Seismic fragility analysis of a tank-piping system based on hybrid simulation and Kriging surrogate modelling

Rocco di Filippo[1], Giuseppe Abbiati[2], Osman Sayginer [1], Oreste S. Bursi[1]

[1]University of Trento, Department of Civil, Environmental and Mechanical Engineering (DICAM), Trento, Italy.
e-mail: rocco.difilippo@unitn.it, osman.sayginer@unitn.it, oreste.bursi@unitn.it

[2]ETH Zürich, Department of Civil, Environmental and Geomatic Engineering (D-BAUG), Institute of Structural Engineering (IBK), Zürich, Switzerland.
e-mail: abbiati@ibk.baug.ethz.ch

ABSTRACT

Seismic risk evaluation of coupled systems of industrial plants often needs the implementation of complex finite element models able to take into account their multicomponent nature and the relevant coupling effects. These models typically rely on an extensive consumption of computational resources [1]. Moreover, the relationships between seismic action, system response and relevant damage levels are often characterized by a high level of nonlinearity, thus requiring a solid background of experimental data. Furthermore, both fragility and reliability analyses depend on the adoption of a significant number of seismic waveforms that are generally not available when the seismic risk evaluation is strictly site-specific.

With the aim to propose a methodology able to manage the above-mentioned issues, this research work presents a seismic reliability analysis of a coupled tank-piping system. The novelty of our approach lies in the adoption of artificial accelerograms [2], finite element models and experimental hybrid simulations to evaluate a reliable and fast surrogate meta-model of our system. As the first step, to obtain the necessary input for a stochastic ground motion model able to generate synthetic ground motions coherent with the site-specific analysis, a disaggregation analysis of the seismic hazard is performed. Hence, we reduce the space of parameters of the stochastic ground motion model by means of an extensive global sensitivity analysis upon the seismic response of our system, evaluated with a simplified MATLAB FEM.

Based on the reduced space of parameters, we generate a large set of artificial waveforms and select, among them, a few signals to provide the input for experimental hybrid simulations. In detail, the hybrid simulator is composed by a numerical substructure, able to predict the seismic sliding response of a steel tank, and a physical substructure made of a realistic piping network.

Furthermore, we use these experimental results to calibrate a refined ANSYS FEM with a special focus on the most vulnerable components, i.e. pipe bends. More precisely, we focus on tensile hoop strains in elbow pipes as a leading cause for leakage, monitoring them with strain gauges. Thus, the procedure to build a numerical Kriging surrogate model [3] of the coupled system based on both experimental and finite element model results is investigated. Finally, the methodology to carry out a seismic fragility analysis based on this surrogate model is presented.

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