Numerical investigation on storage tank buckling near the liquid level under seismic loading

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ABSTRACT

In Nuclear Power Plants, storage tanks are used to contain a large volume of borated water which can be injected into the reactor pool and the spent fuel pool cooling system. Considering they are subjected to the hydrostatic pressure only in normal service conditions, these components are usually designed as thin-wall large shell, which presents the characteristic of being more sensitive to dynamic excitation loads, such as the ones arising from earthquakes.

The most common damages caused to steel tanks of industrial facilities in recent earthquakes are the “elephant foot” buckling and the “diamond shape” buckling, both phenomena are located at the lower part of the cylindrical shell, close to the anchorage. These two kinds of buckling are well-known and usually analyzed within the engineering practice. Nevertheless, the current design standards do not cover another type of instability which is sometimes observed after an earthquake: the shell buckling at the upper part of the cylindrical wall, near the liquid free level, due to the sloshing motion.

The present paper describes the numerical investigations performed on a typical storage tank of the nuclear industry to assess whether the upper shell buckling can lead to a severe damage or not (collapse, cracks). The EUROPLEXUS software is used for the modelling and computation considering its very efficient fluid-structure interaction algorithms and liquid-gas flow models. As a first step, the EUROPLEXUS explicit time integration scheme capability of simulating sloshing motion for a long duration (typically up to 30 s) is validated reproducing the Hinatsu’s experimental tests. As a second step, several simulation tests are run on a full 3D model of the tank to analyze the structure post-buckling states during and after the seismic event.

The numerical results show that the vibration amplitudes on the shell buckling modes are small enough to keep the structure globally in the elastic range, even for strong earthquake with a Peak Ground Acceleration of 0.5g. Only low plastic strains confined near the liquid free level are calculated. It is noted that the deformed shapes at the end of the computation are consistent with the post-seismic observations on actual tanks.