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SEISMIC DAMAGE OBSERVATIONS OF WINE STORAGE TANKS AND CATWALKS

M. Yazdanian[(1)], J. Ingham[(2)], D. Dizhur[(3)]

[(1)] PhD student. Department of Civil and Environmental Engineering, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand, E-mail: myaz864@aucklanduni.ac.nz
[(2)] Professor. Department of Civil and Environmental Engineering, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand, E-mail: j.ingham@auckland.ac.nz
[(3)] Senior Research Fellow. Department of Civil and Environmental Engineering, University of Auckland, Private Bag 92019, Auckland 1142, New Zealand, E-mail: ddiz001@aucklanduni.ac.nz

Abstract

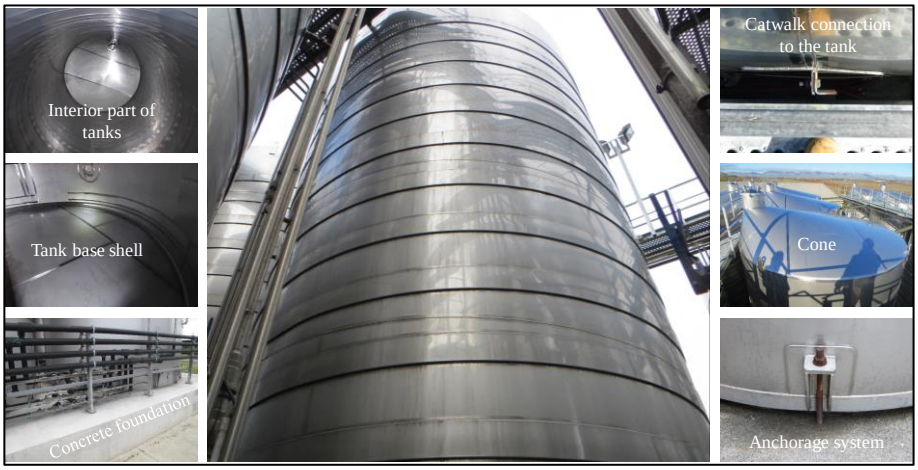
Extensive damage to wine storage tanks following earthquakes in different top wine regions of the world such as Italy, USA, Argentina, Chile, and New Zealand has been reported repeatedly, highlighting that seismic resilience of these structures should be considered. Damage data was collected for the purpose of insurance claims following the 2013 Seddon & Lake Grassmere earthquakes and the 2016 Kaikōura earthquake in New Zealand. The current paper provides a summary of observations from the post-earthquake damage assessment of wineries with an emphasise on the interaction of tanks and catwalks. Based on the damage observations, anchorage system and barrel parts of flat-based tanks sustained the largest damage, while for the case of legged tanks, frame/legs part of the tanks sustained the largest damage percentage among the elements of legged tanks. Review of the inventory of 1401 wine tanks from the 2016 earthquake showed that 1150 wine tank had either self-supported or tank-supported catwalks. Analysis of damage statistics for the catwalks following the 2016 earthquakes in New Zealand have also revealed that 26% of 1150 flat-based and legged tanks with both self-supported and tank-supported catwalks sustained damage on their barrel or cone due to catwalk indentation in 2016 earthquake. It is to note that 25% of all this 26% exhibited catwalk indent damage type was due to tank-supported catwalks.

Keywords: *Flat-based tanks, legged tanks, damage data, fragility curves, Earthquakes.*

1. Introduction

Wine storage tanks are an important infrastructure element within wineries. In New Zealand these tanks are typically constructed of stainless steel, have a slender geometry, and have either a flat-based or a legged base configuration (see Figure 1). While legged tanks are mostly un-anchored to the foundation and have an advantage of being relocatable across the winery area, flat-based tanks are usually anchored to the foundation. On average, flat-based tanks have a larger capacity when compared with the legged tanks within a winery. Analyses of earthquake damage data form different parts of the globe such as Chile [1], [2], Italy [3], United States [4], and New Zealand [5], [6] has revealed that wine storage tanks are vulnerable to high-intensity ground shaking from an earthquake.

Marlborough region is the largest New Zealand wine region, which represents approximately 70% of the total producing area of New Zealand wine and has repeatedly experienced strong ground-shaking during the last decade. The purpose of the study reported herein is to provide a brief high-level summary of observations from the extensive post-earthquake damage assessment of legged wine tanks and flat-based tanks. A summary of statistical damage data for the catwalks is also presented herein.



(a) Flat-based tanks and associated elements

(b) Legged tanks and associated elements

Figure 1 – Example of typical wine tank types observed in New Zealand wineries

2. Post-earthquake damage observations of wine storage tanks

Analysis of damage data collected from the in-field post-earthquake assessment of wineries in both 2013 and 2016 earthquake are presented in [6]. Based on the review of damage data within the collected inventory, 50% of 1512 legged wine tanks sustained damage in 2013 earthquakes and 57% of 599 legged tanks sustained damage in 2016 earthquake, with legs/frame of legged wine tanks were the most vulnerable elements of legged tanks [5], [6]. Leg buckling (see Figure 2) were the most frequent type of damage to the legs/frame of legged wine tanks, with 18.5% in 2013 earthquakes and 6.7% in 2016 earthquake. In some cases, tilting or buckling of legs caused complete overturning of the legged wine tanks, causing substantial damage to the neighboured tanks. This overturning failure mode could be a life safety hazard for the wine makers if the earthquake occurs at the working time of day. Review of damage data showed that legged wine tanks with bracing (see Figure 3) within the frame performed better than the unbraced legged tanks that were simply set on the vertical steel legs that are mostly constructed of steel pipes (see Figure 2). Also, the size of vertical legs and the supporting condition of legged tanks were other important factor affecting the seismic performance of legged wine tank. Comparison of inventory between the 2013 and 2016 earthquakes revealed that winery stakeholders proceeded to strengthen the damaged legged wine tanks by converting them to the flat-based tanks (see Figure 4). In some cases, it was also noticed that the winery stakeholders removed the legged wine tanks that showed to be vulnerable and non-compliant with the consultant recommendation.

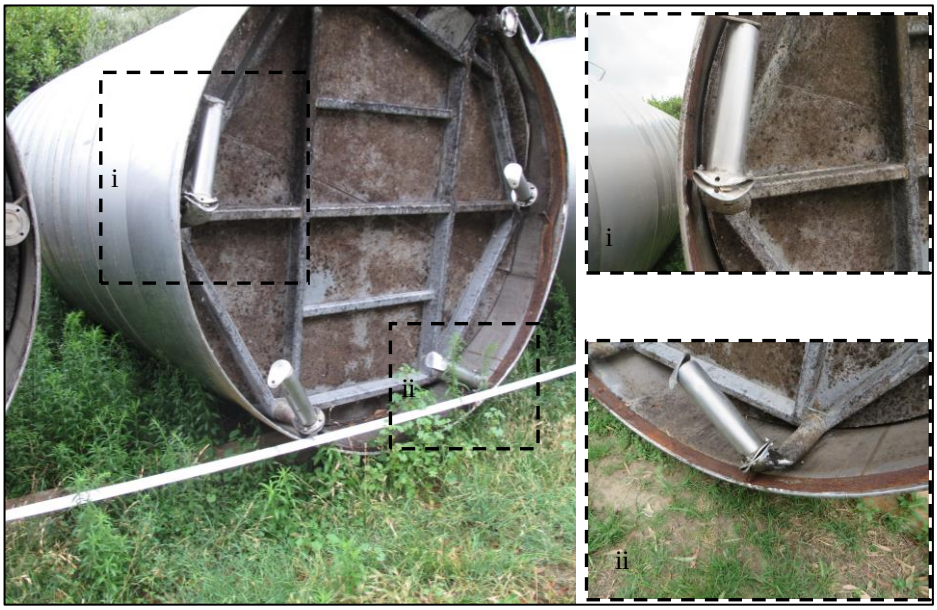


Figure 2 – An example of 22kL unbraced damaged legged wine tanks sustaining leg buckling

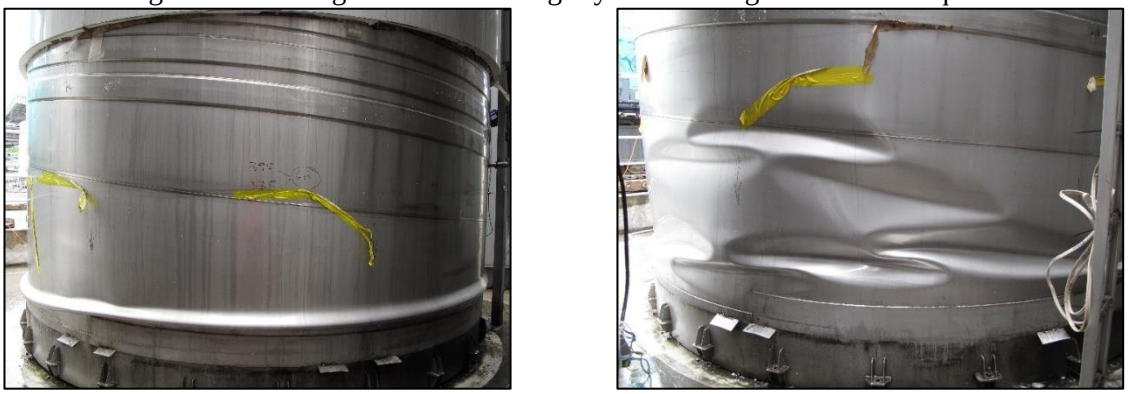

Figure 3 – An example of 50kL braced and anchored legged tank with no evidence of damage

Figure 4 – Damaged legged tanks converted to the flat-based tanks following the 2016 earthquake

Of 546 flat-based tanks, 73% sustained damage in 2013 earthquakes and of 802 flat-based tanks, 69% sustained damage following the 2016 earthquakes. Flat-based tanks have typically larger capacity than the legged wine tanks. Detailed performance and damage statistics related to flat-based tanks are reported in [7]. Flat-based tanks within Marlborough region observed to have different types of anchorage systems and each performed differently and performance of different anchorage systems are reported in [5]. According to the critique of earthquake damage data, anchorage system (see Figure 5) and barrel (see Figure 6) parts of flat-based wine tanks were the most vulnerable part of the flat-based tanks. During the post-earthquake damage assessment of wineries different types of damage to the barrel were identified for the flat-based tanks, with elephant-foot (11%) and diamond-shaped buckling (6.1%) being observed to damage tanks more severe compared with the other type of damage to the barrel (see Figure 6). Retrofitting plans undertaken within the wineries typically incorporate anchorage systems (see Figure 7) that utilise ductile and capacity design approaches to protect the tanks and their contents [8]. It was observed that tanks equipped with such type of anchorage systems performed well during the 2016 earthquake.

(a) Rupture of anchor rod (b) Anchor rod thread shearing

Figure 5 – Damage to tank anchorage systems during the 2016 earthquake



(a) Elephant-foot buckling (b) Diamond-shaped buckling

Figure 6 – Two types of buckling of tank wall observed following the 2013 and 2016 earthquakes

Figure 7 – Energy dissipation devices installed in wineries as part of resilience measures

3. Damage data on wine tanks due to the catwalks

Catwalks are also another element within the wineries constructed of light-weight steel structures providing access the top part of the tanks for the staff within the wineries. Based on the in-field observations, catwalks were either self-supported (see Figure 8) or tank-supported (see Figure 9). Post-earthquake damage assessments of wineries revealed that catwalks caused substantial damage to the wine storage tanks.

This section provides statistical damage data on catwalks and damage percentage to tanks due to catwalks during the 2016 earthquake. Five wineries which collectively contained 1401 tanks were inspected during this damage assessment, of which all five experienced different Peak Ground Acceleration (PGA) that ranged from 0.23g to 0.36g. Of the 1401 wine tanks, 809 (58%) tanks in the inventory had a tank-supported catwalk. 88 (6%) of the inspected tanks did not have any catwalk (see Figure 10), and 87 of the tanks were legged wine tanks with small size capacity. 163 (12%) of the 1401 inspected wine tanks had unclear catwalk supporting conditions. 341 (24%) of tanks had self-supported catwalks, meaning that no connection between the tank and catwalk was noticed during the assessment (see Figure 10). According to the collected data, it was observed that of the 341 wine tanks with self-supported catwalks, 218 (64%) were legged tanks and the other 123 (36%) were flat-based tanks, although the number of flat-based tanks was larger than legged wine tanks within the overall inventory. This shows that the use of self-supported catwalks was more frequent for the legged wine tanks compared with the flat-based tanks. Within the collected inventory, there were some wine tanks mainly with capacity between 0-20kL without any type of catwalk.

Analysis of damage data showed that self-supported catwalks performed well compared to the tank-supported catwalks. Only 5% of self-supported catwalks (17 of the 341) caused damage to wine tanks (see Figure 11). 809 of the tanks in the inventory had tank-supported catwalks, wherein 288 (36%) of tanks sustained damage due to the catwalk indent (see Figure 12).

In summary, analysis of damage statistics following the 2016 earthquakes in New Zealand have also revealed that indenting of the tank wall by catwalk was the most frequent tank damage type to the barrel of the tanks [6], where 26% of 1150 flat-based and legged tanks with both self-supported and tank-supported catwalks sustained damage on their barrel or cone due to catwalk indentation (see Figure 13). It is to note that the majority of damage percentage to the tanks (25%) due to catwalk indent was for the tank-supported catwalks and only 1% of the tanks within the inventory sustained damage from self-supported catwalks.

Figure 8 – An example of self-supported catwalks with no evidence of damage following the 2016 earthquake

Figure 9 – An example of tank-supported catwalks with no evidence of damage following the 2016 earthquake

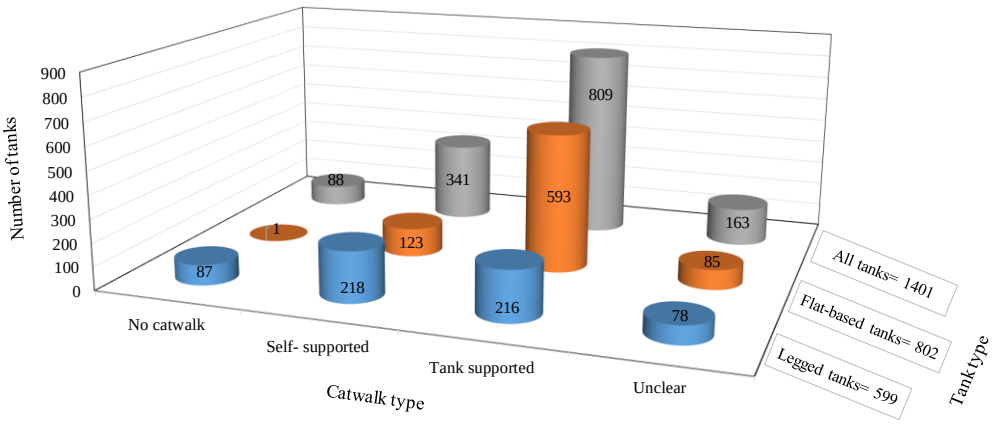


Figure 10. Distribution of catwalk type according to the tank type

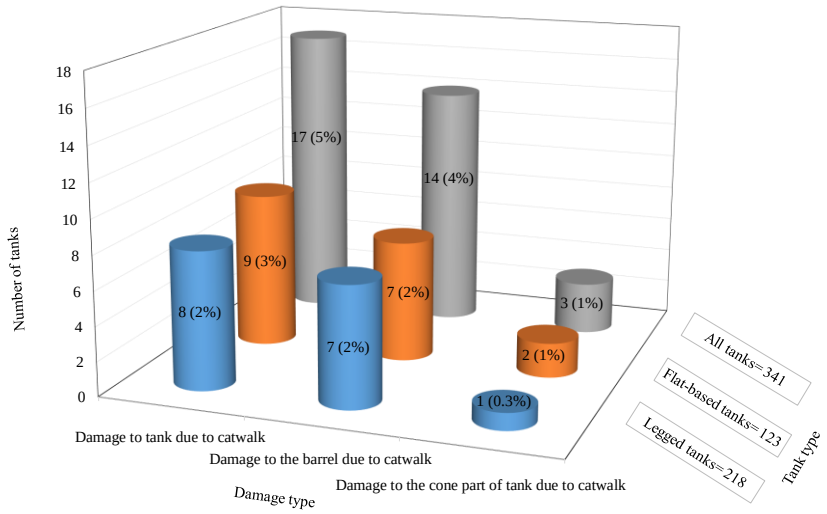


Figure 11. Distribution of damage to tanks and self-supported catwalks according to tank type

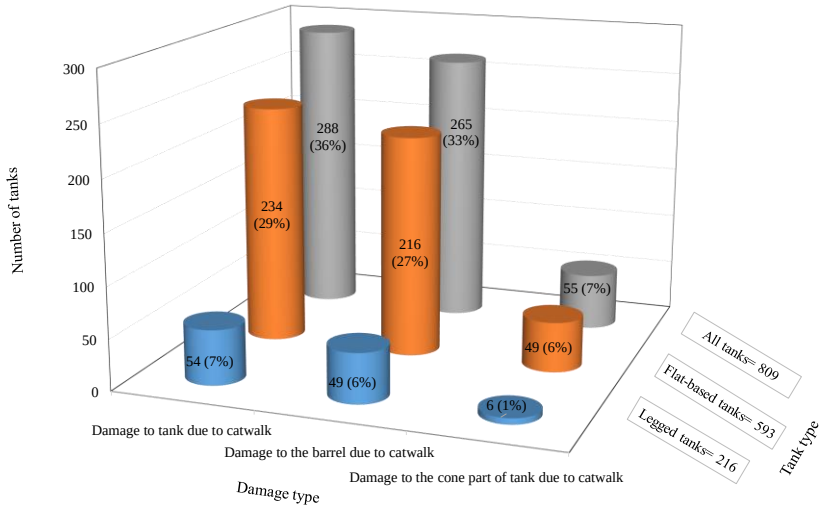


Figure 12. Distribution of damage to tanks and tank-supported catwalks according to tank type

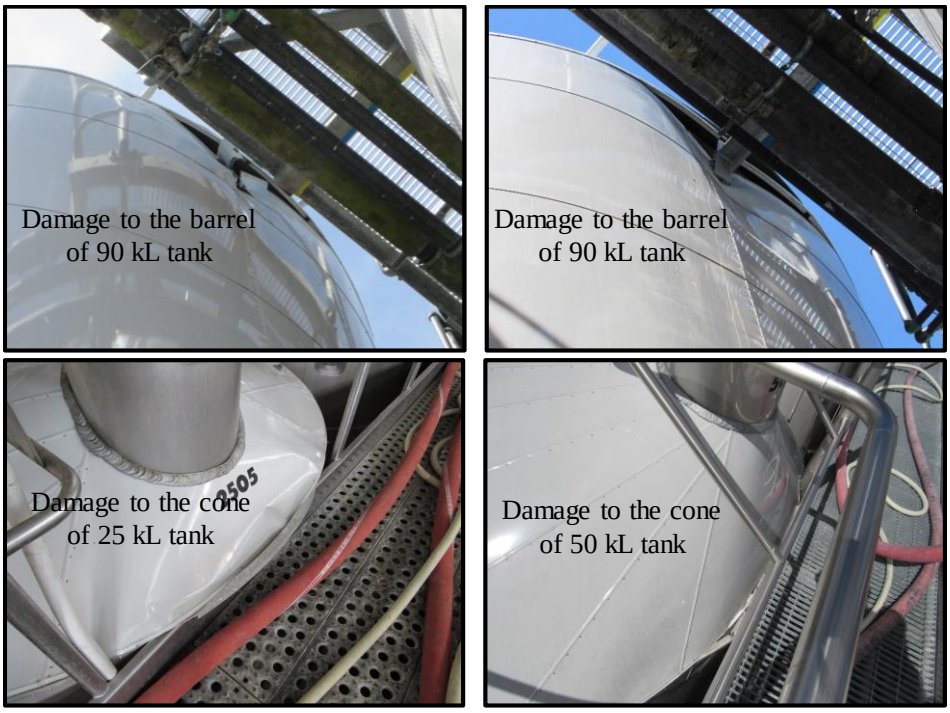


Figure 13 – Example of different flat-based tanks sustaining catwalk indent damage following the 2016 earthquake

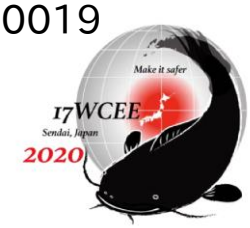
Final remarks

- New Zealand wine industry was largely affected by the 2013 and 2016 earthquakes, resulting in winery stakeholders to incorporate seismic resilience measures. For example, comparison of inventory between the 2013 and 2016 earthquakes revealed that winery stakeholders proceeded to strengthen the damaged legged wine tanks to flat-based tanks or remove the legged wine tanks that showed to be vulnerable and non-compliant with the consultant recommendation. An example of this resilience plans for the flat-based tanks was incorporating new anchorage systems that utilise ductile and capacity design approaches to protect the tanks and their contents. Based on the critique of collected earthquake damage data following the 2013 and 2016 earthquakes a difference in the level of seismic resilience in the wineries in Marlborough region of New Zealand was noticed which was due to the variety in winery tank inventory and winery expenditure on the resilience plans.

- It was highlighted that level of sustained damage to the wine tanks was varied with the level of seismic resilience of wineries. Legs/frame of the legged tanks were the most vulnerable parts of the tanks in both the 2013 earthquakes (40%) and in the 2016 earthquake (44%). For the case of flat-based tanks, anchorage system and barrel part of the tanks sustained the largest percentage of damage.

- Based on the collected inventory, the use of self-supported catwalks was more frequent for the legged wine tanks compared with the flat-based tanks, where of the 341 wine tanks with self-supported catwalks, 218 (64%) were legged tanks and the other 123 (36%) were flat-based tanks.

- Analysis of damage statistics following the 2016 earthquakes in New Zealand have also revealed that 26% of 1150 flat-based and legged tanks with both self-supported and tank-supported catwalks sustained damage on their barrel or cone due to catwalk indentation. It is to note that 25% of all of the exhibited damage was due to tank-supported catwalks.



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