

EARTHQUAKE BASE-ISOLATION OF SECONDARY SYSTEMS USING ELASTOMERIC AND SLIDING SYSTEMS

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Abstract

In most industrial facilities, multi-storeyed structures, and nuclear power plants relatively lighter structures/ secondary systems (SS) are attached to the walls or housed on certain floors of the heavier structures/ primary structures (PS). Different types of failure of the SS are noticed during past earthquakes; namely, failure of the fire-fighting facilities, elastic buckling of liquid storage tank walls, failure of library book shelves, heating, ventilation, and air conditioning (HVAC) systems, chemical storage containers, connections failure of water supply pipes, etc. Safety of the SS is vital for proper functioning of the power plants, industrial facilities, hospitals, and other important structures under some catastrophic events of earthquakes. Failure of the SS may pose life hazards in addition to economical and building functioning losses. Seismic performance of the SS can be improved and those also can be safeguarded effectively from the disastrous effects of earthquake-borne vibrations by using the seismic base-isolation technology. From the review of the literature, it is found that, base-isolation in case of SS is not thoroughly investigated yet for its effectiveness in earthquake response reduction, despite the overall effectiveness of the base-isolation in protecting the PS. Most importantly, there is no investigation that clarifies upon the choice of isolation system and its dynamic parameters to be used for isolation of the SS installed in PS. In view of the unavailability of experimental data and lack of information on the dynamic performance of various types of base-isolation systems used in practice, this doctoral research focuses on addressing these two issues first and furthers the efforts by investigating the base-isolation used for SS. The aim of this research is to assess effectiveness of base-isolation for use in protection of the SS housed within primary system under earthquakes. Moreover, investigating comparative performance of various types of base-isolation systems, viz. (a) elastomeric bearings and (b) sliding systems is aimed. Based on the existing knowledge for manufacturing of the bridge bearings in India elastomeric and sliding bearings are designed, manufactured, and characterized at laboratory. Stability analysis of the elastomeric bearings are conducted by developing its three-

dimensional (3D) finite element (FE) models in a commercially available software ABAQUS®. These bearings are currently manufactured and used in India; and, in this context, the present study is useful for the development of indigenous isolation systems and their implementations for safeguarding the SS.

Effect of the dynamic properties of the SS and their housing elevations (levels) within the PS on the response of both the multi-storied PS and SS are investigated experimentally (shake-table investigations) and numerically. Additionally, an experimental study, using shake-table, on base-isolated and non-isolated anchored SS is also conducted. In the current practice of seismic design of the PS or SS, interaction between the two is often ignored. This interaction effect is studied through the present investigations. Moreover, a mathematical model of a five-storied PS housing a single-storied SS at different floor elevations is developed and verified with experimental results.

Experimental investigations on response of the SS while housing them in two adjacent demonstration buildings at IIT Guwahati campus is set by developing a programme for real-time event monitoring. A continuous real-time response monitoring of the instrumented SS setup using a computer-aided data-acquisition system helps in study of the SS response under real earthquake event. Furthermore, the response of the SS is also studied while modelling them in two real-life reinforced concrete (RC) buildings, one supported with the combination of elastomeric and sliding isolators and another supported on double concave friction pendulum bearing. The studies have showed the effectiveness of the PS base-isolation for protecting the SS.

Deterministic and stochastic response study for piping-type SS are further conducted and comparative assessment of the dynamic response of the piping-type SS is made between fixed-base and base-isolated structures. The stochastic response of the base-isolated PS with SS and fixed-base PS with secondary system are computed in a polynomial chaos framework and the details of the stochastic framework are presented in detail. The seismic response of the floor-mounted liquid storage tank type SS with and without isolation system are further studied. A new isolation system for the light-weight SS is devised and proposed herein.

Based on the aforementioned comprehensive, FE, experimental, and numerical studies conducted on the fixed-base (floor-anchored) and base-isolated SS it is observed and concluded that, in case of the SS equipments design forces should be calculated based on coupled analysis than cascading analysis. Floor response spectra govern the design of the isolation systems for the SS. The sliding isolators being highly nonlinear impart more acceleration while moving from stick condition to slip condition. This type of behaviour is detrimental for the acceleration-sensitive type of the SS. The elastomeric isolators are the smooth-type systems; hence, the floor accelerations in this type of isolation system are less which is beneficial in safeguarding the acceleration-sensitive SS. Base-isolated PS helps in reducing its inter-story drift, which benefits to safeguard piping-type displacement-sensitive SS.