers.

Three parameters are important for the design of the isolation bearings viz. the period of the isolated structure, the damping of the isolation system and the level of ground movement. In the present study the performance of different bearings has been compared.

III. MODELING OF BRIDGE

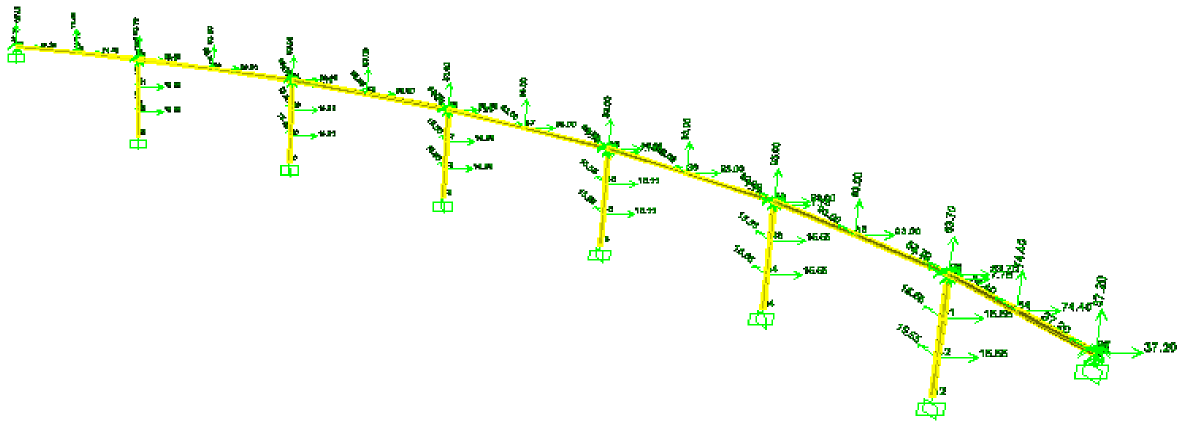


Figure 2 Lumped mass modal of curved bridge in SAP2000.

A continuous single-chamber box girder curved bridge has been considered. The total length of the curved bridge is 165 m with two end span of 20 m and five intermediate spans of 25m. The radius of curvature of the bridge is 150 m. The cross-sectional area of the box-girder is 3.1 m^2. The longitudinal moment of inertia and transverse moment of inertia of the box-girder is 0.60 m^4 and16.58 m^4, respectively. The pier has a solid circular section with cross-sectional area of 1.7671 m^2 and moment of inertia of 0.2485 m^4. The height of the pier is 11 m. The structure has been modelled using the SAP2000 software as lumped mass at discrete point as shown in Fig. 2. The superstructure and the piers have been modelled using beam elements with mass lumped at discrete points. The piers are resting on rock; these have been modelled as fixed at the base. The abutments have been assumed to be rigid. The isolation bearings have been modelled as NLlink elements. For modelling purposes, bilinear force-deformation relationship with yield force, yield displacement, elastic stiffness, and post-yield to elastic stiffness ratio has been considered for all the isolation bearings. Three earthquakes are used for analysis as shown in Fig.3.

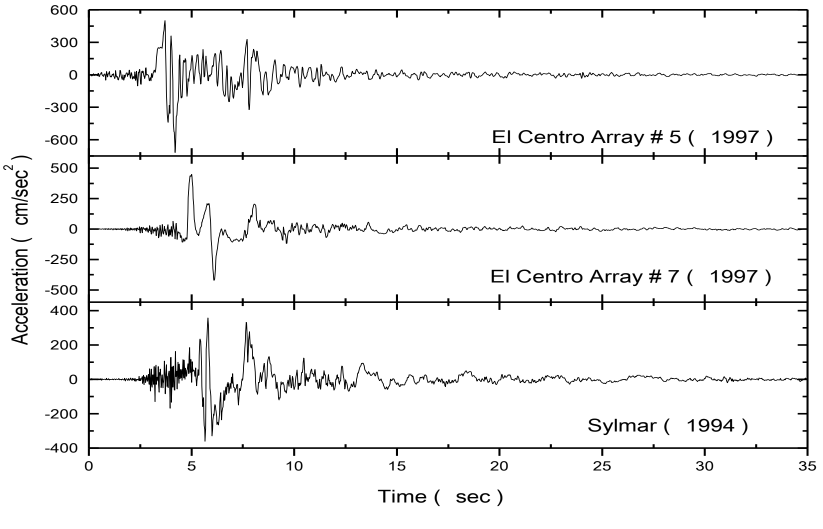


Figure 3. Near field ground motion used in study.

IV. PROPERTIES OF FPS AND TFPS

TABLE 1. Mechanical properties of FPS and TFPS for lateral direction.

Parameters	**FPS**	**TFPS**			
		Outer Top	Outer Bottom	Inner Top	Inner Bottom
Effective Stiffness (kN/m)	968.2916	1694.3523	1694.3523	1694.3523	1694.3523
Effective Damping	0	0	0	0	0
Elastic Stiffness (kN/m)	240900	525380.6	525380.6	525380.6	525380.6
Friction Coefficient, Slow	0.05	0.065	0.035	0.015	0.015
Friction Coefficient, Fast	0.05	0.13	0.07	0.03	0.03
Rate Parameter (sec/m)	43	100	100	100	100
Net Pendulum Radius (m)	1.5546	2.0955	2.0955	0.1905	0.1905
Stop Distance (m)	0	0.4572	0.4572	0.0508	0.0508

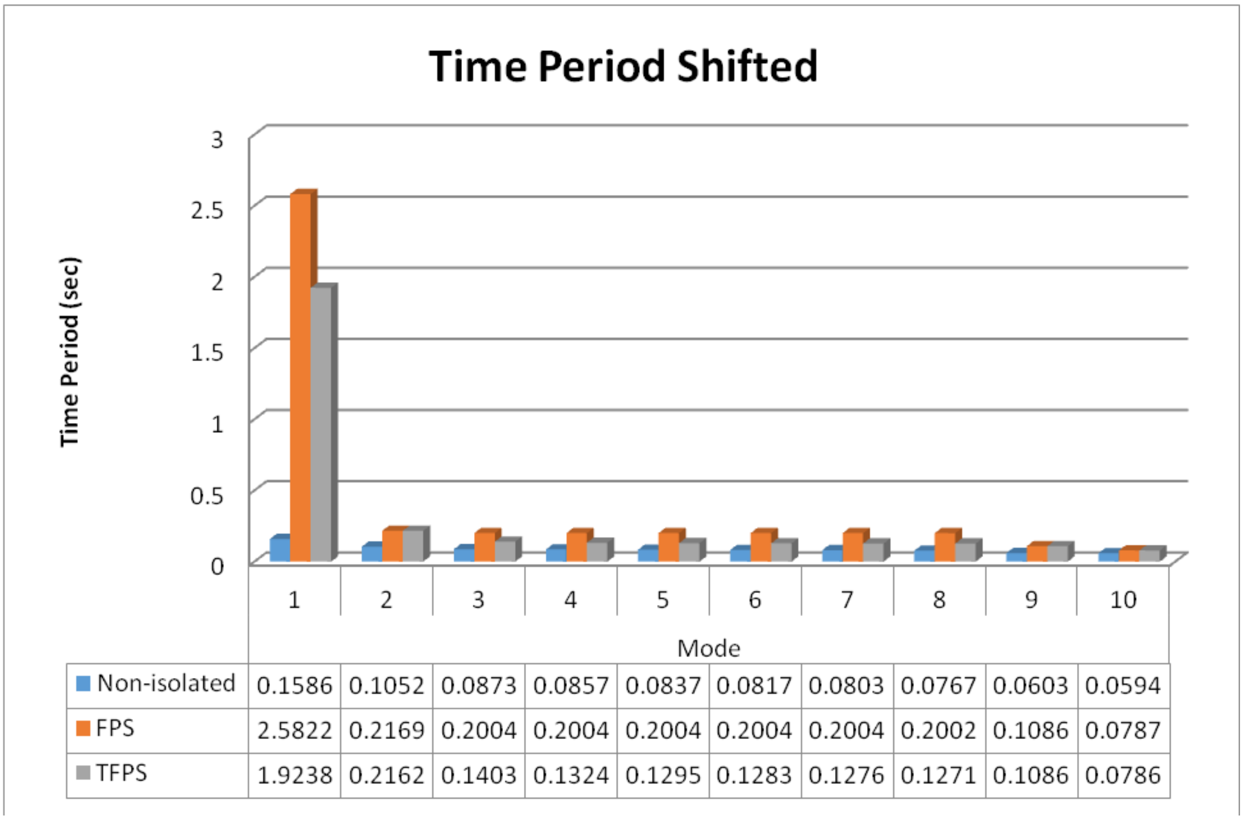
Above mentioned properties of FPS are calculated by using the equation given in [7] and for TFPS directly taken as shown in table TABLE 1. The vertical stiffness of both the isolators is assumed higher compare with lateral one. Some of the assumptions are made like time period of the isolator are 2.5 sec.

VII. RESULTS

The response of the curved bridges with the FPS bearing, TFPS bearings with Non-Isolated Bridge has been determined for three different near field ground motions as shown in Fig.3. The natural period of the isolated structure and damping of the isolation device are the most important parameters affecting the response of the structure. In the present paper the isolation time period of the isolation bearings have been considered as 2.5 sec. In case of responses, the resultant of the responses in the one longitudinal horizontal direction is considered. This is because, the considered bridges are curved bridges and the resultant of the response of perpendicular horizontal directions can be more effective from design consideration of bridges.

TABLE 2 Response of bridge in Isolation and Non-isolation condition.

Response	Non-Isolated	FPS	TFPS	Percent Reduction (%) for FPS	Percent Reduction (%) for TFPS	Remark
Base Shear (kN)	643.70	516.91	313.45	19.70	51.31	El Centro Array #5
	-531.27	-424.84	-265.24	20.03	50.07	
	593.41	443.57	324.68	25.25	45.29	El Centro Array #7
	-596.64	-384.52	-271.39	35.55	54.51	
	465.14	685.06	327.34	32.10	29.62	Sylmar
	-774.82	-525.00	-431.89	32.24	44.26	
Deck Acceleration (m/sec2)	8.70	3.08	1.48	64.56	82.98	El Centro Array #5
	-6.46	-2.50	-1.66	61.29	74.38	
	6.04	2.85	1.63	52.77	73.03	El Centro Array #7
	-5.05	-2.86	-1.67	43.31	67.02	
	8.55	2.99	1.52	64.99	82.19	Sylmar
	-12.14	-2.95	-1.59	75.69	86.91	



	1	2	3	4	5	6	7	8	9	10
■ Non-isolated	0.1586	0.1052	0.0873	0.0857	0.0837	0.0817	0.0803	0.0767	0.0603	0.0594
■ FPS	2.5822	0.2169	0.2004	0.2004	0.2004	0.2004	0.2004	0.2002	0.1086	0.0787
■ TFPS	1.9238	0.2162	0.1403	0.1324	0.1295	0.1283	0.1276	0.1271	0.1086	0.0786

Figure 4. Shifting of time period from Non-isolated to Isolated Bridge.

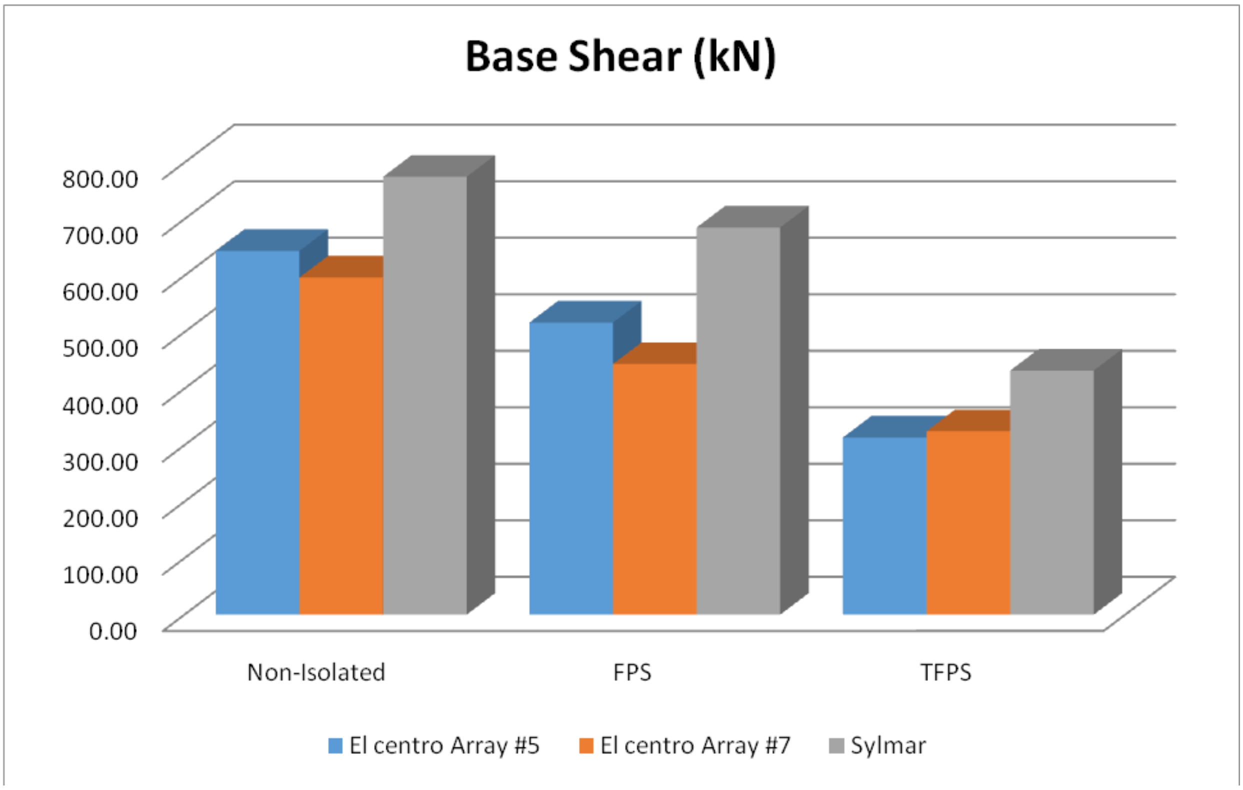


Figure 5 Peak response of base shear in isolated bridge with FPS, TFPS and Non-isolated condition.

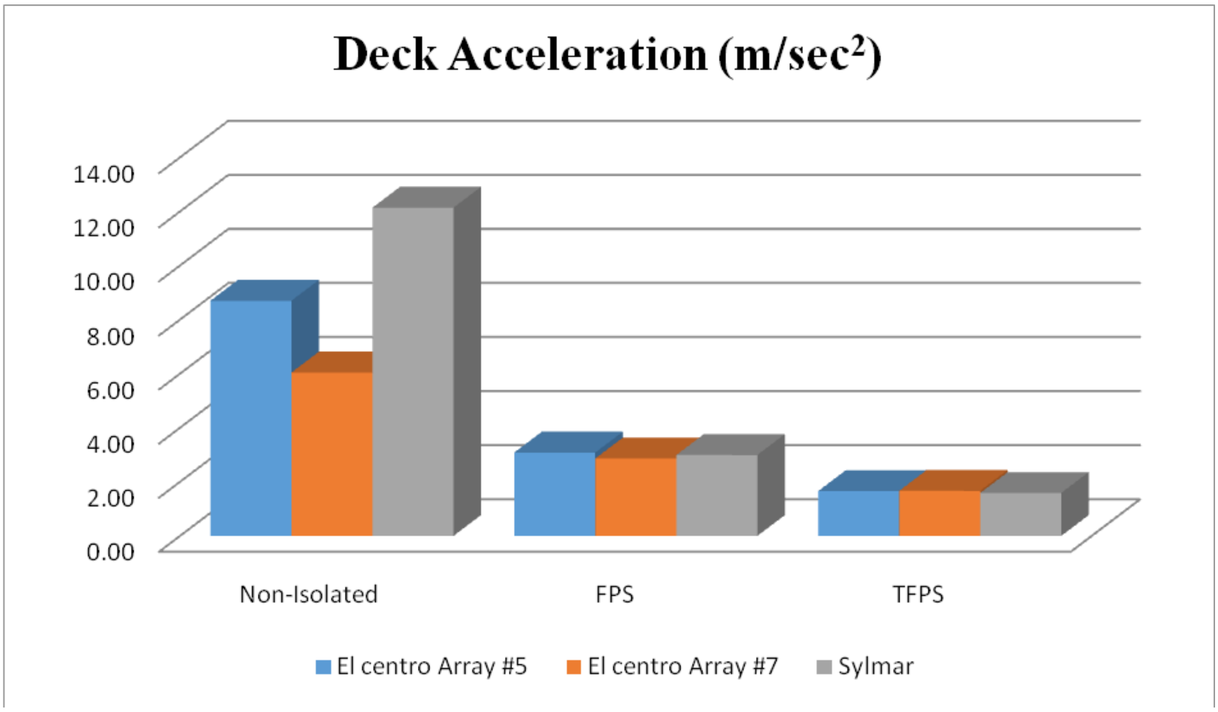


Figure 6 Peak response of deck acceleration in isolated bridge with FPS, TFPS and Non-isolated condition.

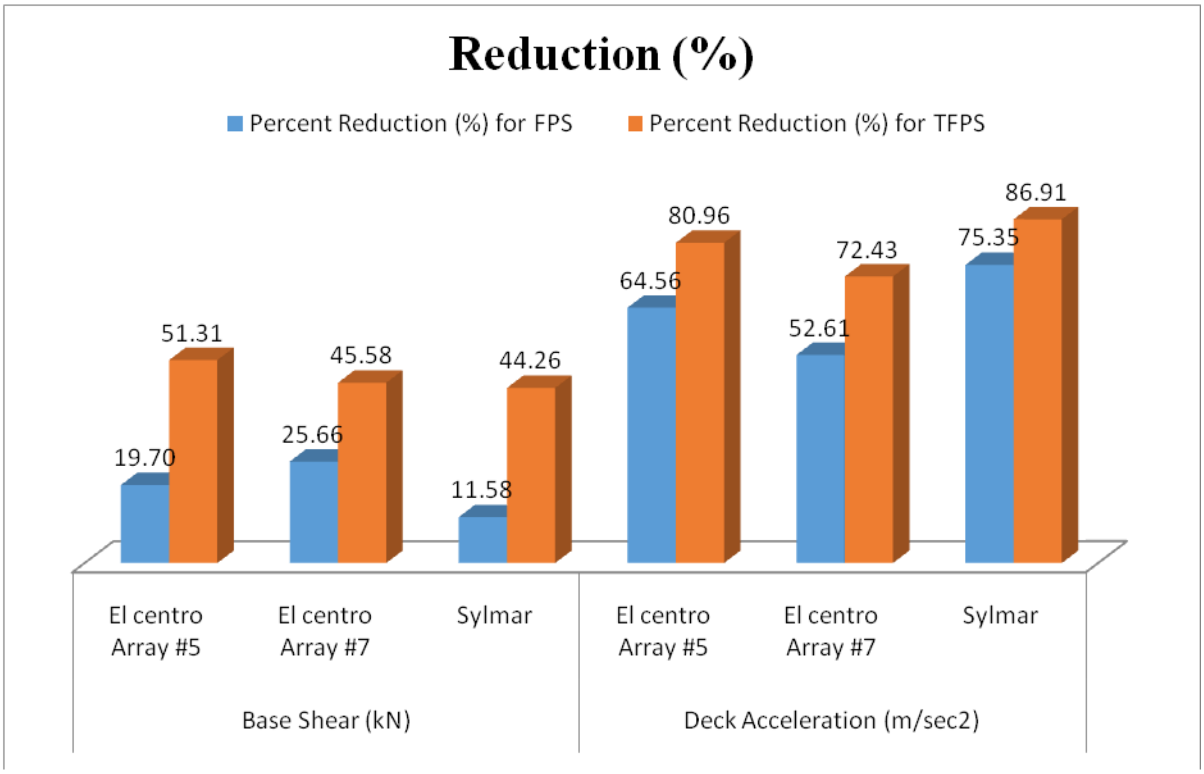


Figure 7 Reduction in base shear and deck acceleration in bridge with FPS and TFPS.

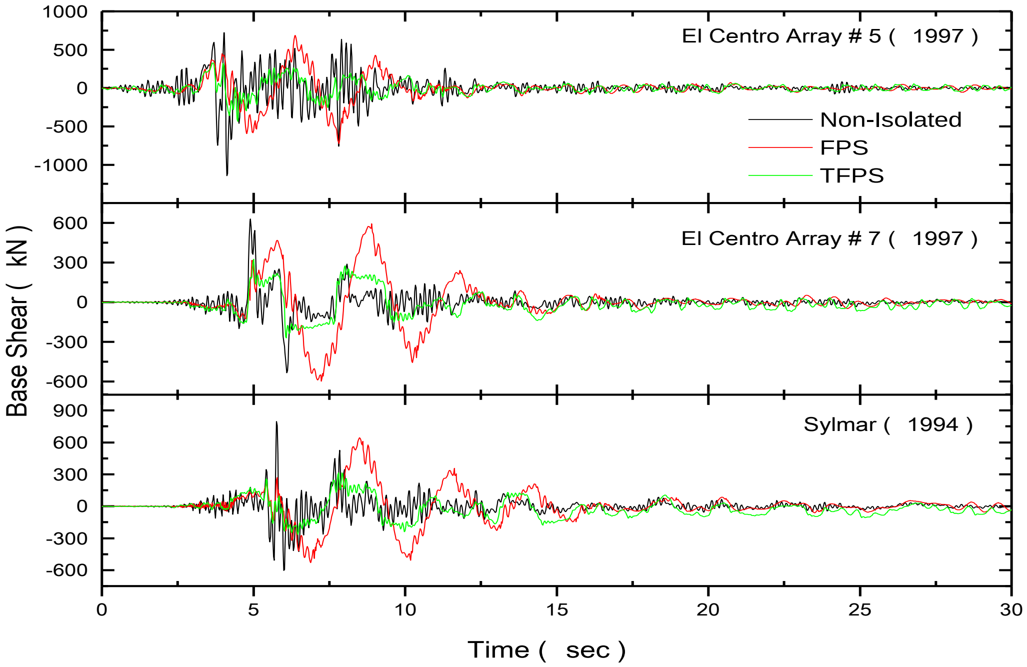


Figure 8 Time variation of base shear in Non-isolated and isolated bridge with FPS and TFPS.

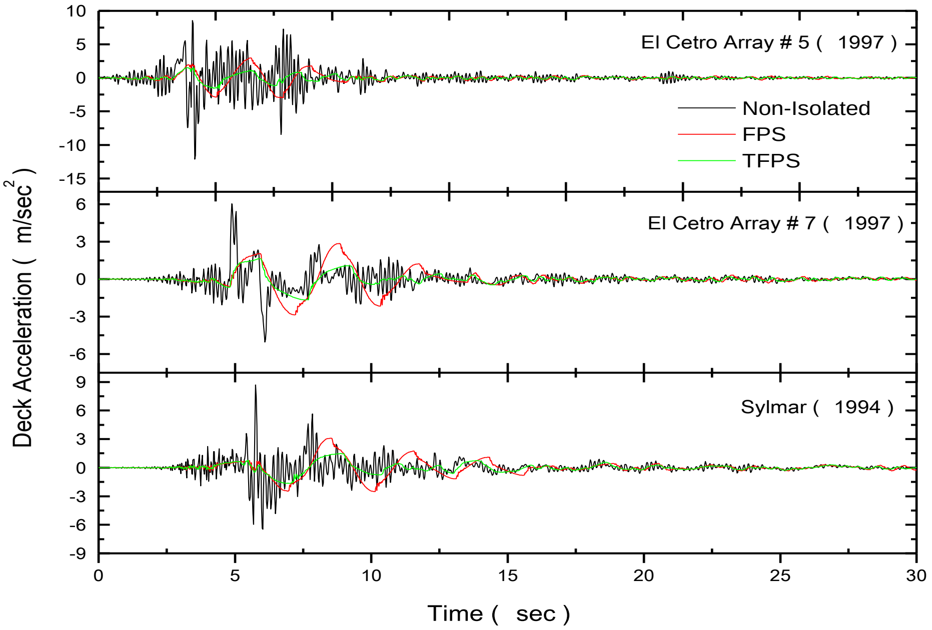


Figure 9 Time variation of base shear in Non-isolated and isolated bridge with FPS and TFPS.

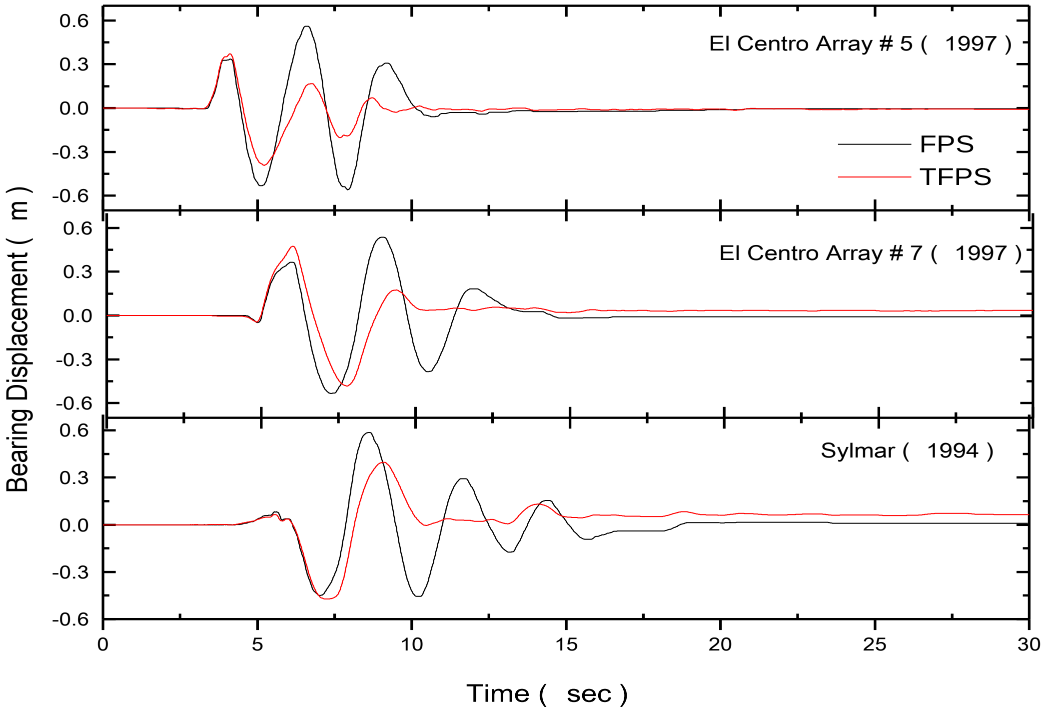


Figure 10 Bearing displacement of bridge with FPS and TFPS.

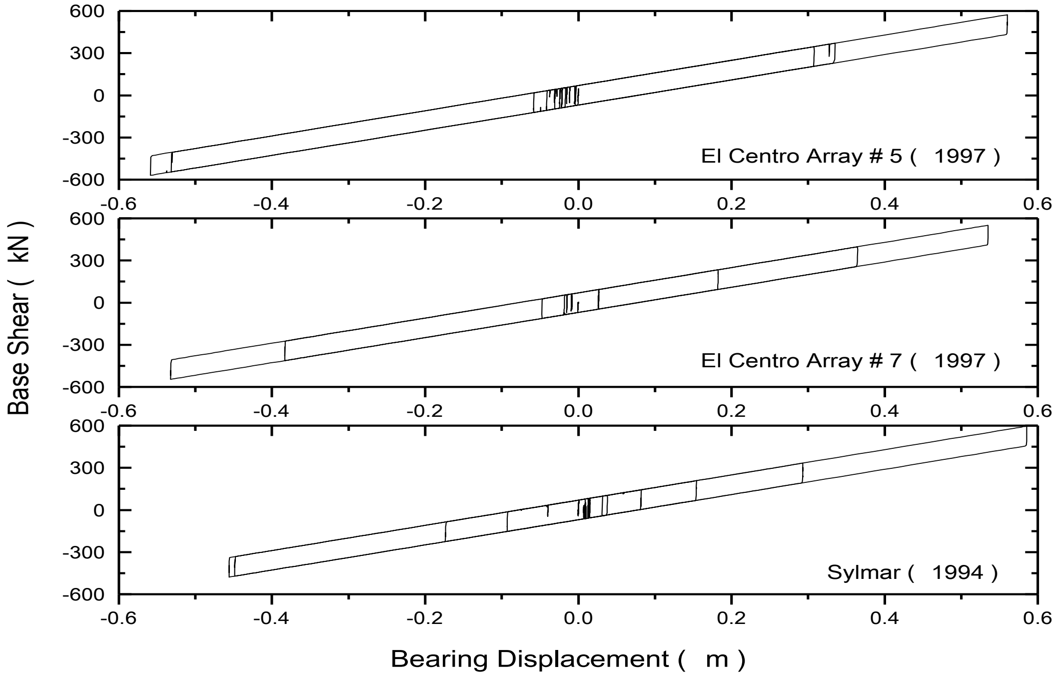


Figure 11 *Hysteresis behavior of isolated bridge with FPS.*

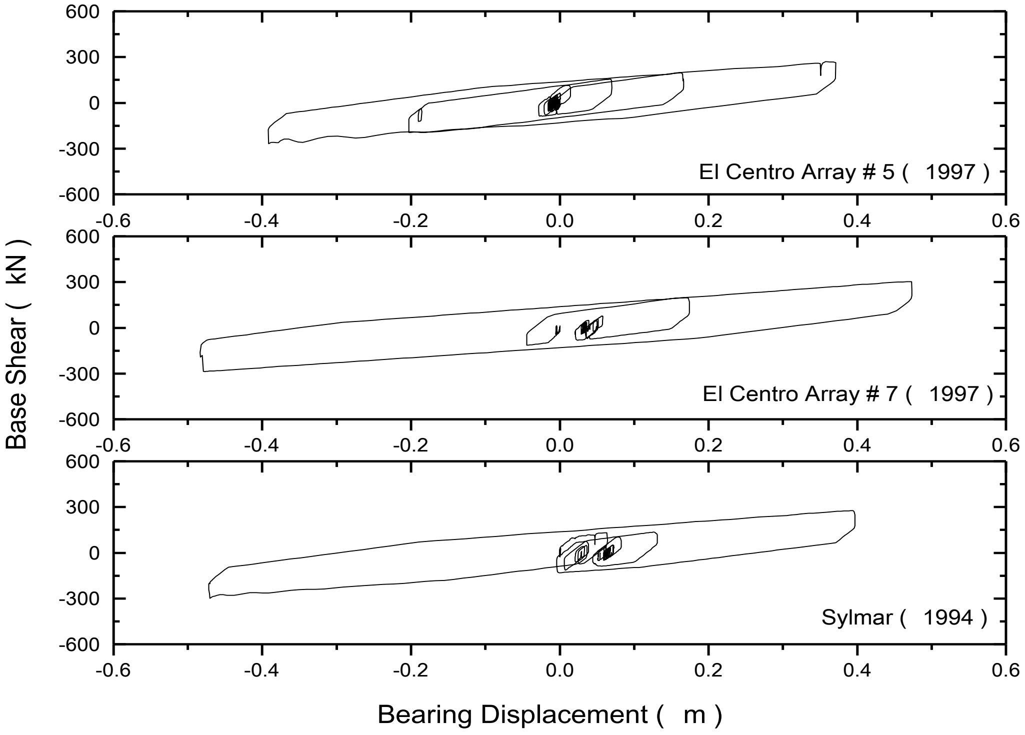


Figure 12 Hysteresis behavior of isolated bridge with TFPS.

VIII. CONCLUSIONS

This paper investigated the effectiveness of the curved continuous bridge with seismic isolator, FPS and TFPS. SAP2000 used evaluating the response isolator and bridge by using fast nonlinear analysis method.

On the basis of the results, conclusions are made as:

1. Fast nonlinear analysis in SAP2000 produced results with acceptable accuracy in the study.
2. The Force-displacement relationship of bridge under three real earthquake ground motion have been shown in Figure 11, Figure 12, based on the area which is accumulated by the devices TFPS dissipate more energy compare to FPS and work up to design based earthquake.
3. Response of the curved bridge for base shear and deck acceleration shows the reduction of 45% to 80% which is as expected from the isolated structure. TFPS gives larger reduction compare to FPS.
4. Fundamental time period is shifted from 0.158 (non-isolated bridge) to 2.5 (FPS) and 1.98 (TFPS) which enhance the overall response of the curved bridge.

REFERENCES

[1]. G.Ghosh, A. Kumar, N. K. Verma & H. Rai: “Seismic Response of a Curved Bridge with Isolation Bearings” 15WCEE LISBOA 2012.

[2]. Christian Braun: “The sliding isolation pendulum – an improved recentering bridge bearing”Steel Construction 2 (2009), No. 3

[3]. Shoma Kitayama and Michael C. Constantinou: “Evaluation of triple friction pendulum isolator element in program SAP2000” Report on August 27, 2015.

[4]. R. S. Jangid: “Seismic Response of Isolated Bridges” JOURNAL OF BRIDGE ENGINEERING,DOI: 10.1061/(ASCE) 1084-0702(2004)9:2(156)

[5]. Vasant A. Matsagar and R. S. Jangid: “Seismic Response of Simply Supported Base-Isolated Bridge with Different Isolators” International Journal of Applied Science and Engineering 2006. 4, 1: 53-69.

[6]. Fenz, D.M. and Michael C. Constantinou: “MECHANICAL BEHAVIOUR OF MULTISHPERICAL SLIDING BEARING” Report No. MCEER-08-0007, Multidisciplinary Center For Earthquake Engineering Research, State University Of New York At Buffalo, NY. 2008

[7]. Fenz, D.M. and Michael C. Constantinou: “SPHERICAL SLIDING ISOLATION BEARING WITH ADAPTIVE BEHAVIOR: THEORY,” Earthquake Engineering and structural Dynamics, Vol. 37, No. 2, 163-183.

[8]. Sevket Ates, Michael C.Constantinou: “Example of application of response spectrum analysis for seismically isolated curved bridges including soil-foundation effects” Soil Dynamics and Earthquake Engineering 2011, 31 (2011) 648–661.

[9]. R. K. Dowell: “Nonlinear Time History Seismic Analysis of Bridge Frame Structures”15WCEE LISBOA 2012.