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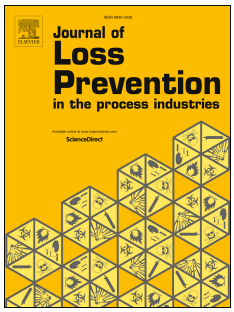


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# Probabilistic Seismic Analysis of an LNG Subplant

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ABSTRACT

Refrigerated liquefied gas (RLG) terminals that are part of lifeline facilities must be able to withstand extreme earthquakes. A liquefied natural gas (LNG, ethylene) terminal consists of a series of process facilities connected by pipelines of various sizes. Although tanks, pipes, elbows and bolted flanges have been a major concern in terms of seismic design, generally, they have not been analysed with modern performance-based procedures. In this study, the seismic performance of pipes, elbows and bolted flanges is analysed and seismic fragility functions are presented within the performance-based earthquake engineering framework.

Particular attention was paid to component resistance to leakage and loss of containment even though several different limit states were investigated. The LNG tank, support structures and pipework, including elbows and flanges, were analysed with a detailed 3D finite element model. For this purpose, we developed a mechanical model of bolted flange joints, able to predict the leakage limit state, based on experimental data. A significant effort was also devoted to identification of a leakage limit state for piping elbows, and we found the level of hoop plastic strain to be an indicator. Given the complexity of the FE model of the LNG plant, we selected the Cloud method for probabilistic seismic demand analysis, due to its advantages in terms of consistency in the seismic input and of computational savings. Then, using a series of nonlinear time history analyses, we studied the behaviour of critical components such as elbows and bolted flange joints. In order to develop fragility curves, we selected a set of 36 ground motions from a database of historic earthquake accelerations. The results of seismic analysis show that bolted flange joints remain significantly below their leakage threshold whilst elbows at the top of the LNG tank are likely to show leakage. Moreover, fragility functions were computed, based on a linear regression approach, and we deduce that elbows located on the tank platform are relatively unsafe against earthquakes. Finally, the estimated probability of loss of containment was above the probability associated with ultimate limit states involved in structural Eurocodes.

Keywords: Seismic Risk; LNG Plant; Piping network; Elbow; Vulnerability analysis; Leakage; Plasticity.