Seismic Assessment of Water Storage Tank
City of Pacifica/Lalanne-Volckmann/Ryland Homes California

MMI Engineering performed a detailed assessment of the seismic vulnerability and potential failure mechanism for 1.5 million and 3.5 Million Gallon (MG) unanchored steel water tanks, located a few hundred feet from the San Andreas Fault. The assessment was performed to assess risk to a proposed development in close proximity to the tanks.

The 1.5MG tank had a diameter of 75 feet and a total shell height of 53 feet. The 3.5MG tank had a diameter of 108 feet and a shell height of 47 feet. Traditional analyses using AWWA D-100 showed that both tanks would fail under normal operating water levels, and a reduction of close to 50% for the 1.5MG tank and 67% for the 3.5MG tank was required to ensure acceptable performance. Other more refined approaches, such as Modified Manos analysis, showed better performance compared to the AWWA D-100 analysis, but still predicted failure. Flow pattern studies from the tank site suggested that in case of failure, water from the 1.5MG tank would inundate homes in the proposed development. A detailed nonlinear time history analysis was performed to study the dynamic response of the tank to gain insight into the actual failure mode. This was needed to compute the water flow rate for the design of a deflection wall and diversion channel, which would direct flow away from the proposed development.

Analysis was based on the application of representative site acceleration time histories in an explicit finite element analysis using LS-DYNA. The finite element model geometry included a representation of the tank fluid contents into its impulsive and convective components. Non-linear material properties were used for all major structural steel elements. Seismic motions were applied to the model base in the form of acceleration time histories. Uplift was permitted between the tank's bottom plate and its foundation.

The results obtained indicated that the tank response was dominated by bottom plate bending and membrane action as the tank uplifts. The analysis predicted the onset of "Elephant's Foot" buckling in the tank shell. Accumulated plastic strain levels of up to 9% were predicted in the bottom plate. Low cycle fatigue assessment based on the Coffin-Manson Law indicated that the bottom plate could absorb the predicted levels of plasticity developed during seismic loading without rupture.

MMI's assessment of the tank using sophisticated nonlinear time history analysis showed that the tank had sufficient capacity to withstand seismic shaking (~0.9g) without failure, whereas the traditional simplified AWWA D-100 analysis showed the tank to fail. This was partly due to overly conservative assumptions of ignoring the base plate membrane capacity in the AWWA D-100 analyses.