SEISMIC PERFORMANCE OF FIXED BASE AND BASE ISOLATED LIQUID STORAGE TANKS CONSIDERING SOIL-STRUCTURE INTERACTION

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under the supervision of

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August 2020

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Declaration by the Research Scholar

This is to certify that the Thesis entitled "**Seismic Performance of Fixed Base and Base Isolated Liquid Storage Tanks Considering Soil-Structure Interaction**", submitted by me to the Indian Institute of Technology Mandi for the award of the Degree of Master of Science (by research) is a bonafide record of research work carried out by me under the supervision of **Dr. Sandip Kumar Saha**. The content of this Thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any Degree or Diploma.

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Declaration by the Research Advisor

This is to certify that the Thesis entitled "**Seismic Performance of Fixed Base and Base Isolated Liquid Storage Tanks Considering Soil-Structure Interaction**", submitted by **Mr. Hitesh Kumar** to the Indian Institute of Technology Mandi for the award of the Degree of Master of Science (by research) is a bonafide record of research work carried out by him under my supervision. The content of this Thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any Degree or Diploma.

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ABSTRACT

Liquid storage tanks are used to store water, chemical, petroleum, liquified natural gas, and various other industrial products. Considering the crucial importance of liquid storage tanks for society and industry, these are categorized as lifeline structures. Such structures must remain functional even in the worst case of a natural or manmade hazard, like earthquake, fire, blast, etc.

It is quite common in practice that the liquid storage tank structures are analyzed and designed assuming the rigid base condition, i.e. omitting the effect of soil-structure interaction (SSI). Studies on liquid storage tanks with rigid reinforced concrete walls suggest that the assumption of a rigid base may not hold for the tank structure resting on soft soil. Limited studies can be found out on the seismic behavior of liquid storage tanks with flexible steel walls considering soil-structure interaction (SSI), especially when the tank structure is equipped with mitigation measure like base isolation system.

The present study develops a detailed numerical framework for modeling the soil-liquid-structure interaction, and subsequently, thoroughly investigates the seismic performance of fixed base (i.e., uncontrolled or without base isolation) as well as base isolated liquid storage tanks. The scope of the study includes two of the most common structural configurations of cylindrical shaped liquid storage tanks with flexible walls, namely ground supported and elevated. Lumped mass approach is considered for modeling the liquid storage tanks. The base isolated tank structures are considered isolated with elastomeric bearings, such as laminated rubber bearing and lead rubber bearing.

The effect of SSI is investigated on the seismic fragility and peak seismic responses of various structural configurations of liquid storage tanks, which also includes investigating the seismic effectiveness of base isolation system. Seismic fragility is expressed in terms of tank wall buckling, which is related to the hydrodynamic shear forces and moment induced at the tank base. For the seismic fragility analysis, the soil domain is assumed as homogenous half-space, and the computationally efficient substructure approach is adopted to model the SSI system. Seismic fragility curves are developed for different configurations of the tanks, base conditions (rigid base and flexible base), and soil types (in case of flexible base). Thereafter, a detailed finite element model for the soil domain is adopted to investigate the effect of multi-layered

soil on the seismic responses of liquid storage tanks. Lastly, the critical soil parameters are considered as uncertain, and assigned with suitable probability distribution functions, to investigate their effect on seismic responses of liquid storage tanks. Overall, it is concluded that the slender tanks possess the highest probability of failure regardless of the soil stiffness and the presence of base isolation system. Further, it is observed that in the case of fixed base tanks, the soil-structure interaction can likely reduce the amplitude of peak base shear and overturning moment. The present study suggests taking into account the effect of soil-structure interaction when the soil underlying the tank structure is relatively soft or when the site is prone to strong earthquakes.

Keywords: Base isolation, Earthquake, Liquid storage tank, Seismic fragility, Soil-structure interaction (SSI), Uncertainty.

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