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Seismic Response of Multi Storey RC Building with Friction Pendulum Bearing System

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Abstract: Buildings are very important after any natural hazards such as earthquake. The structural and nonstructural components are should repair and safe after earthquake. So to mitigate the effect of earthquake on the structure the friction pendulum base isolation technique to improve the performance of building. The basic idea of friction pendulum system is to reduce the earthquake demand on building and increase the fundamental time period on the structure. The aim of this study to investigate the finite element modeling of friction pendulum system for different radii of a multi-story building subjected to earthquake force by using SAP2000 V18 software. In this study G+12 story building is used as a model. Nonlinear time history analysis is carried out for building. El-Centro earthquake is used for time history analysis. The result obtained shows the reductions in base shear in both directions, net displacement, and increase in the time period of the building when radius is increases.
Keywords: Base isolation, Friction pendulum, Earthquake, Non Linear Dynamic Analysis, Time History Analysis, Friction Co-efficient

I. INTRODUCTION

Friction pendulum is one type of base isolation. It is use the characteristics of a pendulum to lengthen the natural period of the isolated structure so as to avoid the strongest earthquake forces. During an earthquake, the supported structure moves with small pendulum motions. Since earthquake induced displacement occur primarily in the bearings, lateral loads and shaking movements transmitted to the structure are greatly reduced.

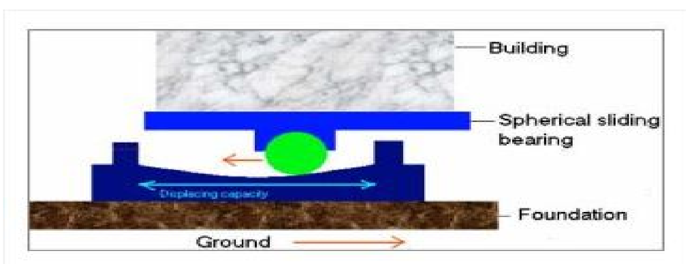

Fig.1 Friction pendulum isolation

A. *Advantages of FPS*

1) It provides strength and stability.
2) FPS can accommodate much larger levels of displacement
3) By increasing the sliding period, the base shear is reduced and displacements are increased.
4) Reducing the co-efficient of friction further reduce base shear and increases displacement.
5) Curvature of the FP controls the frequency of the device.
6) The isolator period is independent of the mass of the supported structure.
7) They are less expensive to install than other base isolation system.
8) Their versatile properties make them effective for a wide range of structures and earthquakes.
9) They have reliable and consistent properties, which are not affected by change in temperature.

B. *Disadvantages of FPS*

1) This device more expensive.

2) The system offers only some re-centering capabilities.
3) There are problems associated with adverse torsional motions in asymmetric structure.
4) It can suffer from stick-slip motion and non-uniform pressure distributions on the sliding interfaces.

II. FINITE ELEMENT MODELING IN SAP2000

SAP 2000 IS general purpose finite element program which performs the static or dynamic, linear or Non-linear analysis of structural systems. It is also a powerful design tool to design structure following AASHTO specifications. The SAP2000 graphic user interface (GUI) is used to model, analyse, design and display the structure geometry, properties and analysis results. The analysis procedure can be divided into three parts
Pre-processing
Solving
Post processing
In sap software building is modelled by using following element

A. Frame Element

The Frame element is a very powerful element that can be used to model beams, columns, braces, and trusses in planar and three-dimensional structures. Nonlinear material behaviour is available through the use of Frame Hinges. The Frame element uses a general, three- dimensional, beam- column formulation which includes the effects of biaxial bending, torsion, axial de formation, and biaxial shear deformations.

B. Shell Element

The Shell element is a type of area object that is used to model membrane, plate, and shell behaviour in planar and three-dimensional structures. The shell material may be homogeneous or layered through the thickness. Material nonlinearity can be considered when using the layered shell. The Shell element is a three- or four- node formulation that combines membrane and plate bending behaviour. The four- joint element does not have to be planar. Structures that can be modelled with this element include:
1) Floor systems
2) Wall systems
3) Bridge decks
4) Three-dimensional curved shells, such as tanks and dome
5) Detailed models of beams, columns, pipes, and other structural members

C. Non-Linear Link Element

The Link element is used to connect two joints together. Link element may exhibit up to three different types of behaviour: linear, non-linear, and frequency-dependent, according to the types of properties assigned to that element and the type of analysis being performed. A Link element is a two-joint connecting link. Link element is assumed to be composed of six separate springs, one for each of six deformational degrees of freedom (axial, shear, torsion, and pure bending).
There are two categories of Link properties that can be de fined: Linear/Non-linear, and Frequency-Dependent. A Linear/Non-linear property set must be assigned to Link element. The assignment of a Frequency-Dependent property set to a Link element is optional. All Linear/Non-linear property sets contain linear properties that are used by the element for linear analyses, and for other types of analyses if no other properties are defined. Linear/Non-linear property sets may have non-linear properties that will be used for all non-linear analyses, and for linear analyses that continue from nonlinear analyses.
Frequency-dependent property sets contain impedance (stiff ness and damping) properties that will be used for all frequency-dependent analyses. If a Frequency-Dependent property has not been assigned to a Link element, the linear properties for that element will be used for frequency-dependent analyses
Link Property is assumed to be composed of six internal “springs” or “Hinges,” one for each of six internal deformations. Each “spring” may actually consist of several components, including springs and dashpots. The force deformation relationships of these springs may be coupled or independent of each other. Figure 2 shows the springs for three of the deformations: axial, shear in the 1-2 plane, and pure-bending in the 1-2 plane. It is important to note that the shear spring is located a distance dj2 from joint j. All shear deformation is assumed to occur in this spring; the links connecting this spring to the joints (or ground) are rigid in shear. Deformation of the shear spring can be caused by rotations as well as translations at the joints. The force in this spring will produce

a linearly-varying moment along the length. This moment is taken to be zero at the shear spring, which acts as a moment hinge. The moment due to shear is independent of, and additive to, the constant moment in the element due to the pure- bending spring.
The other three springs that are not shown are for torsion, shear in the 1-3 plane, and pure- bending in the 1-3 plane. The shear spring is located a distance dj3 from joint j. The values of dj2 and dj3 may be different, although normally they would be the same for most elements.

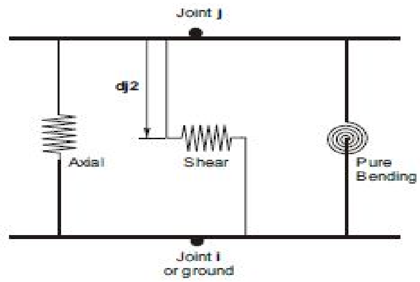

Fig. 2 Internal spring hinges

III. MODEL DETAILS

G+12 RC building take for the investigation of this paper. It is modeled by using SAP 2000 software. Non-linear time history analysis carried out by considering El-Cento. Comparison between three different friction pendulum radiuses and fixed building

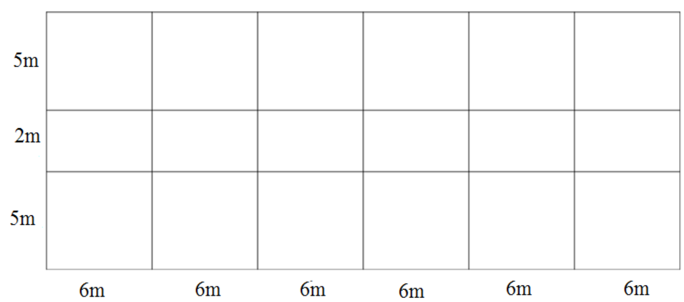

Fig. 3 Building plan

The RC building is taken for the study and its structural details such as grade of concrete, grade of steel, beam sizes, columns sizes and all other parameters are assumed as per table 1

TABLE 1
Geometry property of building

Grade of concrete	M40
Grade of steel	Fe 415
Floor to floor height	3m
Plinth height above GL	1m
Parapet height	1.2m
Slab thickness	150mm
External wall	230mm
Internal wall	150mm
Column	450 x 450 mm
Beam	300 x 500 mm

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Loads acting on building are shown in table 2.

TABLE 2
Loads on Building

Live	3kN/m^2
Floor Finish	1kN/m^2
Parapet	3.6 kN/m
External	11.5kN/m
Internal	7.5 kN/m

Properties of friction pendulum bearing used for analysis

TABLE 3
Property of friction pendulum isolator

Type	FPS
Vertical Stiffness	29000000 kN/m
Linear Stiffness	1450 kN/m
Non-linear Stiffness	29000 kN/m
Damping	0.1
Radius of dish	1m,1.5m.2m

The G+12 RC building is taken for the study. The 3-D view of fixed structure and friction pendulum structure are shown in fig.4 and fig.5.

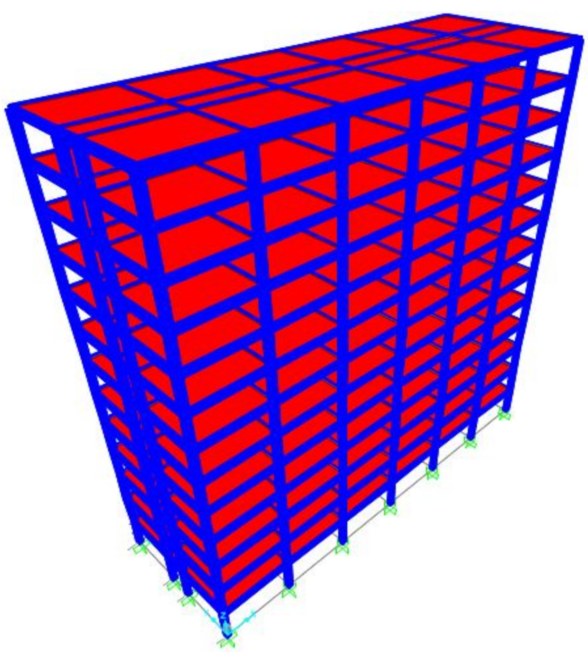
Fig. 4 3-D Model of fixed base structure

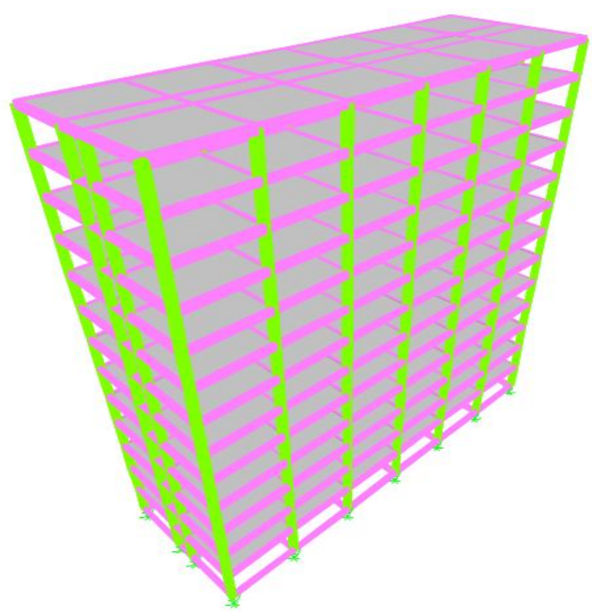
Fig. 5 3-D Model of friction pendulum structure

IV. RESULTS AND DISCUSSION

In this study, comparison between fixed base structure and friction pendulum structure with three different radius of curvature is done. Use of friction pendulum system the base shear, net storey displacement and storey drift ratio as reduces. Time period is increases in the friction pendulum structure.

A. Time Period

Modal period of fixed base structure and friction pendulum system (FPS) are compared.

TABLE 4 Time period value

Mode	FPS	Fixed
1	3.289	1.90816
2	3.2565	1.86959
3	3.0513	1.7498
4	0.9030	0.62901
5	0.8906	0.60652

B. Base Shear

The graph shows (fig 6.) the maximum base shear in X & Y direction

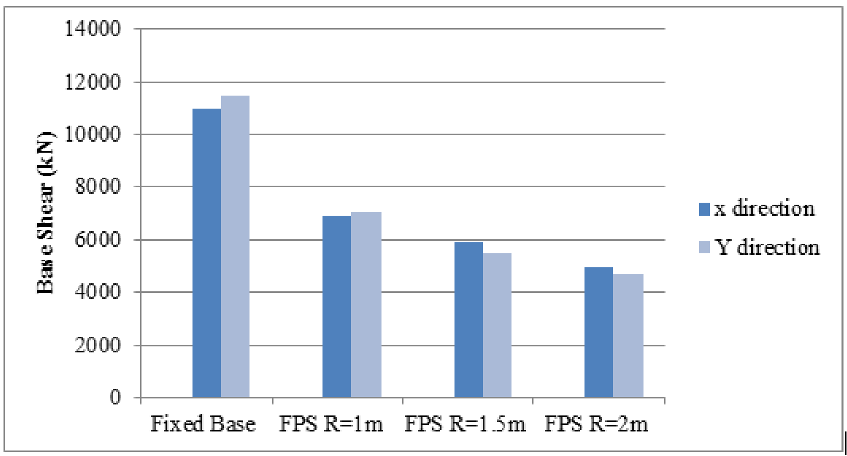

Fig. 6 Base shear in X & Y direction

C. Net Storey Displacement

The graph shows (fig. 7) the displacement of the structures

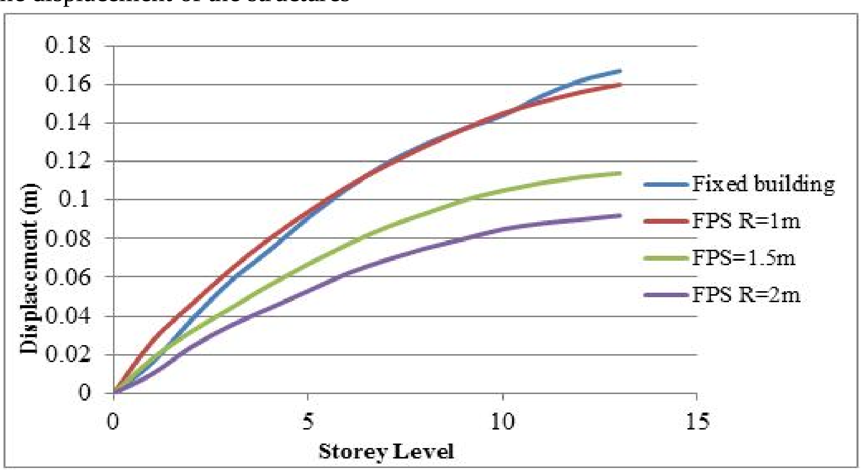

Fig. 7 Net storey displacement

D. Storey Drift Ratio

The graph shows (fig. 8) the storey drift ratio of the structures

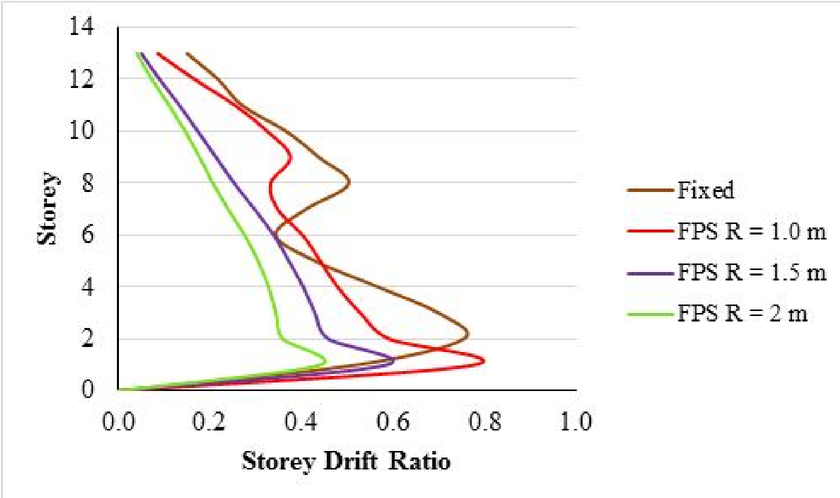

Fig. 8 Storey drift ratio

V. CONCLUSIONS

A. Friction pendulum base isolation method has proved to be a reliable method of earthquake resistant design.

B. The results of the research show that the response of the structure can be reduced by the use of FPS.

C. Time period of FPS with different radius structure increased as compared to the fixed base structure.

D. Parameters such as net storey displacement, story drift ratio and base shear increase with increase the radius of the building. Compare to parameters in three different radius of FPS the best radius is R= 2m

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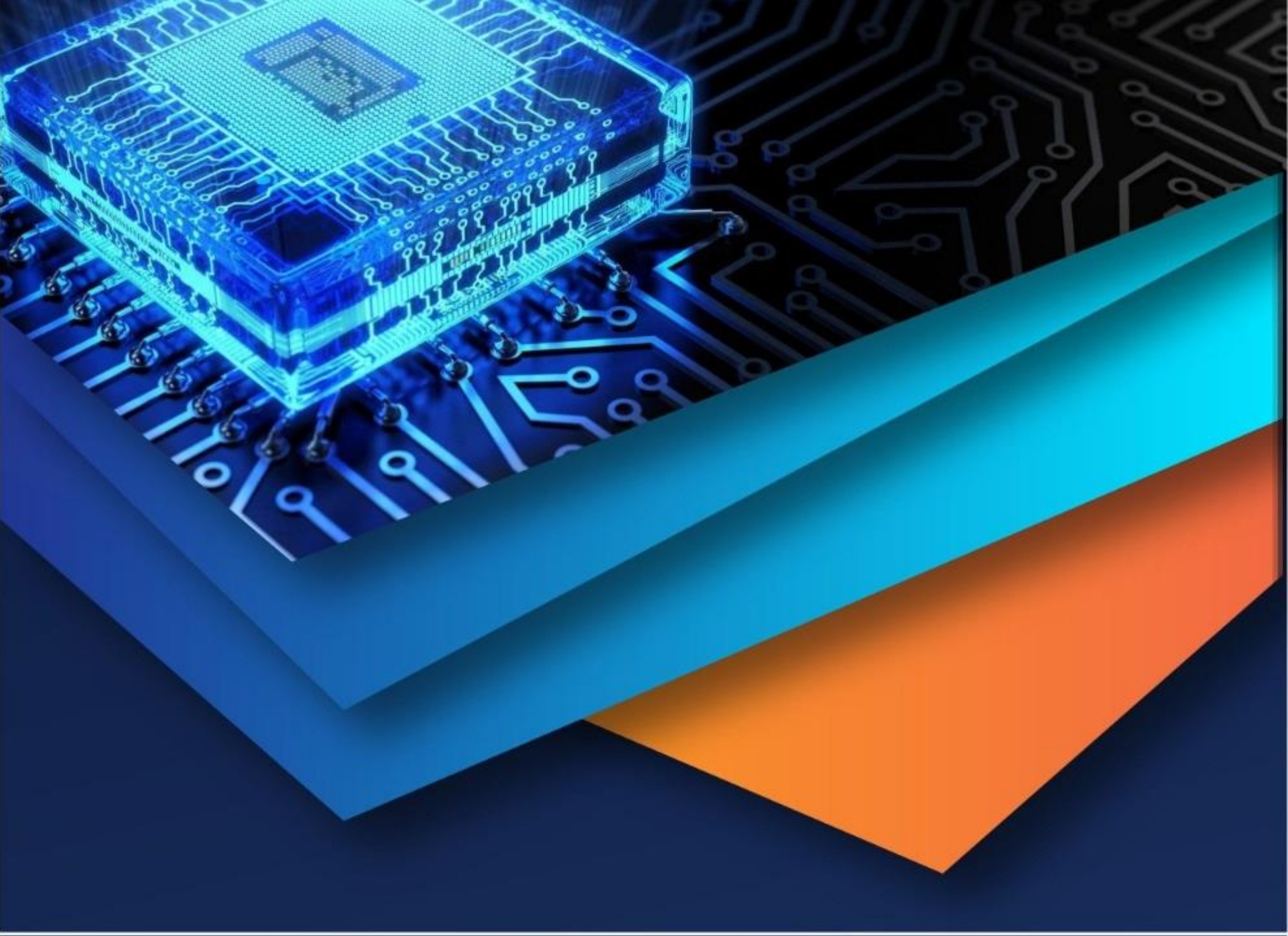

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