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A REVIEW: MITIGATING THE SEISMIC EFFECT ON BASE ISOLATED STRUCTURES COUPLED WITH FRICTION PENDULUM BEARINGS

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Abstract

Base isolation has become one of the most popular, successful and reliable tools that play an important role to ensure earthquake resistant design of structural safety. It also ensures the safety of non-structural elements, thereby keeping the building operational even after a severe earthquake. At the present works base isolation system coupled with Friction Pendulum Bearing (FPB) in which the superstructure is isolated from the foundation using specially designed concave surface and bearing to allow sway under its natural period during the seismic events. A case study of identical conventional base isolation using friction pendulum bearings (FPB) are added to a hypothetical open ground storied regular base-isolated building modelled in the most seismically active region in India (Zone V). The finite element model of the structure was placed in a seismic zone as per IS: 1893 (Part-1)-2002. According to time history analysis some modeled structures observed that isolated model exhibited greater displacements, storey displacements and story drift were comparatively low which will result in less buckling of columns and hence to a safer design. It was also observed that values of overturning moment & storey shear of isolated building is evaluated. Base isolation with FPB system as very innovative of a (G+8) storied building, it is found that the building was protected, leading to the hypothesis that base isolation is an ideal technique for structures.

Keywords: Base Isolation, FPB, Earthquake scaling, Seismic strengthening, THA.

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1. Introduction

The seismic design of structures has been one of the most important, trusting and interesting issues in the last century. Base isolation is a mechanism that provides earthquake resistance to the structure of the high rise. From reviewed by many researchers, in seismic zone base isolation may be used to provide an effective solution for a

wide range of seismic design problems. The comparison of analytical outcome with the records for an actually recorded low intensity earthquake (Kobe Japan, 1995) is done by carrying out a time history analysis.

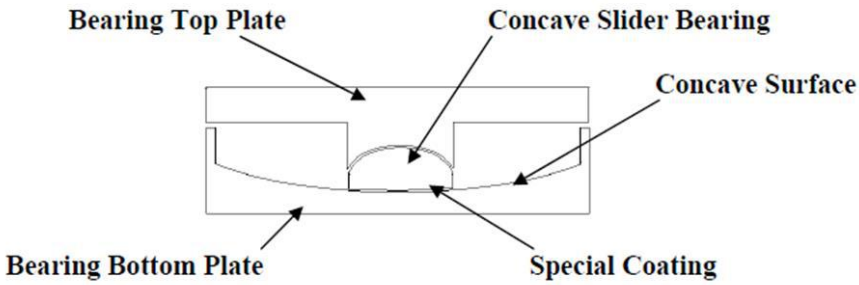

Fig. 1- Cross - Section of Friction Pendulum Bearing

Friction Pendulum Bearings are specially designed for each facility based on the load capacity requirements, earthquake displacement capacity, soil conditions, and the height of the structure being supported. The sliding systems exhibit best performance under a variety of severe earthquake loading and are very effective in reducing the large levels (G+8) of the superstructure acceleration. These base isolators are characterized by their insensitivity to the frequency content of earthquake excitation, because of the tendency of sliding system to reduce and spread the earthquake energy over a wide range of its frequencies. There is another advantage of sliding isolation systems over conventional friction pendulum bearings. Due to development of the frictional force at the base isolation, it is proportional to the mass of the structure, and the center of mass and center of resistance of the sliding support coincides. Consequently, the storey torsional effects produced by the asymmetric building are diminished. To study the behavior of base isolated buildings as compared to conventional fixed base buildings under actual seismic scenario, two identical G+8 buildings have been modeled in ETABS software.

Fig. 2 - Concept of Sliding Friction Pendulum

A simple pendulum type response model is shown in Figure 2 to illustrate the similarity to friction pendulum system. The concept of sliding systems is marked by sliding of an articulated slider on spherical concave surface.

Objectives of This Study

This dissertation work has been undertaken with the following objectives

- To review the literature, covering various types of base isolation systems and the dealing of isolated structures.
- To study the performance of friction pendulum bearings (FPB) using published works as a reference and understands the behavioral aspects of FPB.

- To develop a simplified model of a medium-rise hypothetical building with identical parameters and alternatively providing it with a fixed base and FPB isolated support.
- To carry out dynamic seismic analysis on the modelled buildings using scaled records of acceleration time histories and compare their results.
- To study the comparative behavior of identical conventional and base-isolated (G+8) storied buildings for high-intensity seismic zone and comment on the feasibility of using base isolation for highly seismic areas.

2. Literature Review

Sliding friction pendulum isolation system is one type of flexible base isolation system suitable for small to large-scale structures. In the past few years, the Friction Pendulum System (FPS) has become one of the accepted devices for seismic isolation of structures. The concept of isolating the structure from ground shaking during a strong earthquake. Earthquake resistance base isolation systems like the FPS are designed to lengthen the structural period far from the dominant frequency of the ground shake and to dissipate vibration energy during an earthquake [3]. Some of the real-world applications of FPB are given below-

(1) Hacheem and Al-Shimmari [6] studied the finite element analysis of friction pendulum system (FPS) of a high rise building or structures and without base isolation subjected to two real different earthquakes (el Centro & Loma Prieta) using an engineering software program (ETABS) and concluded storey displacement, storey drift and base shear in isolated systems is much smaller in comparison with the fixed-base systems.

(2) As the research into base isolation increased, modern sliding base isolators came about in the late 1980s. The first analytical and experimental study on Friction Pendulum (FP) isolation bearings were conducted by Victor Zayas [7]. A Friction Pendulum system is a friction type of sliding bearing that uses gravity as the restoring force. The isolated system consists of an articulated friction slider that travels on a spherical concave moving surface. The frequent curvature sliding surface is characterized by a nominally single-valued friction coefficient.

(3) Alternatives to standard FP systems have been proposed, with the intent of improving the response and possibly reducing the size of the bearings. A major system with multiple sliding bearings is a Triple Pendulum Friction Bearing. Details on some multi-surface devices derived from the FP can be found in the works of Fenz and Constantinou [8=9] amongst others. Tension capable bearings have been proposed by Roussis and Constantinou (2006). Kasalanati and Constantinou (2005) proposed the use of prestressing tendons as a means of overcoming uplift issues.

(4) Nikolay Kravchuk, Ryan Colquhoun, and Ali Porbaha California [10] developed a base isolation system to physically show the concept of friction pendulum system in the laboratory for earthquake engineering education. The responses of a single degree of freedom system with isolation and without base isolation were studied and compared for free forced vibrations using the accelerometers attached to the top of the model

structures and the system showed significant development in the dynamic response of the model structure by reducing the lateral acceleration and increasing the damping of the operating system.

(5) Yu. N. Drozdov, V. A. Nadein, and V. N. Puchkov [11] studied the performance of sliding systems under near-fault motions and found that the friction coefficient of various isolation systems is typically dependent on the relative velocity at the sliding interface. The response of the building system is analyzed to investigate the performance of the sliding system and concluded that sliding base isolation is found very effective in controlling seismic response.

(6) Fanel Scheauarjav [12] conducted a theoretical study on single friction pendulum bearing systems and double friction pendulum systems, and their applications and concluded that the friction systems perform very well under a variety of severe earthquake loadings and are quite effective in reducing the large levels of the superstructure's acceleration without inducing large base displacements, comparative study of different type base isolation systems has shown that the repercussion of the sliding system does not vary with the frequency content of earthquake ground motion. Friction dampers have high potential and low cost and they can be utilized in both energy dissipation and re-centring.

(7) M. Malekzadeh And T. Taghikhany [13] studied the seismic behaviour of structures isolated by DCFP bearings is compared with the response of the same buildings using the fps bearing. A series of nonlinear dynamic analysis were carried out under ensembles of ground motions at three different hazard levels. The result supports the advantages of dcfp isolation systems and dcfp acts as an adaptive isolation system, since stiffness and damping in proportion to the level of input ground motion, and can control peak acceleration and inter-story drift. The specific objectives of the study are (i) determination of the seismic response of building with and without base isolation system (ii) study the seismic performance of various types of Friction Pendulum isolation systems (single, double and triple) in terms of building displacement, inter-story drift and overturning-moment.

(8) More recently, two test programs on full scale isolated buildings have been conducted at the National Institute for Earth Science and Disaster Prevention (NIED) E-Defense shaking table of Japan (Warn and Ryan, 2012; Ryan et al., 2012) [14]. From the first study, it was observed that elastomeric isolation systems could only guarantee the functionality of the structure in case of a near-fault motion but not for a long duration, long-period ground motion generated from a subduction earthquake. The main outcome of the second study was the significant influence of vertical excitation and the amplification of the horizontal accelerations recorded at the various levels of the building as a consequence of the multi-directional stimulation. The findings of these experimental studies suggest that mitigation of the effect of multi-directional seismic excitations may be required to maintain functionality in critical base-isolated buildings and that this may require the use of isolation devices. To this end, Variable Friction Systems (VFS) were recently proposed as promising seismic alternatives to currently available FP systems etc. (Calvi et al., 2016; Calvi and Ruggiero, 2016). The coexistence of materials with other frictional properties within the same device, the use of better-performing materials and a more clever combination of sliding surfaces, open the door to the possibility of new hysteretic responses.

3. Future Scope

- ✓ It is necessary to analyse the cost of using this base isolation with FPB strategies too as economy and efficiency, both are the primary concerns of a structural design engineer. Financial feasibility studies can be carried out by considering various types of isolation systems
- ✓ This work can be further extended by analyzing multiple base isolation systems for different buildings such as OMRF, SMRF, ordinary steel frames, and braced steel frames.
- ✓ Also, since the present study addressed an open ground storey medium-rise building of (G+8) storey, further analysis for low rises and high rises can be carried out by incorporating traditional lateral load resisting mechanisms such as shear walls.
- ✓ Finally, using a record of actual major earthquakes of the Indian subcontinent that occurred in the past, a time history analysis of these models can be carried out to predict their behaviour more accurately.
- ✓ Not much attention was given to the nonlinear behaviour of the models. Capacity curves and Performance levels can be found in accordance with FEMA codal provisions to estimate the actual limit state of collapse

Discussion

The characteristics and type of base isolation coupled with FPB play a vital role in the performance of structure during the effect of the earthquake. The other factors like mass asymmetry, interlaying ground condition, the geometry of structure and height of superstructure also define the response of structure during ground motion. The effect of soil-structure interaction is the widest area of research

4. Summary & Conclusions

Based on the above study it is clear that the performance of fixed base and isolated base structures depends on the type of underlying soil on which the structure rests. For hard strata, the response is relatively satisfactory, a soft soil increases the acceleration, so the energy dissipation of the structure decreases and the frequency increases. The present study has been concentrated on a typical square plan for the (G+8) storey buildings. Two models were same prepared with one being fixed base and the other being base isolated using Friction Pendulum Bearing (FPB). Linear Time History Analysis LTHA was carried out and the records of Kobe earthquake of Japan (1995).

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