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Study of base isolation using friction pendulum bearing system

Tessy Thomas[1], Dr. Alice Mathai[2]
[1]*(Civil Engineering Department , Mar Athanasius College of Engineering/ Mahatma Gandhi University, India)*
[2]*(Civil Engineering Department , Mar Athanasius College of Engineering/ Mahatma Gandhi University, India)*

Abstract: *Base isolation is a technique developed to prevent or reduce damage to buildings during an earthquake. It is a design principle by which flexible supports (isolators) are installed beneath every supporting point of the structure generally located between the foundation and the main structure. One type of base isolation system is Friction Pendulum System (FPS) use the characteristics of a pendulum to lengthen the natural period of the isolated structure so as to avoid the strongest earthquake forces. In this bearing type, the superstructure is isolated from the foundation using specially designed concave surfaces and bearings to allow sway under its own natural period during the seismic events. Since earthquake induced displacements occur primarily in the bearings, lateral loads and shaking movements transmitted to the structure are greatly reduced. In this paper, finite element model of the isolator is developed and its nonlinear static analysis is done. The analytical response of the model is studied for buildings with various storeyes and the results are interpreted.*
Keywords - *Base isolation, High rise building, Finite Element Model, Friction pendulum bearing.*

I. Introduction

Base isolation generally involves introducing components which are horizontally flexible to allow lateral displacement, but vertically stiff to safely carry gravitational loads (i.e. static weight of structure). The horizontal flexibility increases the period of the structure which lowers peak acceleration levels during an event. A fixed-base building (built directly on the ground) will move with an earthquake's motion and can cause extensive damage as a result [1]. When a building is built away (isolated) from the ground, resting on flexible bearings or pads known as base isolators, it will only move a little or not at all during an earthquake.

The seismic isolation method is a creative seismic design method intended to protect the structure against the seismic risk and reduce the seismic energy and forces that structure suffer and not directly resist those forces. If the foundation is rigidly attached to the superstructure, all of the force of the earthquake will be transferred directly and without a change in frequency to the rest of the building. Earthquakes shake the base of buildings laterally, applying what is called shear force to the foundation. When such a large force is same frequency as that of the building's natural frequency, the building will collapse. The main concept behind base isolation is allowing slight lateral movement of the base in order to increase the fundamental time period of the structure. This increase in the period will cause the structure to be less sensitive to seismic forces and will result in less structural damage [2]. Fig. 1 shows the deformed configuration of a multi-storeyed building with and without base isolators.

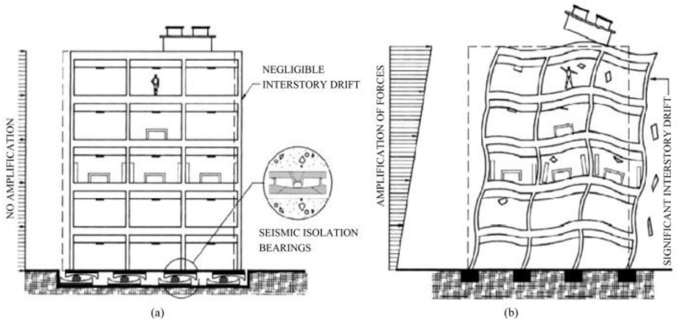

Fig. 1 (a) Isolated structure & (b) Fixed base structure

II. Friction Pendulum Bearing

Sliding friction pendulum isolation system is one type of flexible isolation system suitable for small to large-scale structure. In recent years, the Friction Pendulum System (FPS) has become a widely accepted device for seismic isolation of structures. The concept is to isolate the structure from ground shaking during strong

earthquake. Seismic isolation systems like the FPS are designed to lengthen the structural period far from the dominant frequency of the ground motion and to dissipate vibration energy during an earthquake [3].
The sliding properties of the surface materials are key for the performance of the isolation system. The FPS consists of a spherical stainless steel surface and a slider, covered by a Teflon-based composite material. 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. This isolator uses its surface curvature to generate the restoring force from the pendulum action of the weight of the structure on the FPS [4]. The Fig. 2 shows the typical cross section of a FPS base isolator and Fig. 3 shows the motion of friction pendulum bearing.

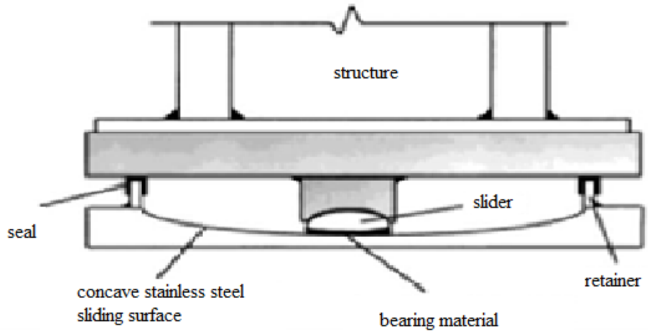

Fig. 2 Cross section of friction pendulum bearing

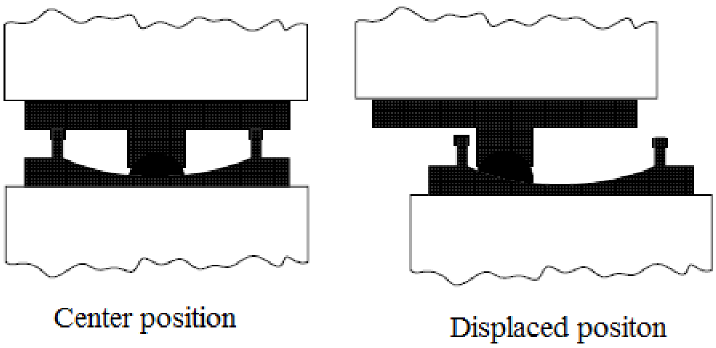

Fig. 3 Motion of friction pendulum bearing

III. Finite Element Model

An establishment of appropriate finite element model for an actual practical problem depends to a large degree on the following factors: understanding of the physical problem including a qualitative knowledge of the structural response to be predicted, knowledge of the basic principles of mechanics and good understanding of the finite element procedures available for analysis. Any structural continuum with an infinite number of degree of freedom can be idealized as an assemblage of finite elements with a finite number of degree of freedom [2]. The general applicability of the finite element method makes it a powerful and universal tool for a wide range of problems. The ANSYS is a software package for the finite element analysis. The FEM model of isolator is created using ANSYS 14.5. The SOLID186 element is used for the modeling of the base isolator and for assigning the contact properties CONTACT174 and TARGET170 are taken. The Fig. 4 and Fig. 5 shows model and the mesh configuration of the isolator. The Fig. 6 shows boundary condition of the isolator.

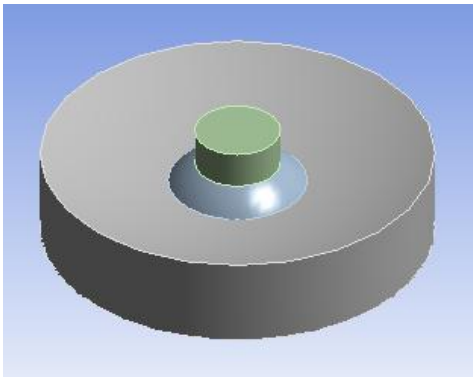

Fig. 4 Model of the isolator

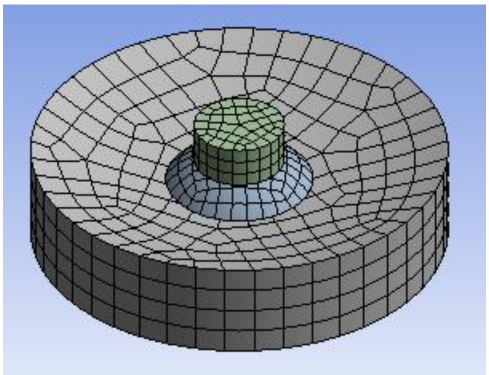

Fig. 5 Mesh configuration of the isolator

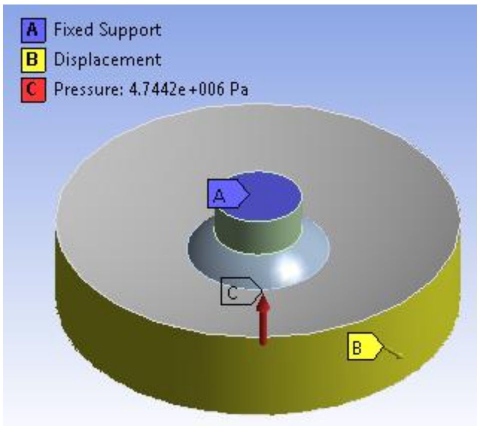

Fig. 6 Boundary condition of the isolator

IV. Analysis And Results

The nonlinear static analysis is conducted for studying the behaviour of the isolator under compressive load and horizontal displacement. The material steel with friction coefficient value 0.1 and the radius of curvature 2235mm is selected for the modeling of the isolator. For a particular storey height (10storey), the displacement controlled analysis is done up to the value of 200mm. Then the analysis is carried for various storey heights (10, 15, 20, 25, 30, and 35). The Fig. 7, 8, 9, 10, 11, 12 shows the stress intensity diagram for various storeyes and the stress intensity values for different storeyes are given in Table 1.

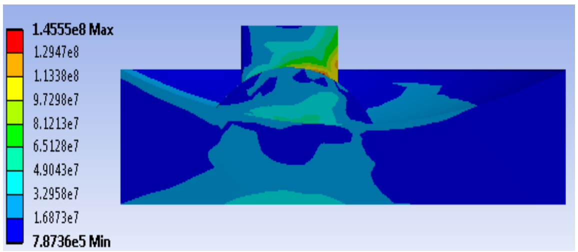

Fig. 7 Stress intensity for 10 storeyes

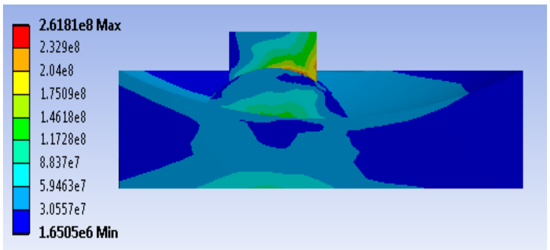

Fig. 9 Stress intensity for 20 storeyes

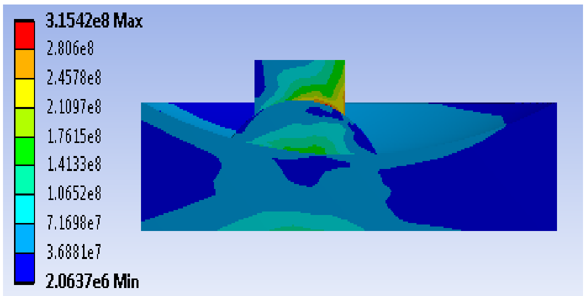

Fig. 10 Stress intensity for 25 storeyes

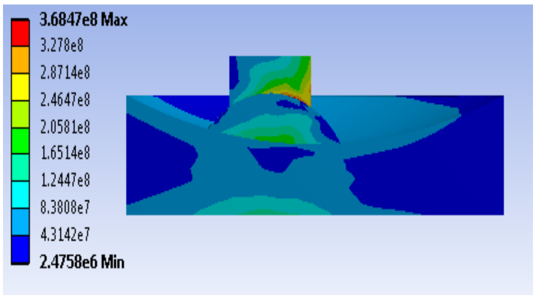

Fig. 11 Stress intensity for 30 storeyes

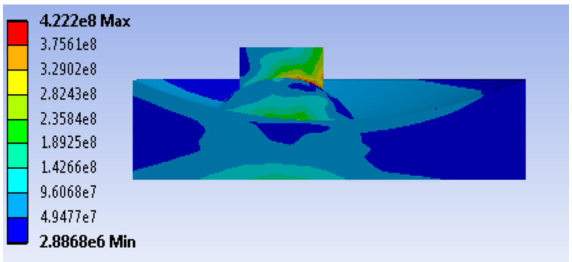

Fig. 12 Stress intensity for 35 storeyes

Table1. Stress intensity results

No. of Storeyes	Stress Intensity Value (MPa)	
	Max	Min
10	146	78.7
15	206	124
20	262	165
25	315	206
30	368	248
35	422	289

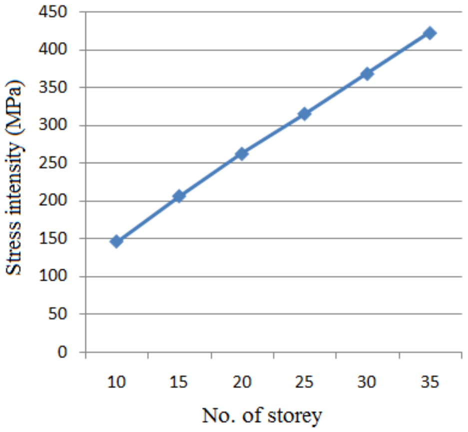

Fig. 13 Number of storey versus stress intensity

The analytical response of the friction pendulum system (FPS) is investigated under same displacement with different storey load values. Here the coefficient of friction and radius of curvature is constant for different storey heights. From the Stress intensity diagram, it is clear that as storey load value increases, its stress intensity also increases. The Fig. 13 shows graphical variation of stress intensity with number of storey. The maximum stress is occurring in the top plate at the contact point in the progressive direction of motion which may be the combination effect of normal & tangential stress. The graphical representation shows that this base isolator designed here is apt for 22 to 30 storeyed building

V. Conclusion

Finite element model of base isolator is created in ANSYS 14.5 software. The behavior of the friction pendulum as base isolator also analyzed. The nonlinear static analysis of base isolator is done for different storey load values. It is concluded that as the number of storey load value increases, stress intensity value also increases. The stress intensity value obtained up to 30-storeyes is within the permissible limits and base isolator can be designed for 22 to 30 storeyed building. From this analysis it is clear that the movement of slider generates a dynamic friction force that provides the required damping for absorbing the energy of the earthquake.

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