Karlsruher Institut für Technologie

Institut für Mechanik
Prof. Dr.-Ing. Karl Schweizerhof
Prof. Dr.-Ing. Thomas Seelig

Diplomarbeitsthema

Diploma Thesis for Civil Engineers

Earthquake Safety of Large Wine Tanks in Seismic Regions (Chile)

During the February 27 of 2010 earthquake in the zone of Maule in Chile, the wine industry lost 125.000.000 liters of wine, which is about the 10% of the national production per year. The major loss occurred in the stainless steel tanks that most of the vineyards use for the process of the wine. These tanks have capacities from 12.000 to 300.000 liters, and almost all the tanks that had wine inside suffered damage which ranged from light damage to total loss.

Almost all the tanks were designed with no provision for earthquake loading, which explains most of the damage. Fortunately, the earthquake happened before the harvest of the grapes, which starts in March. If the earthquake should have happen in May, the loss of production has been estimated to 80%.

After the earthquake had happened, the industry started to look for earthquake design provisions, but they discovered that even in highly seismic regions as California, there were no seismic provisions for wine tanks, and some of the vineyards or tanks suppliers were using the provisions given by the API seismic regulations that are intended for oil tanks which are different in size, support conditions, etc.

Some of the problems are:

1. The larger tanks are circular tanks supported by reinforced concrete mats, but they are not totally clamped. They can be with some restrictions in the horizontal displacement and some of them are free to slide.

2. The tanks usually have openings for cleaning them that are closed by doors or hatches that open laterally in the lower part of the tank. If the reinforcement of this area is not strong enough, the door opens and the wine is emptied very fast which leads to an upper buckling of the tank, Figure 1 and 3.

3. Another problem is the overall stability of the tank which can overturn causing its total loss.

4. Failures also can occur because of badly designed welds as can be seen in Figure 2. In this picture a total failure of the bottom to mantle weld is shown. Only the bottom part has remained in position over the mat.

To study the earthquake safety and performance of the wine tanks, it is necessary to realize that they are thin shell structures filled with liquid that can slosh inside. Therefore, it is necessary to model these tanks using finite elements for the shells. One possibility to model the liquid inside is to use added mass with springs. Other possibility is to include fluid elements and study the tank with structure fluid interaction. The analysis should be dynamic using for this real ground motion acceleration as the one shown in Figure 4.

Intended plan of work

1. Revision of different types of failures reported in the pictures taken at the damaged vineyards
2. Selecting and modeling of four types of tanks with different capacities, different support conditions and different levels of liquid inside them.
3. Material testing: tension tests of some stainless steel specimens to determine properties.
4. Select some acceleration records to perform dynamic analysis of the wine tanks
5. Work a finite element model of the tanks to analyze the stresses and deformations
6. Do dynamic analyses of the different tanks
7. Preparation of report, paper and poster

Supervision (Betreuung): Professor J. Crempien (Visiting Prof. from Santiago, Chile)

Professor K. Schweizerhof

Figure 1. Buckled Tank

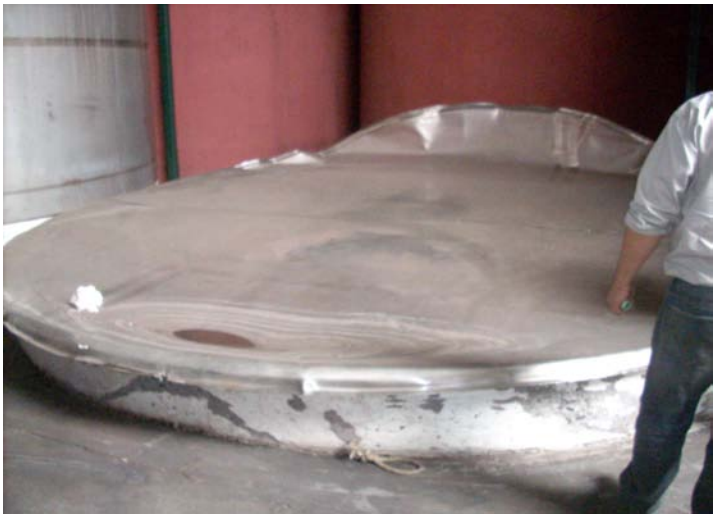

Figure 2. Failure of bottom to mantle welding of tank

Figure 3. Failure of the cleaning doors.

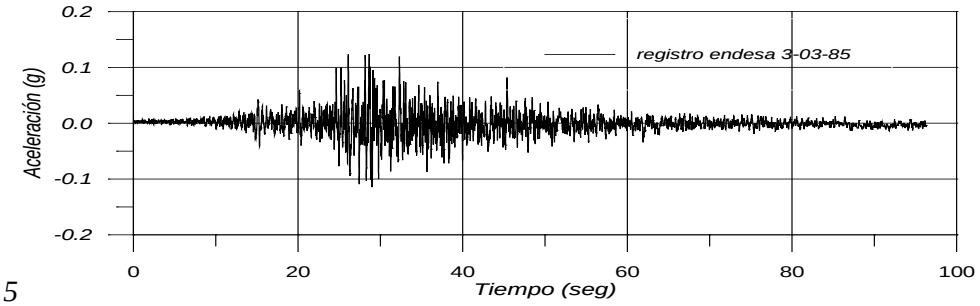

Figure 4. Acceleration record at Downtown Santiago, 1985