Geocomp

Technologies to manage risk for infrastructure

Project Brief

Kawasaki Refinery Seismic Retrofit

Client:

TONEN Corporation

Location:

Kawasaki City, Japan

Services Provided:

Extensive risk assessment to quantify the sources and magnitudes of risk from earthquake related causes and to determine the most cost effective means of reducing that risk.

Value Provided:

- Developed a risk-based methodology to assess the risk created by earthquake shaking
- Probabilistic analyses conducted to determine overall risk for the site
- Evaluated various potential means of reducing risk
- Methodology was successfully applied to three sites

Publication:

Drs. John T. Christian and Gregory Baecher selected this project to include as a chapter in their book, *Reliability and Statistics in Geotechnical Engineering*, as one of the best examples of practical application of risk analysis to geotechnical engineering for a major civil engineering facility.

Background & Project Challenges

In the early 1970's, TONEN Corporation became concerned with the seismic stability of three large oil storage tank farms at their Kawasaki Refinery. The refinery is located in a highly seismically active region. The entire facility was constructed over reclaimed land made by sedimenting sand and silt dredged from Tokyo Bay. The original foundation design did not consider earthquake loads.

Geocomp Role & Accomplishments

TONEN contacted Professor T. William Lambe who had consulted on the original development of the site. Working as Technical Manager for T. William Lambe Associates, Dr. Marr was assigned Project Manager for this work. After an initial assessment of the site conditions, the Lambe team determined that conventional approaches to foundation design would be very costly and might not result in a corresponding improvement in safety.

Dr. Marr assembled a team of experts to develop a risk-based methodology to assess the risk created by earthquake shaking. That methodology included an evaluation of historical regional seismicity, development of a site-specific seismic intensity curve, and development of event and fault trees to determine which seismic related events and which failure modes contributed to overall risk. Probabilistic analyses were conducted to determine overall risk for the site, where risk was measured as both a probability of failure and a cost of the consequences. The main cause of risk was identified to be failure of multiple tanks due to deformation of their foundations from earthquake shaking.

Dr. Marr devised methods to predict the magnitude of these deformations and the probability that they would cause tanks and firewalls to fail. The work also considered a massive global stability failure triggered by various earthquakes. The risk-based methodology helped determine that the most significant event causing risk was the spill of oil into Tokyo Bay resulting from failures caused by earthquake shaking. With that knowledge, the Lambe team then used the methodology to evaluate various potential means of reducing risk. The most cost effective means of risk reduction proved to be lowering the ground water level within the hydraulic fill. The risk methodology was used to determine how much ground water lowering was required to reach target risk levels set by TONEN management.

The methodology was successfully applied to three sites at a cost savings of $60,000,000 compared to more conventional methods. To limit groundwater drawdown outside the site, we designed and monitored the construction of over 7,000 meters of cutoff wall constructed using the slurry wall technique with soil/bentonite backfill. These were the first soil/bentonite slurry walls constructed in Japan. The Japanese Regulatory Agency adopted this groundwater reduction approach as the required method of seismic retrofitting of oil storage tank facilities located on liquefiable ground.