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Predicting Dynamic Capacity Curve of Elevated Water Tanks: A Pushover Procedure

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Abstract

Despite the importance of water tanks for water supplies and supporting the community resilience through the firefighting usages in catastrophic conditions, post-earthquake situations especially, a few studies have been done on seismic behavior of water tanks so far. The scope of this paper is to propose a new pushover procedure to evaluate seismic responses of elevated water tanks (EWT) supported on the concrete shaft in the form of dynamic capacity curves (i.e. base shear versus top displacement). In this regard, a series of shaft supported EWTs are simulated considering soil-structure and fluid-structure interactions. The shaft is modelled with frame elements and plastic hinges are assigned along the shaft to consider the material nonlinearity. The effect of soil-structure interaction and fluid-structure interaction are considered through the well-known Cone model and modified Housner model, respectively. At first, parametric studies have been conducted to investigate the effects of various essential parameters such as soil type, water level and tank capacity on seismic responses of EWTs using incremental dynamic analysis (i.e. nonlinear-time-history-analyses with varying intensities). Thereafter, pushover analyses as nonlinear static analyses are performed by variation of lateral load patterns. Finally, utilizing these results and comparing them with mean IDA curve, as an exact solution; a pushover procedure based on the most reliable lateral load patterns is proposed to predict the mean IDA curve of the EWTs supported on the concrete shaft. The obtained results demonstrate the accuracy of the proposed pushover procedure with errors limited to 30 % only in the changing stage from linear to nonlinear sections of the IDA curve.

Keywords: Elevated Water Tank; Soil-Structure Interaction; Fluid-Structure Interaction; Load Pattern; Incremental Dynamic Analysis (IDA); Pushover; Nonlinear Response History Analysis (NLRHA).

1. Introduction

Water tanks are used for drinking, firefighting, agriculture, and different industrial plants [1-4]. To keep the required water pressure in the water network, engineers use EWTs, which increase the head of water in the network. Failure to these structures has a negative impact on the overall performance of the water network and degrade the resilience of water networks and consequently, the overall serving community (i.e. by increasing the potential of human losses and economic damages) after severe hazard such as seismic events. A review on the past earthquake demonstrates the vulnerability of EWTs having reinforced concrete shaft-type supports. For instance in 2001 Bhuj earthquake, three EWTs collapsed completely, and many more were damaged severely (Figure 1), and similar damages were observed in 1997 Jabalpur earthquake [5].

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