SEISMIC II/I ANALYSIS OF SBLC SYSTEM TEST TANK

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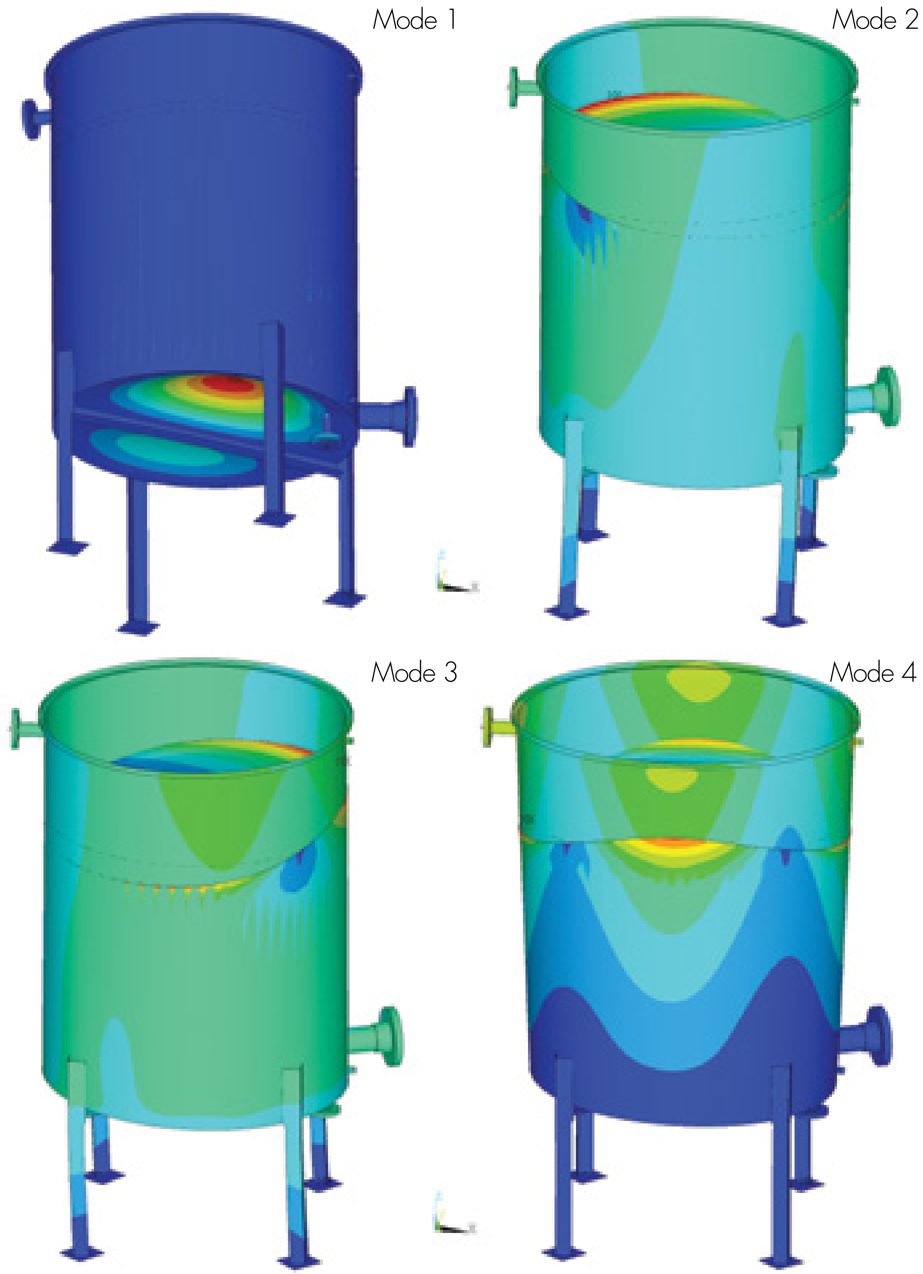

Figure 1. Modal results for the original SBLC test tank including contents, without lid. First four modes: Mode 1 (7.4 Hz), Mode 2 (8.9 Hz), Mode 3 (9.1 Hz) and Mode 4 (11.1 Hz).

Structural Integrity recently completed calculations in support of the seismic qualification of a standby liquid control (SBLC) system test tank, which originally had not been designed considering seismic loads. The SBLC system is a backup system that can be used for nuclear reactor shutdown from full power in the event that the control rods cannot be inserted. The system carries a liquid control chemical (boron, in solution) and consists of a large storage tank, pumps, valves, piping and a small test tank, which is used periodically during testing. The test tank is classified as non-safety related but is located near safety related components and equipment. A seismic II/I evaluation was required to ensure that the test tank, if filled with water, would not collapse and damage safety-related components during a design basis earthquake (DBE).

We used modal analysis of the test tank to provide an initial evaluation of seismic performance, to determine whether the structure qualified as rigid or flexible, and to determine whether significant modes coincided with the amplified range of the response spectra. Modal plots for the original tank with no attached lid, 75% full of water, are shown in Figure 1. Including fluid contents,

- Mode 1 for the original tank is a vertical mode involving the tank bottom plate at 7 Hz.
- Mode 2 is N-S sidesway at 9 Hz;
- Mode 3 is E-W sidesway at 9 Hz; and
- Mode 4 is a horizontal mode involving ovalization of the tank at 14 Hz.

The fluid participates in the mode shape; the sloshing water level is visible in Figure 1. Results demonstrate that the lateral response modes of the original tank were closely correlated with the amplified region of the horizontal response spectrum.

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The existing design basis calculations for the test tank only included seismic evaluation of the anchor bolts. After an initial evaluation and modal analysis showed that the test tank legs were not adequate under DBE conditions when the test tank was filled with water, the station designed a retrofit for the tank that included bracing for the legs and supplementary support for the tank bottom. We used the finite element model of the tank developed for the seismic qualification to evaluate retrofit options as well as to establish adequacy of the final tank support configuration.

Modal analysis of the retrofitted tank, Figure 2, demonstrates the benefit of adding lateral support. The cross-bracing effectively minimizes tank sidesway modes and removes tank sidesway from the flexible range of the seismic response spectrum. With the legs braced, tank lateral modes occur at 28 Hz and 29 Hz, close to the rigid response region of the horizontal response spectrum.

Next, we evaluated the test tank for seismic load combinations by the response spectrum method, with superimposed seismic and dynamic loads imposed by attached piping. The nozzle loads applied in the piping load cases were generated by the station using component stiffnesses obtained from our finite element model at the nozzle locations. Stress results for the tank are shown in Figure 3 for the controlling load combination. Stresses were found to be low except at the tank bottom plate. Further nonlinear elastic-plastic analysis of the tank, including stress stiffening, showed that the bottom plate would remain intact during the loading event, with stresses by elastic-plastic analysis no higher than 35 ksi.

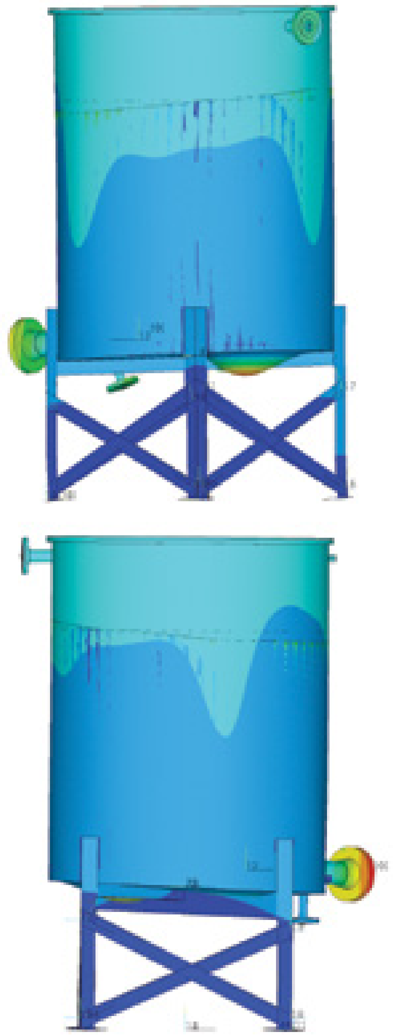

Figure 2. Modal results for final retrofit of the SBLC test tank. Mode 9 (top), 28.2 Hz; Mode 10, 29.3 Hz.

Figure 3. Results of final load combination series with all loads superimposed. Principal stress contours, controlling load combination