
CASE STUDY: 65,000 GALLON WINE TANK ON CALIFORNIA'S NORTH COAST

ONGUARD DESIGNS ITS SEISMIC ANCHORAGE SYSTEM FOR A NEW ABOVEGROUND STORAGE TANK ON A SKIRT

ABSTRACT

This case study outlines ONGUARD's seismic design approach for a new liquid storage tank on a skirt holding about 65,000 gallons of wine. The 10 gauge stainless steel tank is 20.3 ft in diameter and has 27.0 ft tall walls. It sits on a 1.0 ft tall concrete-filled 7 gauge stainless steel skirt. ONGUARD presents two energy-dissipating seismic solutions for this tank on a skirt. The solutions compare two different design approaches, one aligning with API Standard 650 and the other aligning with NZSEE's "Seismic Design of Storage Tanks" 2009 Guideline.

INTRODUCTION

This study begins with collecting all the preliminary design information. Next, the seismic anchorage design approach is discussed. Two possible design solutions are presented and compared, and a final solution is selected. Lastly, closing remarks note ONGUARD's preferred design approach.

PRELIMINARY DESIGN INFORMATION

ONGUARD begins its design by gathering preliminary information including tank construction parameters, site ground motion parameters, and seismic design factors.

TANK CONSTRUCTION PARAMETERS

First, ONGUARD consults with the client to determine what tank construction information is available. With new construction applications, the tank builder provides tank construction drawings to collect design parameters (e.g. Figure 1). Figure 2 is a photograph of these tanks built according to tank construction drawings provided.

TANK CONSTRUCTION PARAMETER	SYMBOL	VALUE	UNITS
Nominal volume	V_{tank}	65,000	gal
Tank wall height	H_{tank}	27.0	ft
Diameter	D_{tank}	20.3	ft
Top cone height	H_{cone}	2.0	ft
Turret height	H_{turret}	0.7	ft
Minimum skirt height	H_{skirt}	1.0	ft
Maximum slab height	H_{slab}	24	in
Tank wall thickness	T_{wall}	10	gauge
Tank floor thickness	T_{floor}	7	gauge
Tank skirt thickness	T_{skirt}	7	gauge
Tank floor slope	$[-]$	2.39	°

Table 1: Tank Construction Parameters

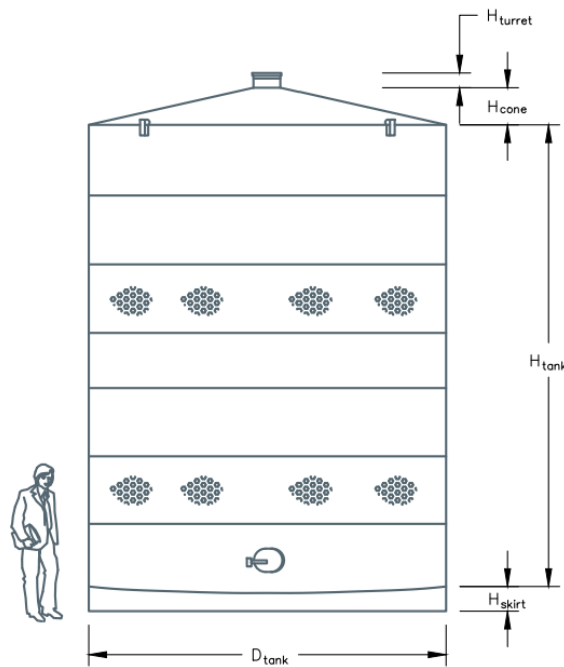


Figure 1: Liquid storage tank construction drawing



Figure 2: Liquid storage tanks built according to the tank construction drawings



Figure 3: An example of an OG PRO anchor mounted between skirt and slab. The anchor is welded to a backing plate which reinforces the skirt. A hole is drilled into the slab beneath the anchor enabling epoxy fixing of the anchor stud into the slab.

With tanks on skirts, ONGUARD designs new anchors to be installed between the stainless steel skirt wall and the slab.

SITE GROUND MOTION PARAMETERS

Next, ONGUARD uses the facility's street address to lookup site ground motion details. These details are provided by the Structural Engineers Association of California in the form of an [OSHDP Seismic Design Map](#) [1], which references ASCE 7. If the client is able to provide a geotechnical report, it may be used in substitution of the OSHDP Seismic Design Map.

SITE GROUND MOTION PARAMETER	SYMBOL	VALUE	UNITS
Site Class	[-]	D - Stiff Soil	[-]
Numeric seismic design value at 0.2s spectral acceleration	S_{DS}	1.691	[-]
Numeric seismic design value at 1.0s spectral acceleration	S_{D1}	0.920	[-]
MCE_R ground motion (for 1.0s period)	S_1	0.812	[-]

Table 2: Site Ground Motion Parameters

SEISMIC DESIGN FACTORS

Lastly, API 650 [2] is referenced to determine the seismic design factors for the ONGUARD anchorage system.

SEISMIC DESIGN FACTOR	SYMBOL	VALUE	UNITS
Convective response modification factor (see below)	R_{wc}	2.0	[-]
Impulsive response modification factor (see below)	R_{wi}	4.8	[-]
Seismic use group	I	1.0	[-]

Table 3: Seismic Design Factors from API 650 Section E.5 [2]

Important note: the response modification factors from Table 3 are used to calculate anchor force demands. These demands are used to specify the anchor yield load for the selected anchor. Using a capacity design approach, all other components of the structural system are designed for demands 15% greater than the anchor yield load.

DESIGN APPROACH DISCUSSION

Today's most prominent seismic tank design standards and guidelines are not consistent in assuming anchor force distribution.

Three anchor force distributions form the basis of three seismic tank design approaches identified in NZSEE's "Seismic Design of Storage Tanks" Guideline [3]. These anchor force distributions are depicted in Figure 4.

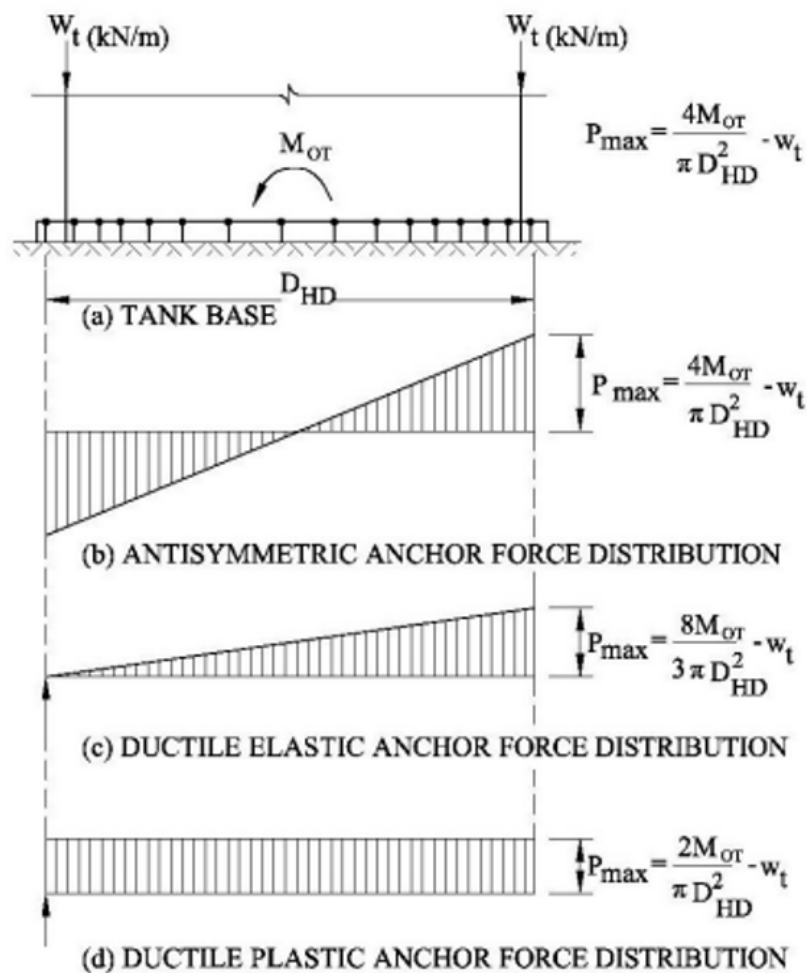


Figure 4: Three possible anchor force distributions depicted in NZSEE's "Seismic Design of Storage Tanks" 2009 Guideline [3]. The anchor force distribution dictates how the seismic forces interact with the liquid storage tank.

To demonstrate the effects of choosing between these approaches, ONGUARD designs two possible seismic tank solutions using two design approaches in this study. They are referred to as Approach A and Approach B.

DESIGN APPROACH ANALYSIS

APPROACH A – ANTISYMMETRIC

This design approach uses the antisymmetric anchor force distribution, which assumes elastic anchor performance as described in both API Standard 650, Welded Tanks for Oil Storage, Thirteenth Edition [2] and AWWA Standard D100-21, Welded Carbon Steel Tanks for Water Storage [4].

APPROACH A DESIGN RESULT	SYMBOL	VALUE	UNITS
Overturning moment acting on tank slab	M_s	3,490	kip-ft
Maximum load per foot width acting on anchor ring	w	8.2	kip/ft
Anchor selection	[-]	OG PRO 81 MKIV	[-]
Number of anchors	n	26	[-]
Design force per anchor (ASD)	P	20.1	kip
Design capacity per anchor	ϕT_n	20.1	kip
Backing plate dimensions	[-]	11 x 11 x ½	in
Stud embedment depth	H_{ef}	19	in
Minimum slab thickness	H_{slab}	21	in
Minimum edge distance (between stud and slab edge)	c	26	in

Table 4: Approach A design results

APPROACH B - DUCTILE ELASTIC

This design approach uses the ductile elastic anchor force distribution, which assumes ductile anchor performance as described in NZSEE's "Seismic Design of Storage Tanks" Guideline [3].

APPROACH B DESIGN RESULT	SYMBOL	VALUE	UNITS
Overturning moment acting on tank slab	M_s	3,490	kip-ft
Maximum load per foot width acting on anchor ring	w	5.4	kip/ft
Anchor selection	[-]	OG PRO 81 MKIV	[-]
Number of anchors	n	20	[-]
Design force per anchor (ASD)	P	17.3	kip
Design capacity per anchor	ϕT_n	17.3	kip
Backing plate dimensions	[-]	11 x 11 x 1/2	in
Stud embedment depth	H_{ef}	16	in
Minimum slab thickness	H_{slab}	18	in
Minimum edge distance (between stud and slab edge)	c	13	in

Table 5: Approach B design results

RESULTS COMPARISON

Both design approaches result in the same overturning moment acting on the tank slab (M_s) since the magnitude of total force acting on the tank is held constant.

Approach A requires a greater number of anchors (n) since the anchor ring sees a greater maximum load per foot width (w). The anchor ring is the diameter of the ring of anchors securing the tank and skirt to the slab. Since the anchor ring sees a lesser force per nominal width in Approach B, it requires fewer anchors to keep the tank secured to the slab.

The design force and design capacity per anchor vary since the number of anchors and loading of anchors differ for each design approach.

Approach B has a smaller design capacity per anchor, meaning each anchor and its associated stud experiences less tension in a design-level earthquake. Less tension on the stud means the stud embedment depth can be reduced. Stud embedment depth is related to the slab thickness and edge distance which are constrained to avoid concrete breakout. Because stud embedment depth can be reduced, the minimum slab thickness and minimum edge distance can both be reduced.

SOLUTION SELECTION

Approach B is preferred since it requires a lesser number of anchors, a thinner slab, and shorter edge distance. Fewer anchors means a reduction in both hardware and labor installation costs. A thinner slab and shorter edge distance reduces overall slab volume, resulting in reduced concrete costs. The shorter edge distance also allows tanks to be installed closer together and requires a smaller slab footprint.

CLOSING REMARKS

Approach B, the approach using the ductile elastic anchor force distribution, is ONGUARD's preferred approach. ONGUARD found this approach has more accurate anchor force distribution for a tank with ductile anchors such as OG PRO MKIV anchors and provides better protection to the tank walls. ONGUARD has found Approach A overestimates the anchor forces when ductile anchors are used.

Recognizing today's conflicts in seismic tank design approach, ONGUARD developed its own research to gain a better understanding of a tank's actual distribution of base forces with ductile anchors during an earthquake. ONGUARD uses this research to justify its design decisions and expects to see this research adopted more widely in the future.

REFERENCES

- [1] "[OSHPD Seismic Design Maps](#)". *Structural Engineers Association of California*.
- [2] "Welded Tanks for Oil Storage, API Standard 650, 12th Edition". *API*. 2013
- [3] Priestley, M. J. Nigel et al. "Seismic Design of Storage Tanks". *NZSEE*. 2009.
- [4] "AWWA D100-21 Welded Carbon Steel Tanks for Water Storage". *AWWA*. 2021