UNCERTAINTY QUANTIFICATION AND SEISMIC FRAGILITY OF BASE-ISOLATED LIQUID STORAGE TANKS

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by

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submitted
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Dedicated to my parents and wife

For their endless love, support and encouragement

CERTIFICATE

This is to certify that the thesis titled, "**UNCERTAINTY QUANTIFICATION AND SEISMIC FRAGILITY OF BASE-ISOLATED LIQUID STORAGE TANKS**" being submitted by **Mr. Sandip Kumar Saha** to the Indian Institute of Technology Delhi for the award of the degree of **DOCTOR OF PHILOSOPHY** is a record of the bonafide research work carried out by him. He worked under our supervision for the submission of thesis, which to our knowledge has reached the requisite standard as demonstrated by excellent international publications in journals and conferences.

Further, the contents of his research work, in full or in parts, have not been submitted to any other institute or university for the award of any degree or diploma to the best of our knowledge and belief.

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ABSTRACT

Liquid storage tanks play an important role in civil society and in many industries such as aviation, oil refinery, nuclear, power generation and others. Failure of such lifeline structures during earthquake may impart extreme difficulties on rescue operation due to unavailability of the basic needs, such as water, milk, fuel and power. Besides these direct impacts, failure of tanks may cause further catastrophic accidents by initiating fire or spreading radioactive substances. In nutshell, the risk of human life loss and huge economic loss, due to such failures, necessitate increased protection of the liquid storage tanks from devastating earthquakes. One of the effective measures, to protect structures against earthquake force, is to use seismic base isolation technique. Moreover, seismic analysis of structures in the probabilistic domain and reliability based design has gained popularity over the years among the structural engineering community. In addition, it is important to consider the uncertainties involved in the earthquake excitation as well as in the isolation parameters during seismic response analysis of base-isolated structures. The assessment of the seismic protection can be performed using fragility analysis, in a more convincing way, by considering the uncertainty in the seismic demand and capacity.

Herein, the effects of the modeling approaches for the liquid storage tank and base isolation system on the seismic response of the base-isolated liquid storage tanks under uni- and bi-directional earthquakes are investigated. The response of the base-isolated liquid storage tanks under near-fault earthquakes is studied to examine the suitability of the equivalent pulse type acceleration input in place of recorded near-fault earthquake acceleration. Seismic fragility of the base-isolated liquid storage tanks is evaluated under stochastic earthquake ground motions using Monte Carlo (MC) simulation. Different earthquake intensity measure (IM) parameters are compared for the fragility analysis. Influence of the uncertain isolation parameters and level of uncertainties, on the peak response distribution of the base-isolated liquid storage tanks, is investigated using response surface model (RSM). Thereafter, seismic fragility of base-isolated liquid storage tanks, considering the uncertainty involved in the isolator parameters and earthquake ground motions, are carried out using the RSM based simulation technique. Further, generalized polynomial chaos (gPC) expansion technique is used to investigate the effect of uncertainties in the isolation parameters on the peak response quantities and fragility of base-isolated liquid storage tanks under random base excitation. Different approaches, presented herein, to evaluate the seismic fragility of base-isolated liquid storage tanks are also compared. An assessment of various isolation systems, to enhance

the protection level of liquid storage tanks under devastating earthquake, is carried out through development of fragility curves.

It is observed that the modeling approaches, for the liquid storage tanks and isolation systems, significantly affect the peak seismic response of base-isolated liquid storage tanks. Generalized polynomial chaos (gPC) expansion technique is found to be capable of modeling the parametric uncertainties in dynamic analysis of base-isolated liquid storage tank. Uncertainties in the excitation and isolation parameters significantly influence the peak seismic response, and thereby play a crucial role in the evaluation of seismic fragility of the base-isolated liquid storage tanks. However, it is further observed that the uncertainty in the isolation damping has lesser effect on the seismic fragility of base-isolated liquid storage tanks. Furthermore, equivalent linear modeling of the isolator non-linear hysteretic behavior does not affect the seismic fragility for the base-isolated liquid storage tanks significantly. It is observed that the base isolation helps to reduce the probability of failure of liquid storage tanks and it diminishes the effect of uncertainties in the base excitation, i.e. earthquake. The RSM based and gPC expansion based simulations are observed to be accurate and time efficient alternative to direct MC simulation that requires high computational efforts. Further, it is observed that the enhancement in the seismic performance of the liquid storage tanks varies significantly for the different isolation systems commonly used in practice.

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