Comparative Shake Table Study on Seismic Performance of Base Isolated Structure

Umesh.R.Patel, Sonali Pandey
Civil Engineering Dept., Smt. S.R. Patel Engineering College, Unjha
umeshpatelcvl@gmail.com,sonalipandey07@gmail.com

Abstract : The aim of this paper is to do a comparative study of the response of a base isolated structural system with the corresponding response of a structural system without base isolation in order to investigate the effectiveness of the isolation system. An experimental shake table study is carried out to compare the seismic behavior of with and without base isolation system. Base isolation system, namely the friction pendulum bearing type of double concave friction pendulum (DCFP) bearing is used. Study on seismic performance are carried out on four structural configurations consisting of model without base isolation, model with base isolation, model without base isolation with mass and model, with base isolation without mass. There were total different sixteen model with different storey height G+1 storey, G+2 storey, G+3 storey, G+4 storey analyzed and compare the seismic response of the structure subjected to earthquake motion in above four structural configurations. From experimental study it was found that the top storey displacement of model with base isolation reduced to 60% to 70%. The results show that the response of isolated system is found to be less in comparison to without base isolation implying that the isolation is quite effective in reducing the displacement response of the systems.

Keywords: seismic design, Base isolation, Shake table, Displacement, Friction Pendulum Bearing

I. Introduction

Base isolation is thought of as a seismic design approach in which the building is protected from the hazards of earthquake forces by a mechanism which reduces the transmission of· horizontal acceleration into the structure. The main concept in base isolation is to reduce the fundamental frequency of structural vibration to a value lower than the predominant energy-containing frequencies of earthquake ground motions. The other purpose of an isolation system is to provide an additional means of energy dissipation, thereby reducing the transmitted acceleration into the superstructure. The role of the base isolator under seismic loading is to isolate the structure from the horizontal components of the earthquake ground movement, whereas the vertical components are transmitted to the structure relatively unchanged. Base isolator deflects and absorbs the seismic input energy horizontally transmitted to the structures. The design methods of base isolation systems have been improved, and experimental studies on the base isolators have been performed by many investigators.

Sliding isolation systems employ sliding interfaces (usually Teflon-steel interfaces) to support the weight of the structure. These interfaces provide little resistance to lateral loading by virtue of their low friction. Recentering capability is provided by a separate mechanism.

In the friction-pendulum system, the isolated structure is supported by bearings, each of which consists of an articulated slider on a spherical, con-cave chrome surface. The slider is faced with a bearing material, which, when in contact with the polished chrome surface, results in a maximum sliding friction coefficient of the order of 0.1 or less at high velocity of sliding, and a minimum friction coefficient of the order of 0.05 or less at very slow velocity of sliding. The FPS bearing acts like a fuse that is activated only when the earthquake forces overcome the static value of friction. Once set in motion, the bearing develops a lateral force equal to the combination of the mobilized frictional force and the restoring force that develops as a result of the induced rising of the structure along the spherical surface. This restoring force is proportional to the displacement and the weight carried by the bearing, and it is inversely proportional to the radius of curvature of the spherical surface.

II. Materials and Methodology

1. Friction Pendulum System

The friction pendulum system (FPS) is a sliding type isolation system and consists of a spherical stainless steel surface and an articulated slider, covered by Teflon based composite material. It works on the principal of simple pendulum. Friction Pendulum bearings are seismic isolators that are installed between a structure and its foundation to protect the supported structure from earthquake ground shaking.

A significant amount of the recent research in base isolation has focused on the use of sliding/frictional elements to concentrate flexibility of structural system and to add damping to the isolated structure. The advantages of sliding type system over conventional rubber bearings are (i) the friction force developed at the base is proportional to the mass supported by that bearing implying that there is no eccentricity between the center of mass of the superstructure and the center of stiffness (therefore, if the mass distribution is different from that assumed in the original design, the effects of torsion at the base are diminished), (ii) the frictional isolators do not have any unique natural frequency, and therefore, those dissipate the seismic energy over a wide

ISSN:2319-6890 (online), 2347-5013(print)
1 May 2018

range of frequency input without the risk of resonance with the ground motion and (iii) the frictional type of system ensures a maximum acceleration transmissibility equal to maximum frictional force.

2. Structural Configuration

In the present study focused on evaluate performance of structure without base isolated and with base isolated structure with friction pendulum bearing type isolator under the effect of earthquake ground motions. To study seismic response of structure with different building storey (G+1, G+2,G+3,G+4) with & without base isolation, with & without base isolation with mass using friction pendulum bearing subjected to earthquake motion. Evaluate the joint displacement of top storey of bare frame models. There are different 16 bare frame model analyzed subjected to earthquake motion. The experiment performed under the four following configuration for G+1 storey,G+2 storey ,G+3 storey ,G+4 storey bare frame model.

Table 1 Structural configurations

Symbol	Types of configuration
A	without base isolation
B	with base isolation
C	without base isolation with mass
D	with base isolation with mass

3. Prototype bearing configuration

In the friction pendulum system bearing type of double concave friction pendulum (DCFP) bearing were fabricated. In this bearing have upper and lower sliding concave surface shown in fig 1. Friction coefficient of that concave surface is 0.02 to 0.08.

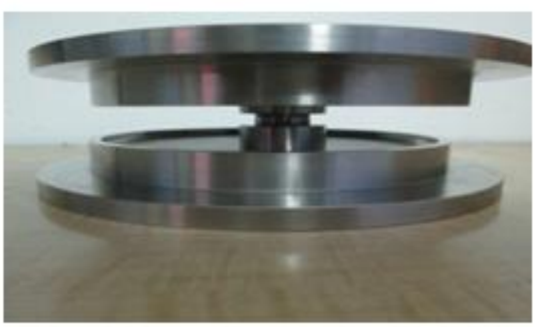

Fig.1 Real picture of Friction pendulum bearing

4. Experimental shake table study

The shake table tests were carried out by using a uni-axial shaking table. Steel building bare frame model of different storey dimension 300mm X 300 mm where built from steel angle section. In the shake table experiment servo motor frequency, amplitude of shaking plate and number of cycle were given as an input. Then, there were four different storey bare frame model with base isolation and four model of with base isolation with mass put on slab were connected with top plate of bearing assembly and bottom plate of bearing assembly was connected with the shake table plate with bolts. Then uni-axial and tri-axial Accelerometer were attached with different storey of bare frame model. Accelerometer is connected with sixteen channel analyzer &analyzer connecting it with the computer. The control software is used “NVGATE” the hardware control and provide much more accurate control over the table motion. Models were tested for different frequency and amplitude. The data were acquired for with and without base isolation system and peak model responses were plotted for different model in the form of top floor displacement. There was one accelerometer placed at the base of the shake table for table acceleration and in prototype where the other accelerometer were mounted at the joint of each floor.

Fig 2 G+4 storey model with isolation

Fig 3 G+4 storey model without isolation

Fig 4 G+2 storey model with isolation

Fig 5 G+2 storey model without isolation

An experimental shake table study carried out to compare the seismic behaviour of with and without base isolation system with using the accelerometer. Base isolation system, namely the friction pendulum bearing type of double concave friction pendulum (DCFP) bearing is used. Studies on seismic performance are carried out on four structural configurations model without base isolation, the model with isolation, the model without isolation with mass and model with isolation

ISSN:2319-6890 (online), 2347-5013(print)
1 May 2018

with mass. There were total different sixteen bare frame model with different building models G+1 storey,G+2 storey,G+3 storey,G+4 storey and study seismic response of structure using friction pendulum bearing subjected to earthquake motion. The data were acquired for with and without base isolation system of different sixteen bare frame model by testing of bare frame models at frequency 15Hz with 20 mm amplitude. The peak value from recorded shake table earthquake response of top floor displacement were considered. Compare all result for 20 mm amplitude, 20 cycles, 15 Hz frequency of servo motor.

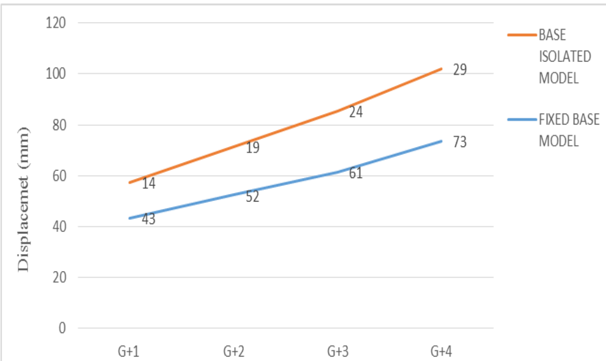

Fig 6 Top floor displacement at 15 Hz servo motor frequency

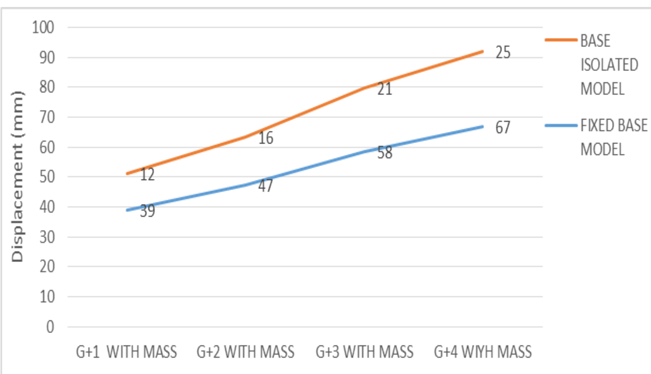

Fig 7 Top floor displacement at 15 Hz servo motor frequency

Figure 6 gives the graphical presentation at for comparison of top floor displacement at 15Hz frequency of servomotor without mass for with and without base isolation system using friction pendulum bearing. From the graphical presentation available in figure 11 can clearly show that the displacement of a base isolated structure using friction pendulum system was reduced for all four storey of building the model than that of a without base isolated structure. From the graph shown that in the case of height decrease displacement was reduced with the height decrease of the model. In the case of both the system without base isolation and with base isolation G+1 Storey model is having a reduction in displacement as compare G+4 storey model. Figure 7 gives the graphical presentation for comparison of top floor displacement at 15Hz frequency of servomotor with mass for with and without base isolation system using friction pendulum bearing. From the graphical presentation available in figure 8 can clearly show that the displacement of a base isolated structure using friction pendulum system was reduced for all four storey of building the model than that of a without base isolated structure. In comparison with and without base isolation top floor displacement of the model with mass reduced with base isolation using friction pendulum system. In the case of with mass and without mass top floor displacement of model reduced with mass in both cases of with & without base isolation.

IV. Conclusion

The primary aim of this work is to evaluate seismic response of isolated structural system is compared with the corresponding seismic response of without base isolated system by experimental study. From experimental study find top floor displacement of all models.

After detailed study of experimental work, following conclusions were made.

1) In comparing both the system with mass and without mass 61% & 64% reduction in displacement was observed between base isolated model and without base isolated.
2) In the case of both system fixed base and base isolated model with mass is having the reduction in displacement 8% to 12% as compared to models without mass.
3) In comparing both the system with mass and without mass G+1 storey model is having reduction in displacement 41% and 43% as compare to model G+4 storey was observed between base isolated model and without base isolated. It was found that the top floor displacement decreases with floor height.
4) From the visual inspection during experiment show that rigid body movement occurred in base isolation system.

From the above study it is concluded that, friction pendulum system is effective in reducing of top floor displacement in experimental study. The top floor displacement of isolated structural models was found to be less in comparison to the corresponding displacement without isolation system. Thus, the isolation system is effective in reducing the dynamic response of the system. The system is effective in protecting the structural system from extreme seismic-loading.

References

i. *Kelly, J.M. (1986). "A Seismic Base Isolation: Review and Bibliography", Soil Dynamics and Earthquake Engineering, Vol. 5, pp. 202-216.*

ii. *Buckle, I.G. and Mayes, R.L. (1990). "Seismic Isolation: History, Application and Performance-A World Overview", Earthquake Spectra. Vol. 6, No. 2, pp. 161- 202.*

iii. *Jangid, R.S. and Datta, T.K. (1995). ''Seismic Behaviour of Base Isolated Building -A-State-of-the- Art-Review", Joumal of Structures and Buildings, Vol. 110, pp. 186-203.*

iv. *Mokha, A., Constantinou, M. C, and Reinhorn, A. M. (1988). "Teflon bearings in a seismic base isolation.Experimental studies and mathematical modeling." Report No. NCEER-88-0038, National Center for Earthquake Engineering Research,State Univ. of New York, Buffalo, N.Y.*

v. *Zayas, V., Low, S. S., and Mahin, S. A. (1987). "The FPS earthquake resisting system, experimental report." Report No. UCB/EERC-87/01, Earthquake Engineering Research Center, Univ. of California, Berkeley, Calif., June.*

ISSN:2319-6890 (online), 2347-5013(print)
1 May 2018

vi. *Mokha, A., Constantinou, M. C, and Reinhorn, A. M. (1988). "Teflon bearings in a seismic base isolation. Experimental studies and mathematical modeling." Report No. NCEER-88-0038, National Center for Earthquake Engineering Research, State Univ. of New York, Buffalo, N.Y.*

vii. *Mokha, A., Constantinou, M. C, and Reinhorn, A. M. (1990a). "Teflon bearings in base isolation I: Testing." J. Struct.Engrg., ASCE, 116(2), 438-454.*

viii. *Mokha, A., Constantinou, M. C, and Reinhorn, A. M. (1990b). "Experimental study and analytical prediction of earthquake response of a sliding isolation system with a spherical surface." Report No. NCEER-90/0020, National Center for Earthquake Engineering Research, State Univ. of New York, Buffalo, N.Y.*

DOI : 10.5958/2319-6890.2018.00099.5