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STUDY ON SEISMIC ANALYSIS OF BUILDINGS USING COMBINATION OF DIFFERENT ISOLATION SYSTEMS ABSTRACT

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ABSTRACT

The basic idea of base isolation system is to reduce the earthquake induced inertia forces by increasing the fundamental period of the structure. The aim of this study is the use of Lead rubber bearing (LRB) and friction pendulum system (FPS) as an isolation device and then to compare various parameters between fixed base condition and base isolated condition. With an aim of better including/understanding the effect of the emplacement of these devices on the response of the structures, the comparative studies were carried out in this article. The analysis is carried out by four comparative studies: the 1st and the 2nd between a fixed base structure and LRB and FPS base isolated ststems and the 3rd and 4th between a fixed base structure combination of isolation systems. The isolated structure by FPS system decreases displacements, accelerations and shear forces compared to the structure isolated by LRB. The isolated structure with Comb-1 system decreases the displacements and shear force compared to the isolated structure with LRB system and isolated structure with Comb-2 combined system. From this study, we conclude that the use of FPS as a unique isolator is a good idea when the total cost is considered as an important thing. However, combining the FPS with a rubber-based isolator provides a good seismic isolation to the structure. In addition, the number and the location of the FPS at the base of a structure when is combined with a rubber-based isolator affect the response of the structure.

INTRODUCTION

The basic idea of base isolation system is to reduce the earthquake induced inertia forces by increasing the fundamental period of the structure (Trevor and Kelly, 2001). Seismic isolation enables the reduction in earthquake forces by lengthening the period of vibration of the structure. The typical period of isolated buildings is generally kept as 2.0 second (Athamnia B, Ounis AH, 2011). Therefore the significant benefits obtained from isolation are in structures for which the fundamental period of vibration without base isolation is short, less than 1.0 second. Buildings with comparatively higher natural period attract low earthquake forces even without seismic base isolation. In the early stages of development of seismic isolation, prevention of collapse of the structure was the primary goal. Therefore, seismic isolation has mostly been used for low-rise buildings (Kelly and Naeim, 1999). However, later other additional considerations like comfort of occupants, functionality of important buildings during and after earthquakes, non-damage to non-structural elements and contents etc. have exerted an increasingly important influence.

Conventional earthquake-resistant design technique is based on the philosophies that the structural safety must be assured in extreme earthquakes and the structural damage should be minimized or avoided in moderate earthquakes (Soong T.T., Dargush G.F., 1997). To satisfy these design criterions, a structure needs to be designed with sufficient strength to withstand earthquake forces, adequate ductility to absorb earthquake energy and appropriate stiffness to maintain structural integrity and serviceability. In recent years, a new design philosophy i.e. base isolation technique based on aseismic design criteria has emerged aiming at reducing the seismic damage by providing an isolation system at the base of a structure. In isolated structures, due to insertion of a flexible layer between foundation and superstructure, the fundamental time-period of the system increases to a value higher than the predominant energy containing time-periods of earthquake ground motions. Since a base-isolated structure has fundamental frequency lower than both its fixed base frequency and the dominant frequencies of ground motion, the first mode of vibration of isolated structure involves deformation only in the isolation system whereas superstructure remains almost rigid (Yang Y. B. et al., 2003). In this way, the isolation becomes an attractive approach where protection of expensive sensitive equipments and internal non-structural components is needed.

Many mechanisms have been proposed over the last century to try to achieve the goal of uncoupling the building from the damaging action of an earthquake, for example rollers, balls, cables, rocking columns or sand interfaces (F. Braga et al., 2001). However, the concept of base isolation has become a practical reality within the last years with the modification of sliding approaches and the development of multilayer elastometric bearings, which are made by vulcanization bonding of sheets of rubber to thin steel reinforcing plates. These bearings are very stiff in the vertical direction and can carry the vertical load of the building but are very flexible horizontally, thus enabling the building to move laterally under strong ground motion.

At the present moment there are two basic types of isolation systems: one is typified by the use of elastometric bearings, and the other one by the use of gravity-based systems (sliding and frictional). The concept of base isolation in both cases is founded on the decoupling of the building or structure from the horizontal components of the ground motion by interposing structural elements with low horizontal stiffness between the structure and the foundation. This gives the structure a fundamental period that is much longer than both its fixed-base period and the predominant period of the ground motion. The first dynamic mode of the isolated structure (known as isolation mode) involves deformation only ¡n the isolation system while the structure behaves essentially as a rigid body. (Ordonez, D. et al., 2003) The higher modes involve some deformation of the structure, although they contribute little to the earthquake-induced forces. The isolation system does not absorb the earthquake energy, but rather deflects it through the dynamics of the structure; though this effect does not depend on damping, a certain level of damping is important.

From this research, it was demonstrated that the use of base isolation is an advantageous technique to diminish significant damages in structural elements and contents by avoiding the total transmission of the ground motion into the superstructure.

The aim of this study is the use of Lead rubber bearing (LRB) and friction pendulum system (FPS) as an isolation device and then to compare various parameters between fixed base condition and base isolated condition. With an aim of better including/understanding the effect of the emplacement of these devices on the response of the structures, the comparative studies were carried out in this article. In this paper, we will give an insight on the seismic performance of the two mostly used isolation devices (LRB and FPS), after, a proposal of some combinations of these devices to isolate a simple structure in order to investigate the seismic performance of every combination and get some conclusions.

DESCRIPTION OF THE STRUCTURE

The structure used in our study is a building of reinforced concrete of 4 levels with rectangular form in plan including three spans respectively in the two directions, longitudinal and transverse. 3D view of the structures shows in Figure 1. A dynamic analysis of the response by time history is used for the four types of studied structures (at base fixes and base insolated, LRB, FPS, Comb-1, Comb-2).

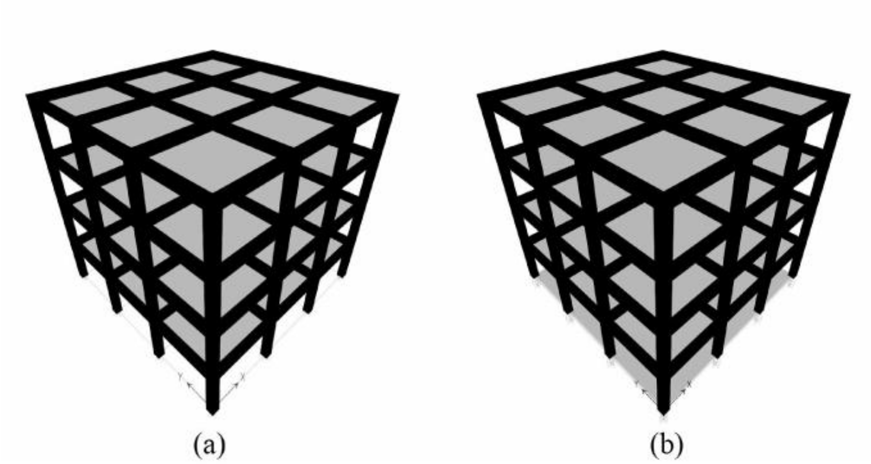

Figure 1. (a). 3d view of the structure without seismic isolation Figure (b). 3d View of the structure with seismic isolation

PARAMETERS OF VARIOUS SYSTEMS OF BASE ISOLATION

Two different isolation systems were investigated when mounted separately and when mounted in combination. Plan view of the building being isolated and various emplacements of the seismic base isolation shown in Figure 2. Black squeres show LRB isolators and red circles show FPS isolators.

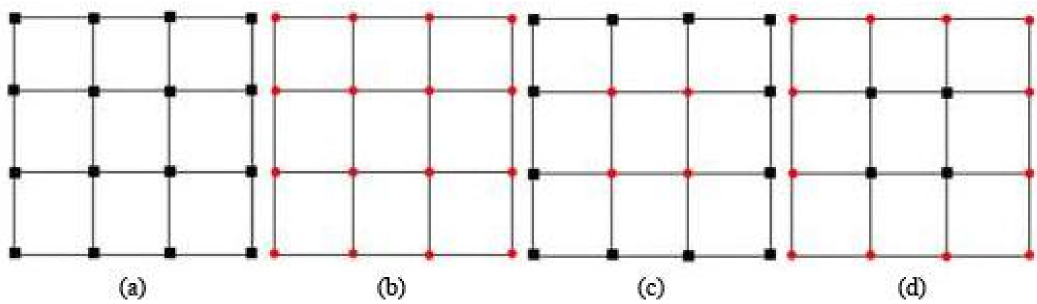

Figure 2. Plan view of the building being isolated and various emplacements of the seismic base isolation. (a). LRB isolation system (b). FPS isolation system (c). Comb-1 isolation system (d). Comb-2 isolation system

The characteristics of the apparatuses of seismic isolation are indicated in the following tables. Table 1 shows Parameters of LRB isolation system and Table 2 shows Parameters of FPS isolation system.

Table 1. Parameters of LRB system (Lead Rubber Bearing)

LRB Isolator Input (KN,mm)	
Spring Stiffness along Axis 1 (Axial)	709.4
Spring Effective Stiffness along Axis 2	0.78
Spring Effective Stiffness along Axis 3	0.78
Spring Effective Damping Ratio along Axis 2	0.071
Spring Effective Damping Ratio along Axis 3	0.071
Initial Spring Stiffness along Axis 2	5.49
Initial Spring Stiffness along Axis 3	5.49
Yield Force Along Axis 2	57.47
Yield Force Along Axis 3	57.47
Post-Yield stiffness ratio along Axis 2	0.11
Post-Yield stiffness ratio along Axis 3	0.11

Table 2. Parameters of FPS system (Friction Pendulum System)

Friction Isolator Input (KN,mm)	
Vertical Stiffness	5000
Lateral Stiffness	2000
Coeff of Friction - Lo Vel	0.04
Coeff of Friction - Hi Vel	0.1

SEISMIC EXCITATION

A dynamic analysis of the response by time history is used for the four types of studied structures. One considers an excitation of the the El Centro earthquake 1940 and another Northridge earthquake 1994. The time histories of this excitations are represented on the following figures:

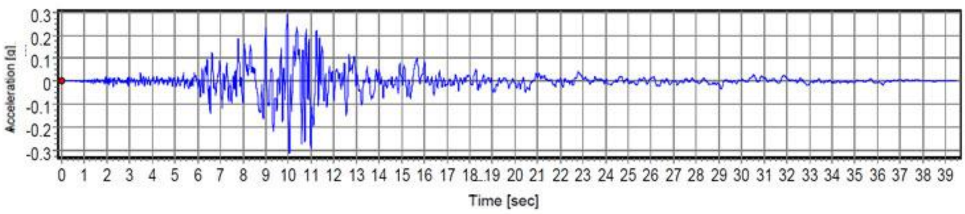

Figure 3. Time history of the the El Centro earthquake 1940.

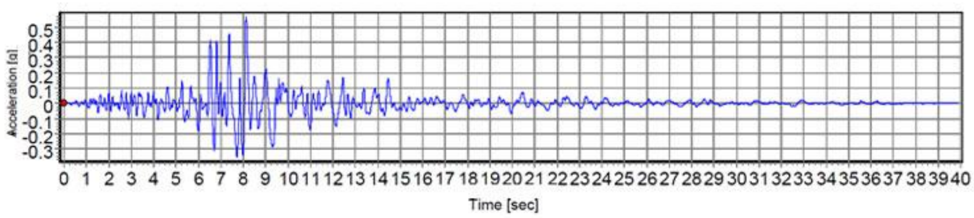

Figure 4. Time history of the Northridge earthquake 1994.

COMPARISON OF THE RESULTS

The analytical results are presented and evaluated for each type of distribution of isolators in this section. A time history analysis using assuming the El Centro 1940 and Northridge earthquake 1994 records and was carried out for every structure. Table 3 summarizes the period of structures, from this table it is clear that the fundamental period is lengthened in the FPS-Isolated buildings (more than three times), so the isolation system provides a high flexibility to the structure.

Table 3. Natural periods of structures for various emplacements of the seismic base isolation

Mode	Fixed-Base Period(s)	LRB-Isolated Period(s)	FPS-Isolated Period(s)	Comb-1 Period(s)	Comb-2 Period(s)
1	0.61778826	1.36510842	2.813616	1.493719029	1.7032144
2	0.58430515	1.3543179	2.8047408	1.463096985	1.67211084
3	0.53712305	1.25633586	2.5918816	1.392281939	1.5966536
4	0.1775424	0.31672914	0.352176	0.285640804	0.32870058
5	0.1755012	0.31359978	0.3472784	0.277621576	0.31655824

After investigating the response of each isolation systems when mounted separately; in this section, the same building was reused and isolated at its base using two different combinations of isolation systems and a time history analysis was carried out for each combination. We considered an excitation of the the El

Centro 1940 and another Northridge earthquake 1994. The dynamic analysis carried out for the four structures (fixed and isolated structures) enabled us to compare the results of displacements of last level in the direction (X). These results are represented as follows:

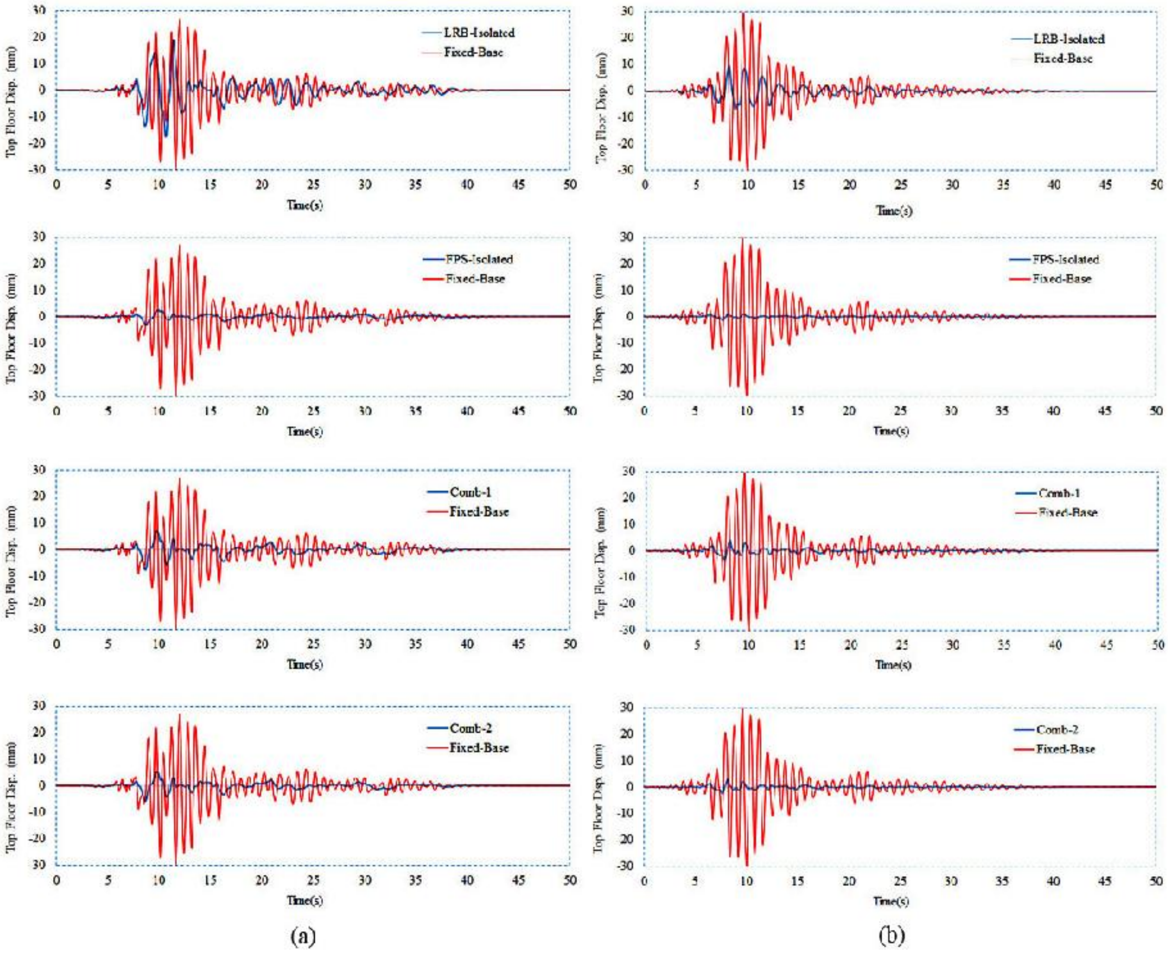

Figure 5. Comparison of displacements at top of the structures. (a). under excitation of the El Centro earthquake (b). under excitation of Northridge earthquake

According to the results obtained, the fixed base structure gives a significant displacement in the last levels compared to the base isolated structure with FPS system (Figure 5). Isolate the structure at its base lengthens the first period, hence provides high flexibility to this latter and shifts the structure from the dominance and severe region of ground motion, the lengthening of period was about 3 times. Table 4 shows the comparison of top level displacements for various emplacements of the seismic base isolation systems.

Table 4. Comparison of top level displacements for various emplacements of the seismic base isolation

Earthquake	Fixed-Base Disp.(mm)	LRB-Isolated Disp.(mm)	FPS-Isolated Disp.(mm)	Comb-1 Disp.(mm)	Comb-2 Disp.(mm)
El centro	26.955	18.936	2.613	6.962	5.225
Northridge	29.712	15.141	1.001	3.976	2.863

A seismic evaluation of the building, isolated in one case with the elastomeric isolators and in another case with the sliding isolators and two cases with combination of both types. The dynamic analysis enabled us to compare the results of displacements, accelerations of last level. According to the results obtained, the fixed base structure gives a significant acceleration in the last levels compared to the base isolated structure with FPS system (Figure 6).

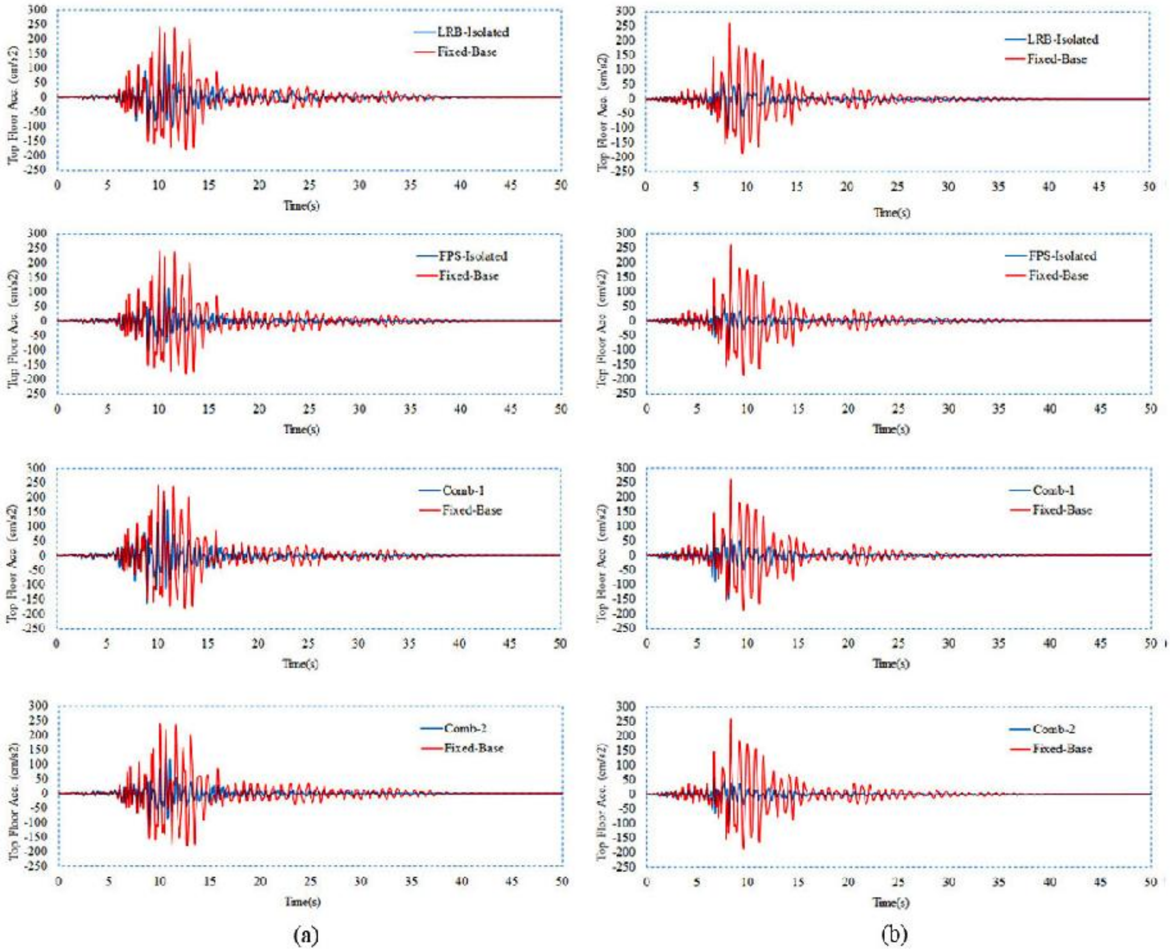

Figure 6. Comparison of acceleration at top of the structures. (a). under excitation of the El Centro earthquake (b). under excitation of Northridge earthquake

CONCLUSION

This analysis carried out by four comparative studies, the 1st and 2nd between the fixed base structure and the base isolated structures (LRB and FPS) and the 3rd and 4th comparative study between two combination of isolated structures. The isolated structure moves on the supports like a rigid body. The system of base isolation decreases the displacements, accelerations and base shear forces. The isolated structure by FPS system decreases displacements, accelerations and shear forces compared to the structure isolated by LRB. The isolated structure with Comb-2 combined system decreases the displacements and shear force compared to the isolated structure with LRB system and isolated structure with Comb-1 combined system. The isolated structure with Comb-2 Isolation system decreases acceleration compared to the isolated structure with Comb-1 combined system and the base isolated structure with LRB system.

From this study, we conclude that the use of FPS as a unique isolator is a good idea when the total cost is considered as an important thing. However, combining the FPS with a rubber-based isolator provides a good seismic isolation to the structure, diminishes the total cost. In addition, the number and the location of the FPS at the base of a structure when is combined with a rubber-based isolator affect the response of the structure.

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