



Optimal intensity measures for resilience-oriented probabilistic seismic demand models of elevated steel tanks

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ABSTRACT

The establishment of a probabilistic seismic demand model (PSDM) represents a pivotal element within the framework of performance-based earthquake engineering (PBEE). This study presents a comprehensive evaluation of optimal ground motion intensity measures (IMs) for elevated steel tanks, considering both base-isolated and non-isolated configurations, to enhance seismic resilience. The methodology involves selecting and categorizing IM-EDP (engineering demand parameter) pairs, performing regression-based PSDM analyses, and assessing IM performance using criteria of scaling robustness, practicality, efficiency, proficiency, and sufficiency. A database of 135 ground motion records is employed to quantify these relationships. Results indicate that, for base-isolated tanks, the Velocity to Acceleration Ratio ($I_{v/a}$), Peak Ground Velocity (PGV), and Spectral Acceleration ($S_a(T_1, \xi)$) emerges as the preferred IM for the elevated tank with base isolation in base shear (V_b), overturning moment (M_b), tower displacement (x_s), and vertical displacement of the liquid surface (d_v), respectively. In addition to non-base isolation, the Modal Mass Participation Ratio (MPMR) obtained optimal values in V_b , M_b , and x_s , and the optimal value in d_v belonged to a Set of IM similar RMSd (d_s) and Spectral displacement (s_d). These findings directly inform resilience-based performance metrics, indicating improved structural reliability, reduced probability of damage, and enhanced recovery potential under seismic events. Ultimately, such advancements contribute to strengthening seismic resilience by enabling infrastructure to withstand better, adapt to, and recover from earthquake-induced disruptions.

1. Introduction

Elevated water tanks are critical components of water distribution systems, providing communities with storage and pressure regulation for potable water supply. However, these structures are vulnerable to ground motion events, which can compromise their stability and integrity. The sensitivity of elevated tanks to ground motion arises from their unique structural characteristics and the dynamic interaction between the tank and its supporting structure [1,2]. During an earthquake, the ground motion induces dynamic forces on the tank's structure, leading to oscillations and potentially causing structural damage or failure. The susceptibility of elevated tanks to ground motion is

influenced by various factors, including the design and construction of the tank, the characteristics of the supporting structure, and the intensity and duration of the seismic event [3–5]. In a broader sense, resilience refers to the capacity of systems and communities to withstand disruptions, adapt to changing conditions, and recover effectively from adverse events [6–8].

A metric used to gauge the severity or degree of ground motion during an earthquake at a particular site is an intensity measure (IM) in earthquake engineering [9]. IMs are frequently based on the physical characteristics of an earthquake, such as peak ground acceleration (PGA) and spectral acceleration during the first period of the structure for a damping ratio of 5%, $S_a(T_1, 5\%)$, peak ground velocity (PGV),

Abbreviations: IM, Intensity Measure; $SaT1,5\%$, Damping Ratio of 5%; FVDs, Fluid Viscous Dampers; MIDR, Inter-Story Drift Ratio; d_v , Vertical Displacement of the Liquid Surface; M, Magnitude; m_b , Stiff Mass; m_s , Sloshing Mass; ξ_i , Impulsive Mass; M_b , Overturning Moment; IDA, Incremental Dynamic Analysis; PGA, Peak Ground Acceleration; PGV, Peak Ground Velocity; RC, Reinforced Concrete; SMRFs, Special Moment Resisting Frames; PEER, Pacific Earthquake Engineering Research Center; R, Source Distance; m_r , Impulsive Mass.; ρ_s , Mass Density; ξ_c , Sloshing Mass.; V_b , Base Shear; T_i , Natural Period.

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