Chapter 5
Assessment of Abastible San Vicente Liquefied Petroleum Gas (LPG) Terminal

Facility Overview

The Abastible San Vicente LPG Terminal (Lat 36° 46′ 22" S, Long 73° 8′ W), located near Talcahuano (Figure 5-1), specializes in the management of Liquefied Petroleum Gas (LPG). The terminal receives bulk liquids from tankers through its modern pipeline system mounted on piles in a pier that extends approximately 2200 meters into the Bay of San Vicente. A plot plan of the facility is shown in Figure 5-2. Construction of the facility began in 2003.

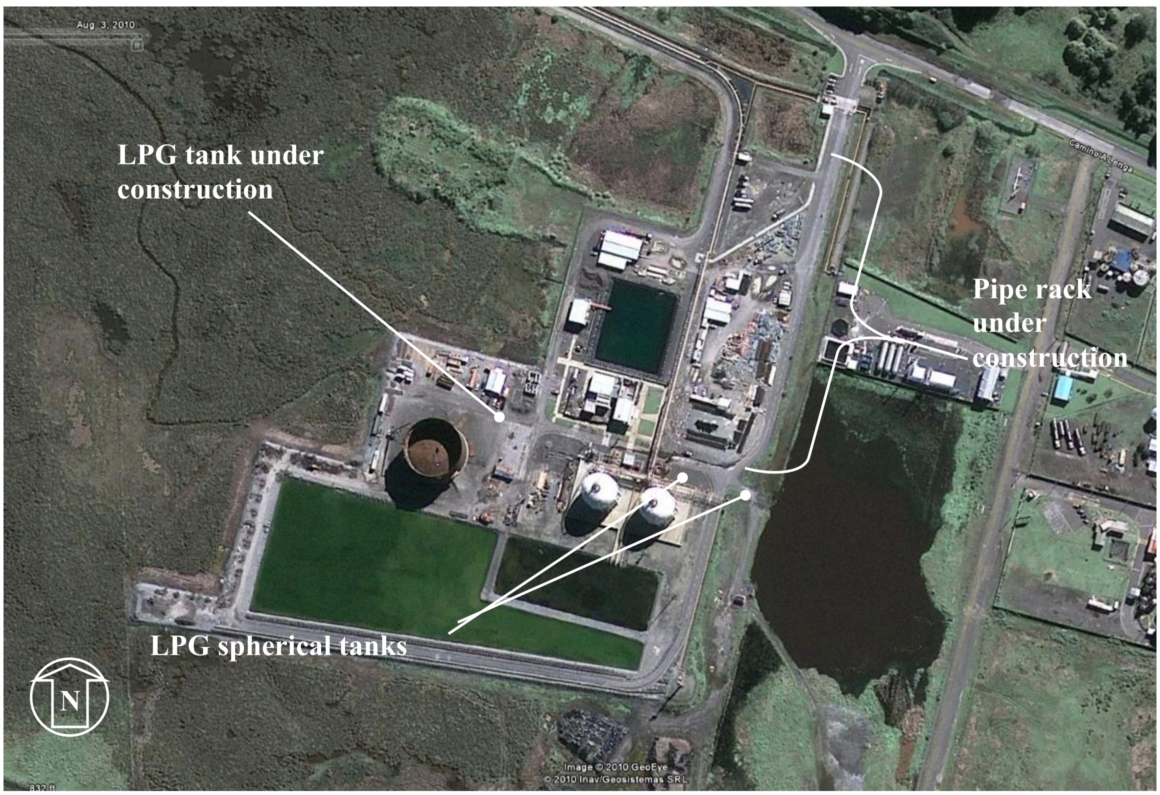

Figure 5-1: Aerial view of Abastible San Vicente LPG facility (Source: GeoEye).

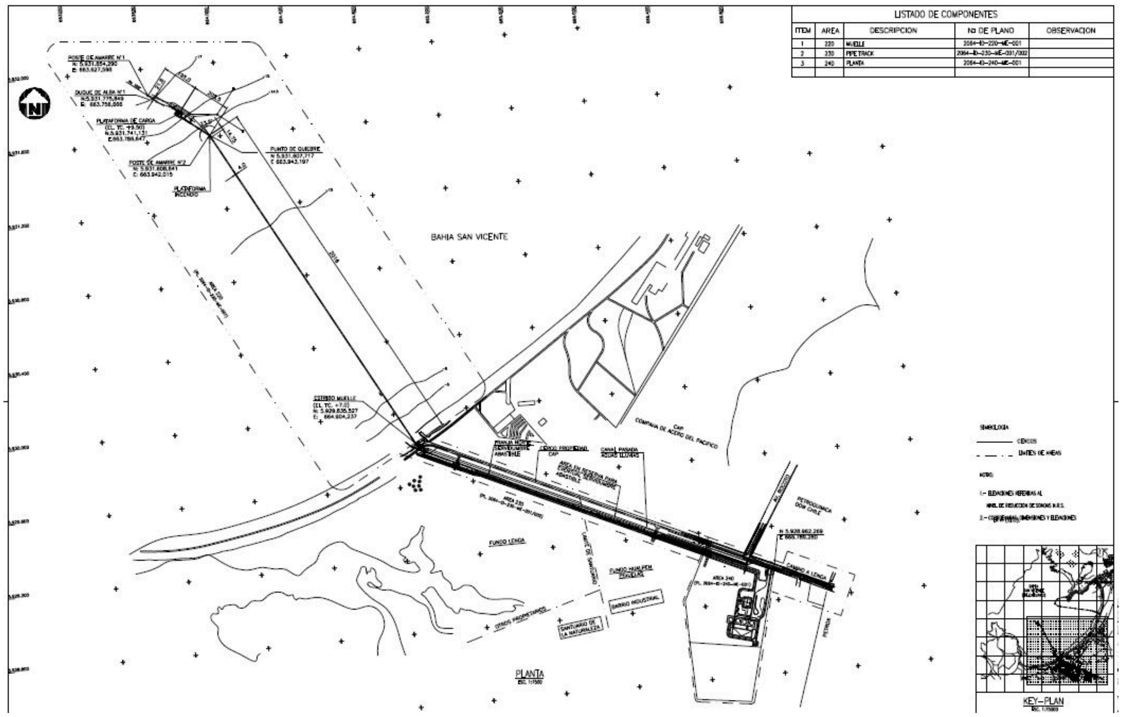

Figure 5-2: Plot plan of Abastible San Vicente LPG Terminal. (Courtesy of Abastible)

Soil Conditions

Soil information and the soil improvement plan used are only available for the LPG tank location. The original soil at the tank site is described in Table 5-1. The elevation of the water table is unknown. The partial soil report made available to the Industrial Assessment Team indicates that the soil beneath the LPG spheres was improved in a manner similar to that used for the LPG tank location.

Table 5-1. LPG Tank Soil Description

Soil Layer	Depth	Description
I	0.3 m	Topsoil, brown silty clay, moderate plasticity with abundant roots
II	0.3 m – 3.1 m	Grayish brown, high plastic clay
III	3.1 m – 16.5 m	Dark gray coarse sand with gravel
IV	16.5 m – 18 m	Saturated dark gray medium sand

The soil improvement consisted of removing the soil beneath the site of the LPG tank to a depth of approximately 3.1 m (depth of sand). The removed soil was replaced by sand taken from Soil layer III (Table 5-1) and compacted to a relative density of 80 percent.

Estimated Response Spectra

The response spectra from the closest ground motion instruments to this location (within 10 km) are shown in Figure 2-2 and Figure 2-3 above. Because this was a subduction zone type earthquake, the ground motions measured at Figures 2-2 and 2-3 are considered to be representative of the ground motions experienced in this region. The actual ground motions experienced at the facilities visited may be different due to local geology.

LPG Spheres Assessment

The Abastible LPG facility contains two 31,472 barrel (bbl) LPG spheres (Figure 5-3) constructed in 2004 when the plant was originally built. Both spheres were full of product at the time of the seismic event. (Appendix I contains drawings of the LPG spheres and tank.)

Figure 5-3: 73.5-ft diameter LPG sphere.

Structure Description

The two LPG spheres (Lat 36° 46′ 22″ S, Long 73° 8′ W) are 73.5-ft in diameter and were designed to the ASME BPVC Section VIII, Division 1. The design pressure of the spheres is 110 psig and the specific gravity of the stored product is 0.625. The thickness of the vessels ranges from 1.237 in. to 1.496 in. The fundamental period of the spheres is 0.355 seconds. Other dimensional information is shown in Figure 5-4. The sphere, supporting columns, and bracing were designed to the seismic requirements of Zone 3 of the Chilean Standard NCh 2369-2003 using a response modification factor R of 3 and an importance factor of 1.2. Zone 3 of the Chilean Standard NCh 2369-2003 roughly corresponds to Zone 4 of the 1997 UBC without near field factor increases.

The bracing system is an ordinary concentrically braced frame. The bracing (Figure 5-5) is made up of built-up 12.8 in. x 5/8 in. thick square tubes fabricated from A572 Grade 50 steel plate. The wing plates are 1.25 in. thick and penetrate the tubular columns. The wingplates are welded to internal circular diaphragms in the columns (Figure 5-6).

Observations

No damage of the LPG spheres, columns, bracing, or foundations were observed.

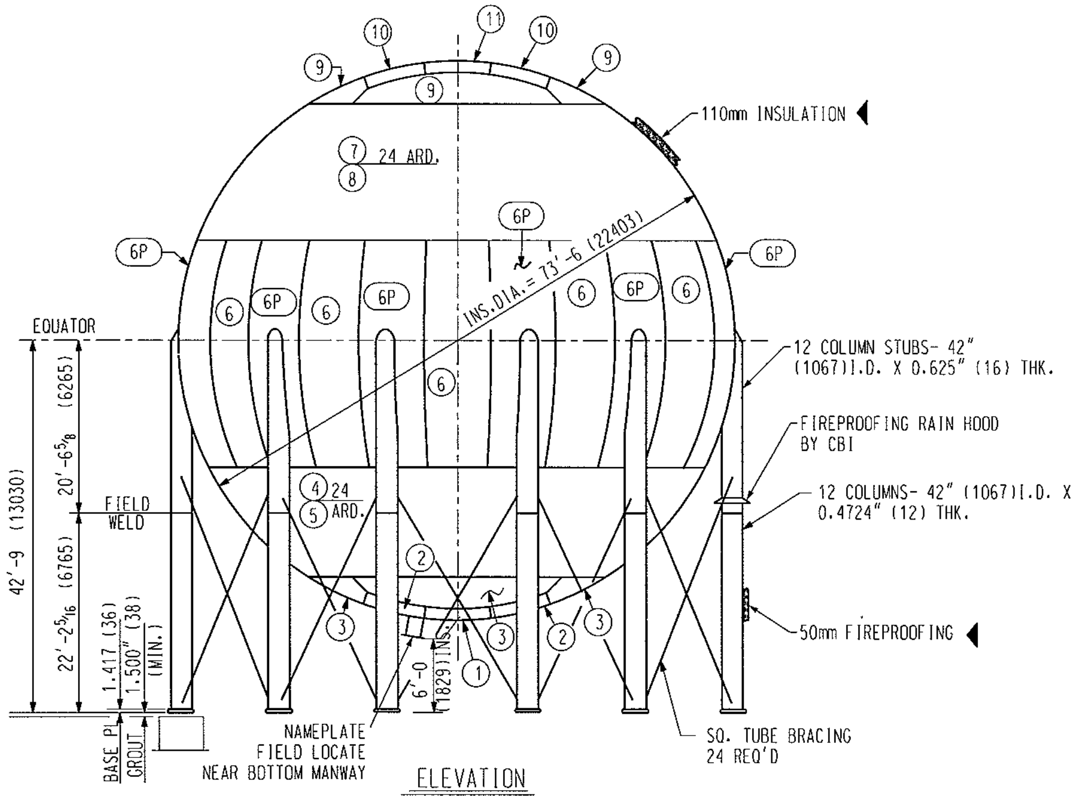

Figure 5-4: Sphere geometry. (Source: Courtesy of CB&I Inc.)

Figure 5-5: Support columns and bracing.

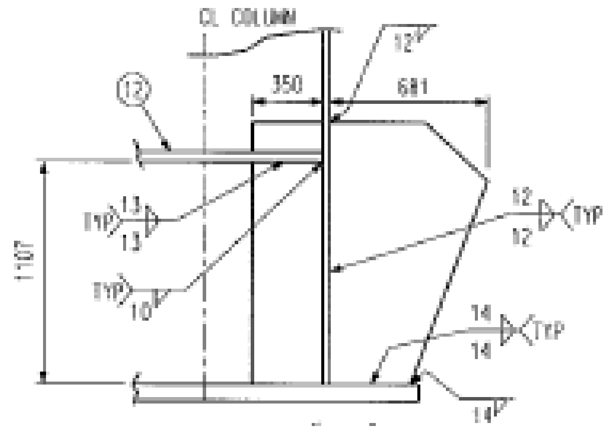

Figure 5-6: Wingplate attachment detail. (Courtesy of CB&I Inc.)

Recommendation Regarding ASCE/SEI 7 and Retrofit of Existing Structures

The seismic design forces and detailing used in the design of the LPG Spheres is very similar to what is currently specified in ASCE/SEI 7. Ordinary concentrically braced frames performed well during the seismic event. Therefore no code changes appear to be warranted based on the observed performance of the LPG Spheres.

LPG Tank Assessment

The Abastible LPG facility contains one 50,000 m^3 refrigerated LPG tank (Figure 5-7) constructed in 2010. The LPG tank had just completed testing and was being insulated at the time of the seismic event. The LPG tank was empty at the time of the seismic event.

Figure 5-7: 123'4″ diameter x 99'2″ LPG tank (under construction).

Structure Description

The LPG tank is a 123′4″ diameter by 99′2″ high single wall dome roof refrigerated storage tank (Lat 36° 46′ 21" S, Long 73° 8′ 4" W) with a suspended deck designed to the requirements of API 620 Appendix R. The design pressure of the tank is 1.5 psig and the specific gravity of the stored product is 0.582 (propane) and 0.601 (Butane). The tank is designed to store LPG at –49 °F. The thickness of the tank ranges from 0.315 inches to 0.935 inches. The fundamental period of the tank is 0.30 seconds and the sloshing period of the tank is 6.44 seconds. Other dimensional information is shown in Figure 5-8. The tank was designed to the seismic requirements of Zone 3 of the Chilean Standard NCh 2369-2003 using a response modification factor R of 4 and an importance factor of 1.2. Zone 3 of the Chilean Standard NCh 2369-2003 roughly corresponds to Zone 4 of the 1997 UBC without near field factor increases.

Observations

Because the LPG tank was empty at the time of the seismic event, no conclusions can be drawn on the possible seismic performance of the tank. However, the performance of the improved soil beneath the LPG tank can be evaluated. The Abastible facility sits on liquefiable soil. As can be seen in Figure 5-9, lateral spreading due to soil liquefaction did occur near the tank. The lateral spreading stopped at the point where the improved soil began. The soil improvement must be viewed as a success.

Recommendation Regarding ASCE/SEI 7 and Retrofit of Existing Structures

The seismic design provisions in ASCE/SEI 7 and its referenced documents for nonbuilding structures, such as tanks and spheres, appear sound. Soil improvement to prevent damage from liquefaction performed well during the seismic event. Therefore, soil improvement should be one of the options considered to mitigate the effects of liquefaction.

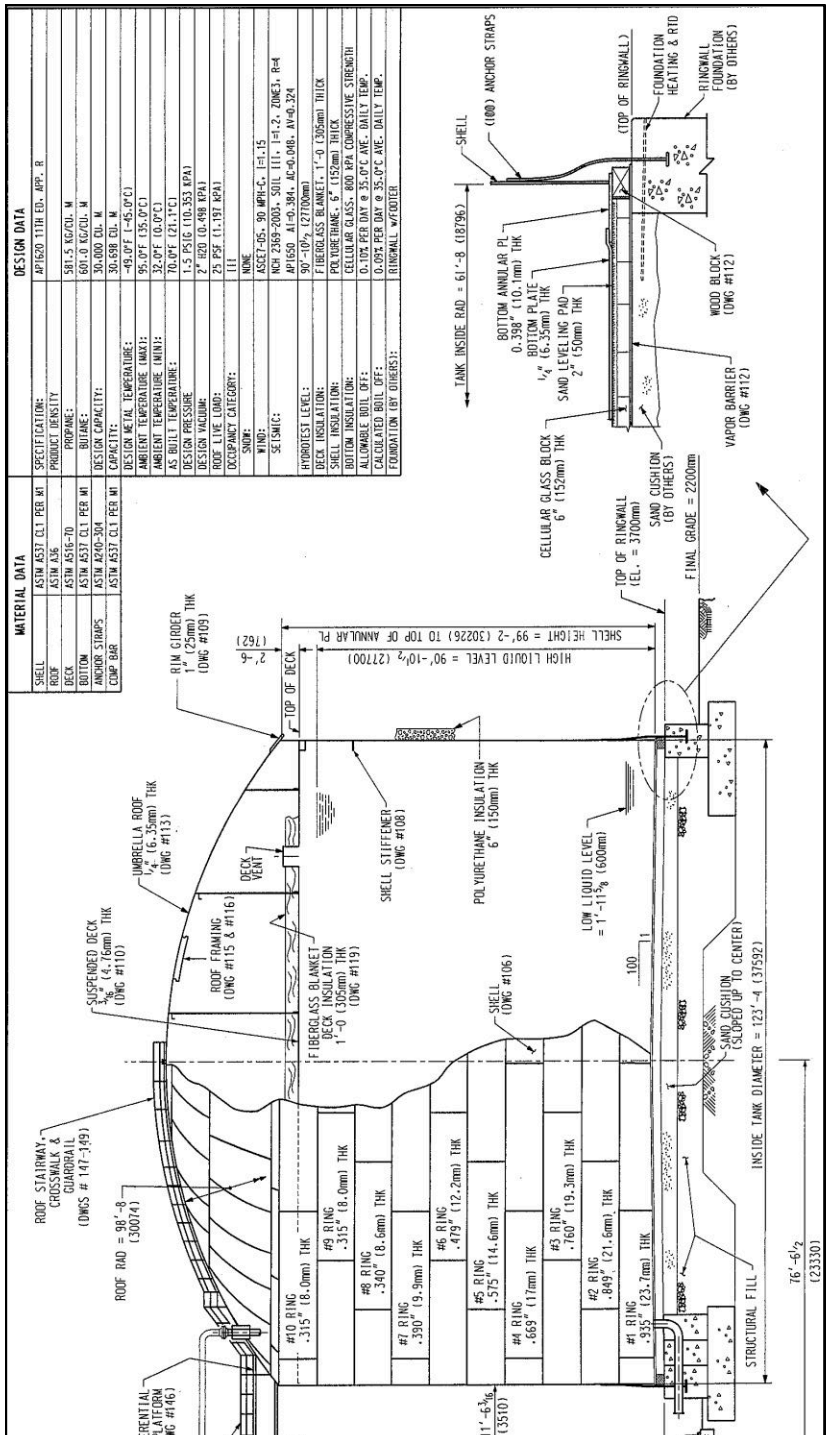

Figure 5-8: LPG tank geometry. (Source: Courtesy of CB&I Inc.)

Figure 5-9: Lateral spreading near LPG tank arrested by improved soil. (Courtesy of CB&I Inc.)

Pipe Rack Assessment

The pipe rack shown in Figure 5-10 was under construction at the time of the seismic event.

Figure 5-10: Pipe rack (under construction).

Observations

The pipe rack was constructed just beyond the outside edge of the improved soil of the tank area. The spread footing foundations of the support columns (Figure 5-11) of the pipe rack were observed to have laterally displaced several inches due to lateral spreading of the soil toward the adjacent marsh areas. The lateral displacement was greater nearer the marsh, creating significant horizontal relative displacements between the pipe rack footings. Care must be taken to ensure that soil improvements cover the entire area of potential liquefaction that the structure is constructed upon.

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Figure 5-11: Effect of lateral spreading on pipe rack column.

Recommendation Regarding ASCE/SEI 7 and Retrofit of Existing Structures

Evaluation of liquefaction potential is critical before a structure is sited or built. Also it appears the evaluation requirements of structures associated with the effects of liquefaction/lateral spreading need to be developed.

Wall Assessment

The wall shown in Figure 5-12 was under construction at the time of the seismic event. The wall also serves as a foundation for one side of a steel pipe support structure. The lightly loaded steel pipe support structure shown in Figure 5-12 used an adjustable double-nut ungrouted base plate support detail commonly used in industrial facilities.

Observations

The wall was constructed near the outside edge of the improved soil of the tank area. Although not obvious in Figures 5-12 and 5-13, the wall was observed to have settled a few inches due to liquefaction of the soil. The pipe support structure settled with the wall.

Figure 5-12: Settlement of wall (under construction).

Figure 5-13: Settlement of wall (additional view).