Protective Systems for Buildings: Application of Spherical Sliding Isolation Systems

by Michael Constantinou

Abstract

The friction pendulum system (FPS) bearing is a form of spherically shaped, articulated sliding bearing. Movement of one part of the bearing with respect to others resembles pendulum motion in the presence of friction The lateral force needed to induce a lateral displacement, μ, consists of a restoring force equal to $W\mu/R$ and a friction force equal to μW, where R is the radius of curvature of the spherical sliding surface. μ is the coefficient of friction and W is the vertical load on the bearing. The lateral force is proportional to the vertical load, a property which minimizes adverse torsional motions in structures with asymmetric mass distribution. The stiffness of the bearing (W/R) is proportional to the supported mass so that the period of vibration is only dependent on the radius of curvature and acceleration of gravity. This allows designs with large period of vibration, which has distinct advantages in applications to light weight structures and soft soil conditions.

In 1989, NCEER and Earthquake Protection Systems, Inc. collaborated on the shake table testing of a large, six-story steel moment frame model with FPS isolators installed below a rigid diaphragm. Under moderate to severe level ground motions, no uplift of the bearings was observed despite the large overturning aspect ratio of the model. The isolated structure could sustain, while elastic, a peak ground acceleration about six times larger than it could sustain under non-isolated, fixed-base conditions. The tests also revealed that the isolated structure did not respond as a "rigid block", but rather it exhibited response with higher mode participation, as a result of the nonlinearity of the isolation system and flexibility of the superstructure (nearly one second period in prototype scale).

In 1991, tests were conducted with a seven-story, 47.5 kip steel model under fixed-base and isolated conditions, and with various braced and moment frame configurations. Moreover, tests were conducted with the isolators placed directly at the base of individual columns, rather than having a rigid base above the isolators. In severe seismic loading, large overturning moments developed, which resulted in up to $\pm 100\%$ variation on the axial bearing load. The tests provided a wealth of data, which were used to refine analytical models for the isolation bearings and verify simplified analysis procedures. The analytical model has been later implemented in the computer program 3D-BASIS-ME.

The research on the seismic isolation of buildings, together with research conducted in parallel on the seismic isolation of bridges, established the FPS system as a highly researched, well understood and effective seismic isolation system. As a result of this research, the FPS system was selected for the seismic isolation of two major structures: the U S. Court of Appeals building in San Francisco and two liquefied natural gas storage tanks in Greece.

Collaboration

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