Calaveras Fault Crossing Design Project

San Francisco Public Utility Commission
San Francisco

The San Francisco Public Utility Commission (SFPUC) required the design of a new pipeline that would face surface fault displacement and wave propagation effects.

MMI Engineering was part of the design team responsible for the design of the new 3,000 foot long, 66-inch pipeline 'Alameda Siphon #4' (AS4), which would extend across Sunol Valley. This new siphon and the three existing siphons (69-inch Siphon #1; 91-inch Siphon #2; and 96-inch Siphon #3) connect the Coast Ranges Tunnel (CRT), bringing water from the Hetch Hetchy reservoir to the Irvington Tunnel, which connects to the Bay Division pipelines that then deliver water to customers in the Bay Area. The new and existing siphons cross the active Calaveras fault, which has a very high likelihood of generating a large earthquake, resulting in 4 to over 5 feet of surface offset. MMI was responsible for the analysis and fault crossing design of the new siphon, and an assessment of the existing siphons for this level of fault rupture displacements, so that the San Francisco Public Utilities Commission (SFPUC) could meet its target reliability goal of providing the average 2030 demand of 300 million gallons a day within 30 days after a major earthquake.

MMI also assisted in developing structural, seismic and geotechnical design criteria. The geotechnical criteria included:

- The computation of soil springs
- Methodology for the estimation of fault displacements
- Definition of fault deformation zone
- Decisions of whether to use median or median plus as standard deviation estimates
- Decisions whether to use probabilistic or deterministic approaches
- Assessment of peak ground acceleration & peak ground velocities
- Assessment of geotechnical parameters for use in design

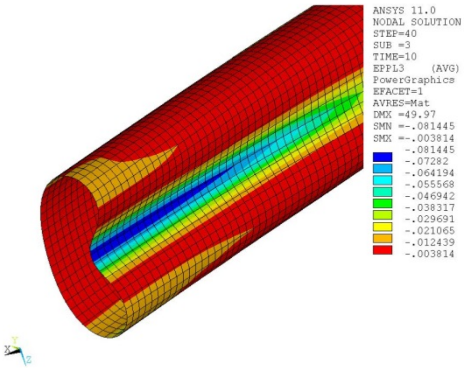
The structural design acceptance criteria included:

- Requirements for pipe material
- Yield to ultimate strength ratios
- Diameter-to-thickness ratios
- Welding requirements

The criteria was developed so that the performance requirements for the siphons met or exceeded the overall objectives of SFPUC. Key elements of the project included:

Alameda Siphon 4 Fault Crossing Design: This 66- inch pipeline was designed for continuous operation in a surface rupturing event on the Calaveras Fault. To support the fault crossing design recommendations, nonlinear analysis was performed using ANSYS, with detailed consideration to soil-structure interaction effects. The analysis also included nonlinear 3-dimensional models to study:

- The ovalisation & local buckling behaviour of the pipeline cross-section
- The design of a special trench
- Tie-in to the 1933 manifold pipe
- The lining & coating requirements of the pipeline
- Fault crossing design specifications - including weld & material traceability requirements



Overflow Pipeline Fault Crossing Design: The 66-inch overflow pipeline takes the overflowing water from the overflow shaft of the Coast Range Tunnel to a local quarry. Maintaining the integrity of the overflow pipeline under a fault rupture scenario was critical because of the high likelihood of the Coast Range Tunnel overflowing due to the shutdown of the three existing siphons. Similar to the AS4 fault crossing design, MMI developed the fault crossing design for the overflow pipeline to ensure it would stay operational under 4 to over 5 feet of surface offset along the Calaveras Fault.

Fault Crossing Assessment of Three Existing Siphons: MMI performed an assessment of the Alameda Siphons 1, 2 and 3 to assess the pipeline performance during the surface rupturing event on the Calaveras Fault. Siphons AS1 and AS3 (built in 1933 and 1965, respectively) are 69-inch reinforced concrete-lined and coated steel cylinder pipe, and 96-inch pre-stressed concrete steel cylinder pipe, respectively. Siphon AS2 is a 91-inch welded steel pipe. The pipelines were not designed to withstand fault rupture displacement and would likely fail during such an event. Recognising the potential for damage, the performance criterion called for the ability to reliably isolate the damaged sections of the pipeline in the event of a failure. MMI performed detailed nonlinear analysis using ANSYS and soilstructure interaction to calculate stresses at the upstream valves and assess whether they would stay operational in a surface rupturing event on the Calaveras Fault.

Assessment and Retrofit of Alameda East Portal (AEP) Manifold: The AEP manifold is located at the east end of the Coast Range Tunnel. The manifold is a 50-foot long, 126-inch diameter steel structure that connects the three existing Alameda Siphons and the new Siphon 4 to the CRT. Seismic assessment of the manifold was performed before and after modifications (to connect the new Siphon 4) to provide blast related security improvements. The assessment was performed using a fully 3-dimensional nonlinear time history analysis using the ANSYS software package. The analysis also considered the effect of seismically induced ground settlement coupled with strong ground shaking.

Mixing Chamber Design for Transient Ground Deformation: MMI performed a detailed nonlinear analysis of the new mixing chamber subjected to transient ground deformations. The mixing chamber being constructed as part of the AS4 project consisted of a series of pipe, valves, and wye crossconnections to the four siphons in a relatively rigid configuration. MMI conducted nonlinear analysis with soil-structure interaction using ANSYS.

Coast Range Tunnel Overflow Shaft: The overflow shaft is an 80-foot vertical shaft located near the western end of the Coast Range Tunnel, less than a thousand feet from the Calaveras Fault. The expected ground shaking at this location during a major earthquake on the Calaveras Fault is estimated to be close to 1.0g. MMI performed a fully nonlinear time history analysis (using ANSYS) to assess potential damage to the concrete liner. The analysis included modelling of soil-structure interaction effects. Acceleration time histories at each spring were applied to incorporate the effect of the propagation of seismic waves. Our sophisticated nonlinear analysis capabilities, alongside our experience in seismic hazards assessment, was key in the successful execution of the work carried out for SFPUC.