Coupling effects on the probabilistic response of tanks and piping systems subject to seismic loading

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ABSTRACT

Usually, industrial plant components, such as tanks, pipe elbows, etc., are analyzed individually to assess their fragilities, i.e., various probabilities of failure conditional on the earthquake intensity measure (hazard demand). Individual fragility curves are then combined to obtain the seismic fragility curve of the overall system, even though this approach neglects coupling effects among different components. This may result in an approximate fragility curve, incapable of representing the actual behaviour of a system composed of a tank and multiple pipes. This paper is an extension of [1] and investigates the coupling effects in the fragility curves using various tank configurations and a reference piping system, whose performance was investigated in [2]. The objective of this work is to evaluate tank geometry effects on the dynamic properties of the piping system and the fragilities. As a first step, a simplified mass-spring model of typical industrial liquid storage tanks was attached in series onto a boundary branch of a piping system. Uncertainty in the coupling was simulated by considering, as a random variable, the geometric aspect ratio of the tanks, i.e., height-to-radius ratios. In order to provide a non-uniform, asymmetric and compact support distribution of the random aspect ratios, a modified version of the well-known beta distribution was formulated and employed. Afterwards, the resulting stochastic models were analyzed via Monte Carlo simulations by examining the random eigenproperties and autocovariance matrices of selected displacement outputs. Fully correlated and uncorrelated input excitation was considered. Most simulations were replicated, applying the stochastic collocation method [3], to investigate the optimal Lagrange polynomial size. Finally, this preliminary analysis was extended to a case study where interactions between a piping system and its components, e.g., realistic FE-based broad/slender tanks, were taken into account. Therefore, coupling/decoupling effects on the overall dynamic response (displacement and stresses) and fragility curves vs. hazard demand of the piping system were examined.

REFERENCES

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