Base Excitational Behaviour of Frictional Pendulum Bearing on Multi-Storied Building

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Abstract— The main objective is to study nonlinear dynamic analysis of different 3D Friction Pendulum System (FPS) isolators and its behaviour during different earthquake motions. The analytical response of the model is studied for buildings with G + 4 storeys with and without Frictional Pendulum Systems using ANSYS Workbench 16.1 and the results are interpreted. The experimental results of the 1940 El Centro, 1995 Kobe, earthquakes show that the proposed isolators can reduce the undesirable seismic responses of the structure by lengthening the fundamental period of the structure during earthquakes, and the Friction Pendulum System (FPS) provides the structure with excellent isolation function under the far- and near- source excitations and strong ground motions with long predominant periods. From these observations, it can be concluded that the proposed FPS isolator is a powerful tool for enhancing the seismic-resistibility of structures.

Key words: Multi-Storied Building, Frictional Pendulum Bearing

I. INTRODUCTION

Base isolation is the most powerful tool of earthquake engineering. It is meant to enable a building to survive a potentially devastating seismic impact through a proper initial design or subsequent modifications. One way to protect a building from resonating with an earthquake is to isolate its foundation, or base, from the ground with devices much like wheels. This technique is called “base isolation”.

Friction Pendulum bearings are seismic isolators that are installed between a structure and its foundation to protect it from damage due to earthquake shaking. The bearings reduce lateral loads and shaking movements transmitted to the structure. They can protect structures and their contents during strong earthquakes, and can accommodate near fault pulses and deep soil sites.

The single pendulum bearing is the original friction pendulum bearing. The single slider maintains the vertical load support at the center of the structural member. During severe ground motion, the slider moves on the spherical surface lifting the structure and dissipating energy by friction between the spherical surface and the slider.

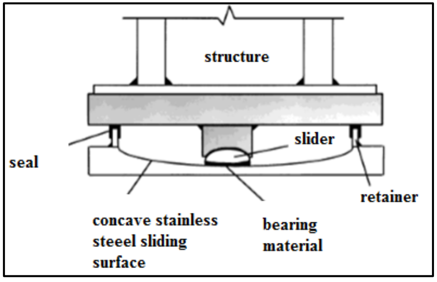

Fig. 1: Cross section of Single friction pendulum bearing**.**

The double sliding surfaces pendulum consists of a combined bearing where the rotation occurs on an internal surfaces while the translation happens on two concave surfaces. By a suitable combination of the sliding surfaces radius and the two sliding materials one can optimize the device response curve by varying the stiffness and energy dissipation.

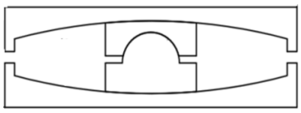

Fig. 2: Cross section of Double friction pendulum bearing

The Triple Pendulum bearing incorporates three pendulums in one bearing, each with properties selected to optimize the structure’s response for different earthquake strengths and frequencies. It consists of four concave surfaces and three independent pendulum mechanisms. The outer slider consists of concave surfaces on either side of a cylindrical inner slider with a low-friction interface on both ends. The outer slider also consists of sliding interfaces between top and bottom outer sliders and the major spherical surfaces of the bearing. The bottom sliding surface is in contact with a spherical surface of a particular radius of curvature, forming the second pendulum mechanism.

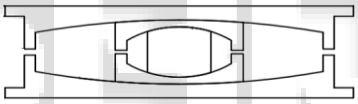

Fig. 3: Cross section of Triple friction pendulum bearing

II. SCOPE& OBJECTIVE

A. *Scope of the Study*

- Development of dynamic response of frictional pendulum bearings
- This work intends to evaluate the best performance of bearing systems during high magnitude earthquake.
- The study of building frame with and without FPBS.

B. *Objectives of the Study*

- To study the dynamic effect of bare frame structure without and with different type of FPS.
- To create 3D models of FPS.
- To carry comparative study between Single, Double and Triple isolators.
- To done parametric study dealing with the coefficient of friction μ (0.05 and 0.2).
- To study the response such as time history analysis and harmonic analysis of FPB systems.
- To investigate which type of FPB system is best for high rise building.

III. METHODOLOGY

- This work studies the performance of different type of Fictional Pendulum Systems under seismic loading using Finite Element Methods (FEM).

- Analysis of G + 4 building frame without FPS system is considered first using ANSYS Workbench 16.1.
- The 3D model of Fictional Pendulum Systems is developed using AUTO CADD Software and is imported to ANSYS Workbench 16.1.
- Along with the different FPS system same G + 4 building frames is analysed.
- The investigation is conducted using the FEM Software ANSYS Workbench 16.1.
- The spectrum of Kobe earthquake, Japan which occurred in 1995 and 1940 El Centro USA, has been used for the seismic analysis.
- The FPBS and bare frame is modelled using the FEM software analysed for Time history analysis and Harmonic analysis is conducted to obtain the response of various parameters studied.

IV. GEOMETRICAL AND MATERIAL PROPERTIES USED

A. *Frictional Pendulum Geometry*

The dimensions of the Frictional pendulum system considered in the study were fixed with reference to the Maurer of seismic isolation system .From analysing the building without FPBS system we got a total vertical load of 0.2 MN which is within a limit of 0.5 MN of typical vertical load carrying capacity required as per Maurer of seismic isolation system manufactures

After that the Frictional pendulum system of a constant radius of 2110 mm were adopted which is not varying when double and triple concave sliding is needed. Coefficient of friction: 0.05 and 0.2 is taken for comparing results. Damping Ratio: 0.2 is taken and Poisson's ratio of 0.3 is taken because bearing is made of steel.

B. *Building Geometry*

The properties of the considered building configurations in the present study are summarized below:

- Number of Storey : G + 4
- Height of each floor: 3 m
- Plan dimensions of each storey block: 6 × 6 m
- Density of concrete: 24 KN/m^3
- Poisson's ratio of concrete: 0.15
- Damping co-efficient: 0.33
- Size of Columns: 250×250mm
- Size of Beams: 250×250mm

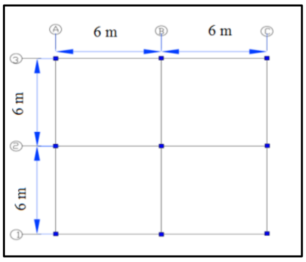

Fig. 4: Plan of Building Model

V. FINITE ELEMENT MODEL

The ANSYS is a software package for the finite element analysis. The FEM model of isolator is created using ANSYS workbench 16.1. The SOLID186 element is used for the modelling of the base isolator and for assigning the contact properties CONTACT174 and TARGET170 are taken. BEAM188 element is used for the modelling of the bare frame. Support condition of bare frame without bearing system and for bearing fixed supports taken.

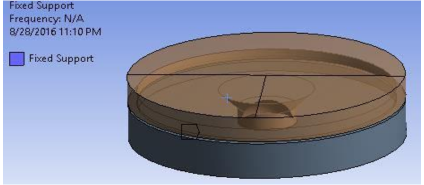

Fig. 5: Support condition of the isolator

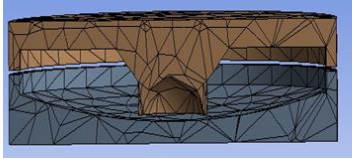
Fig. 6: Mesh configuration of the isolator

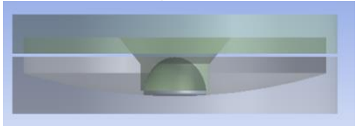
Fig. 7: Model of the Single Pendulum Bearing Isolator

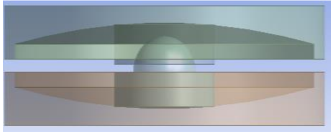
Fig. 8: Model of the Double Pendulum Bearing Isolator

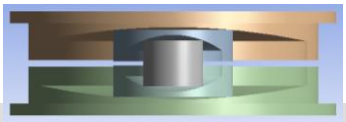
Fig. 9: Model of the Triple Pendulum Bearing Isolator.

VI. ANALYSIS AND RESULTS

Analysis Result For stress in bearing for type of Frictional Pendulum Bearing System and Using Acceleration of Kobe Earthquake (Frictional Co-Efficient Is 0.2)

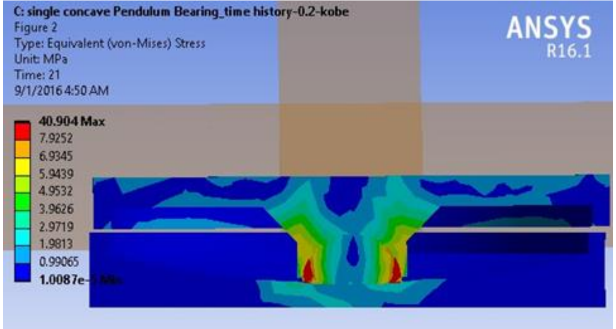

Fig. 10: Equivalent Stress of Single Frictional Pendulum Bearing

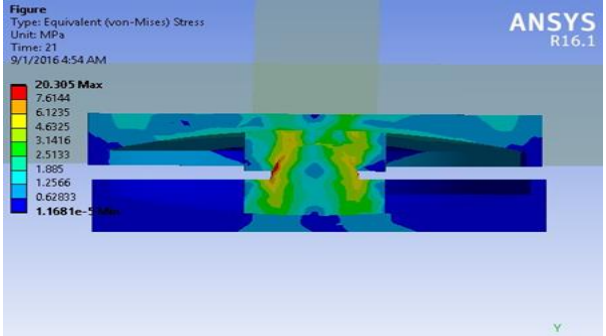

Fig. 11: Equivalent Stress of Double Frictional Pendulum Bearing

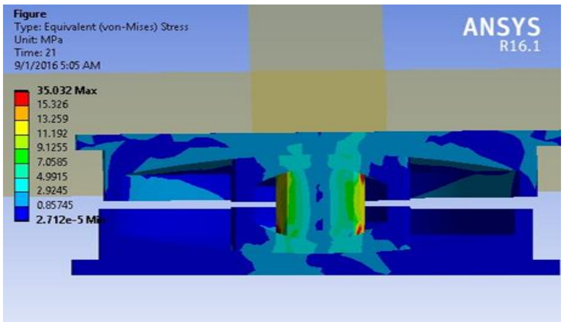

Fig. 12: Equivalent Stress of Triple Frictional Pendulum Bearing

Without Isolator		
	Kobe Earthquake	El-Centro Earthquake
Total Deformation (mm)	31.454	67.245
Equivalent Stress (Mpa)	6.8547	16.356

Table 1: Analysis Results for Building without Isolator on Kobe and El-Centro Earthquakes

WITH PENDULUM BEARING ISOLATOR			
	Kobe Earthquake		
µ	0.05		
Type of FPB	SFPBS	DFPBS	TPPBS
Total deformation(mm)	23.457	23.493	23.608
Total equivalent stress (Mpa)	41.757	20.305	35.032
Equivalent stress of Building (Mpa)	5.286	5.291	5.301

Table 2: Analysis Results For Building with Different Type of Isolator on Kobe Earthquake (µ=0.05)

With Pendulum Bearing Isolator			
	Kobe Earthquake		
µ	0.2		
Type of FPB	SFPBS	DFPBS	TPPBS
Total deformation(mm)	23.45	23.49	23.609
Total equivalent stress(Mpa)	40.9	20.31	35.032
Equivalent stress of Building (Mpa)	5.285	5.293	5.301

Table 3: Analysis Results for Building with Different Type of Isolator on Kobe Earthquake (µ=0.2)

With Pendulum Bearing Isolator			
	El-Centro Earthquake		
µ	0.05		
Type of FPB	SFPBS	DFPBS	TPPBS
Total deformation(mm)	55.529	55.589	55.827
Total equivalent stress(Mpa)	88.012	42.522	73.112
Equivalent stress of Building (Mpa)	11.335	11.345	11.346

Table 4: Analysis Results For Building with Different Type of Isolator on El-Centro Earthquake (µ=0.05)

With Pendulum Bearing Isolator			
	EL-Centro Earthquake		
µ	0.2		
Type of FPB	SFPBS	DFPBS	TPPBS
Total deformation(mm)	55.516	55.548	55.827
Total equivalent stress (Mpa)	88.232	42.947	72.329
Equivalent stress of Building (Mpa)	11.333	11.344	11.345

Table 5: Analysis Results For Building with Different Type of Isolator on El-Centro Earthquake (µ=0.2)

Base Shear				
Earthquake	Kobe		El-Centro	
µ	0.05	0.2	0.05	0.2
SFPBS	12680 N	12678 N	25396 N	25390 N
DFPBS	12684 N	12684 N	25423 N	25404 N
TPPBS	12765 N	12765 N	25541 N	25535 N
Without Isolator	16936 N		40621 N	

Table 6: Base Shear for Different Type of Isolator on Kobe and El-Centro Earthquakes.

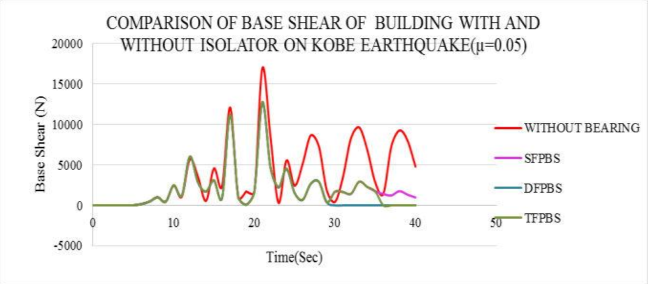

Fig. 13: Comparison of Base Shear for Different Type of Isolator on Kobe (µ =0.05)

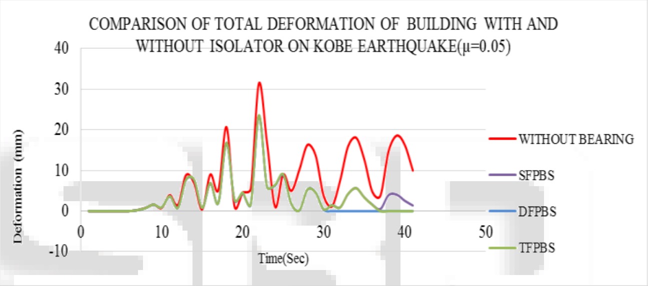

Fig. 14: Comparison of Total deformation of Building for different type of isolator on Kobe (µ =0.05)

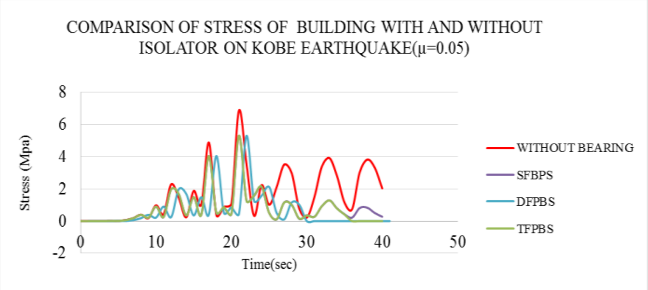

Fig. 15: Comparison of Stress of Building for different type of isolator on Kobe (µ=0.05)

VII. CONCLUSIONS

In order to study this effect a two different coefficient of friction (0.05) and (0.20) have been carried out with constant radius of concave 1055 cm for different type of pendulum bearing on each type of earthquake. As a result of comparison between curves, it has been shown that the larger the friction coefficient the later the isolation mechanism is activated. The base shear decreases with the installation of Pendulum Bearings. It has been shown that base shear in a sliding-based isolated system is 24.952 % for Kobe earthquake & 37.349 % for El-Centro smaller than the one in a fixed-base structure. This can be achieved at the cost of a sliding displacement in bearings. For El-Centro earthquake the reduction of stress will be 31% in building than that without isolators and for Kobe earthquake the reduction of stress will be only 23% that is the pendulum is more effective in reducing stress in building for high magnitude earthquake. By improving the co-efficient of friction there will not be much difference in reduction of deformation of building for different type of pendulum bearings. Here we have different working mechanism for each type of bearing and we have given same co-efficient of friction in each type of analysis for pendulums from that it is clear that double frictional pendulum is more efficient than other two pendulums for reducing stress and deformation in building. As the magnitude of an earthquake increases, the sliding displacement becomes larger. By considering most economical and active FPB in practice could be beneficial for a variety of applications such as buildings with irregular first stories, changing in column arrangement. As the base isolated structure subjected to ground motions with long predominant periods, the proposed isolator also possesses an excellent earthquake-proof benefit without significant sliding displacements. Therefore, it can be concluded that the concepts we have proposed in theory and engineering practice can be regarded as powerful tools in designing and enhancing seismic resistibility of structures located at various types of buildings.

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