Understanding The Tanks We Get

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NZSEE

WEA Conference Blenheim 2016

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Presentation Outline

- The Setting
- Compliance requirements for tanks within the New Zealand regulatory environment
- Tank design
- Expected performance during earthquake shaking and early onset of damage from detailing
- Modern detailing concepts for improved tank performance or reduced operation impacts

The Setting

- At any given time the majority of the wine in production or storage is contained in tanks
- The industry is reliant on the design of tanks for protection of staff and stored product in the event of a natural disaster
- Lost continuity of business can be as, if not more, damaging than the natural disaster itself
- Tank design can be viewed as self-insurance for the product and ongoing operation of any winery

Compliance Requirements within NZ

- If a tank contains a *Hazardous Substance* it must comply with the HSNO Act 1996 and HSNO Transfer Notices
- The definition of a *Hazardous Substance* is as per Section 2(1) of the HSNO Act 1996
- Tanks containing non-hazardous substances must comply with the Building Act 2004
- Tanks operating at pressure (liquids at pressures > 50 kPag) must comply with the Health and Safety in Employment (Pressure Equipment, Cranes, and Passenger Ropeways) Regulations 1999
- Earthquake Prone Building policy

Hazardous Substances ?

- Wine is classified as a food and not as a *Hazardous Substance*
- During production spirits could be a *Hazardous Substance* depending on the % Ethanol
- Chemical stores on site such as bulk Ethanol will be a *Hazardous Substance*

- Industrial gases such as nitrogen, CO_2 and Ammonia are likely to be at pressures that classify their storage container as a pressure vessel

HSNO Act 1996 Requirements

- *…all parts of a stationary container system must be designed, constructed, installed, operated, maintained, inspected, tested, and repaired so that the….system contains any hazardous substance that is put into it without leakage….when subjected to all likely—*
  - a) *operating temperatures; and*
  - b) *pressures; and*
  - c) *stresses and loadings (including **seismic** and wind stresses and loadings); and*
  - d) *environmental conditions*

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HSNO Act 1996 Requirements

- The HSNO Act has prescriptive requirements for:
  - Design Standards to which the design must comply
  - Secondary Containment requirements, volume and strength
  - Spacing between tanks and/or bunding
  - Re-certification periods
- The NZSEE Guidelines are working through the process of being cited as an approved *Code of Practice* under HSNO Act

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Tanks Under the Building Act

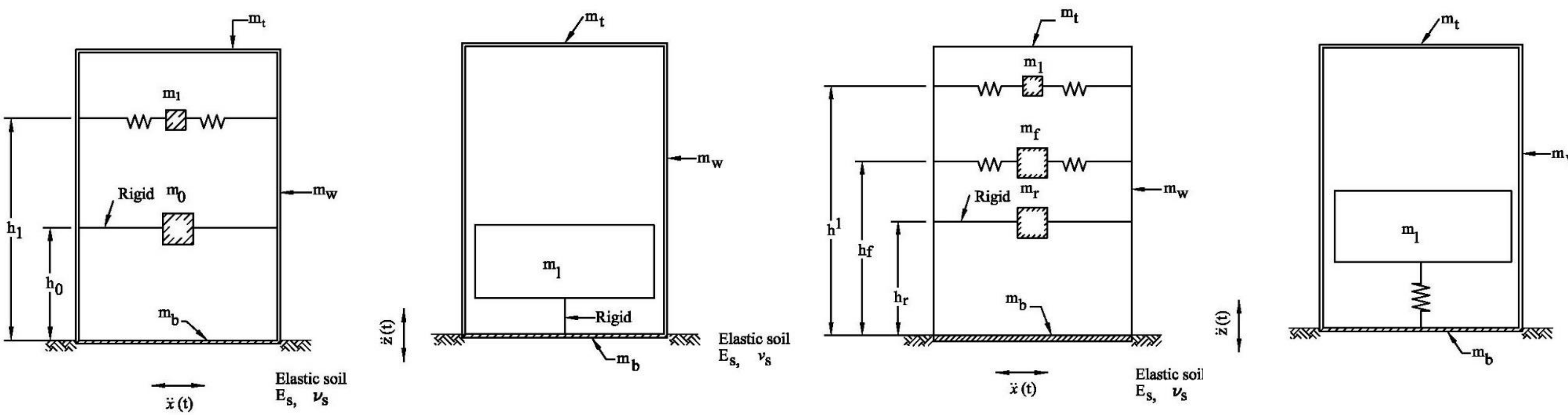
- A tank is defined as a *Building* under the Act as are the foundations and walkways
- Under the Act, buildings are not to be constructed, altered, demolished or removed without a building consent
- The Act exempts certain work from requiring a building consent.
  - “lawful repair and maintenance… or assembly in the same position except complete or substantial replacement of any component contributing to the building’s structural behaviour”
  - “any tank and structural support of the tank… not exceeding 35,000 litres capacity and supported directly on the ground; or not exceeding 8,000 litres and supported not more than 0.5m above the supporting ground…”

Tanks Under the Building Act

- The Act appears to give Building Consent Authorities powers to waive requirements for building consents. This does not remove the requirement for the tank to comply with the Act
- AS/NZS 1170 is the New Zealand Loadings Standard defines:
  - the regional hazards (wind, AS/NZS 1170.2 & seismic, NZS 1170.5)
  - the Importance Level (IL) of the structure. IL2 typically:
    - IL1: presenting a low degree of hazard to life and other property
    - IL3: containing hazardous materials capable of causing hazardous conditions that do not extend beyond the property boundaries
  - the Design Life of the structure. 50yrs for permanent structures
  - tank earthquake actions are outside the scope of NZS 1170.5

Tank Design: Modelling of the System

- Total mass is divided in parts, base, walls, roof and contents
- Contents are further divided into 2 modes:
  - Convective or ‘sloshing’ mode
  - Impulsive or ‘rigid body’ mode (may be further divided into flexible and rigid components)



Base Shear and Overturning Moment

- Base Shear:
  - Found for Convective and Impulsive modes with their respective period and mass
  - Mass of tank walls and roof included in the impulsive mode
  - Modes combined by SRSS method

$$V_i = C_d(T_i)m_i g \qquad C_d(T_i) = C_h(T_i)ZR_u N(T_i, D)k_f(\mu, \xi_i)S_p$$

- Overturning Moment:
  - Found for Convective and Impulsive modes with their respective period, mass, and lever arm
  - Mass of tank walls and roof included in the impulsive mode
  - Modes combined by SRSS method

$$M_i = C_d(T_i)m_i h_i g$$

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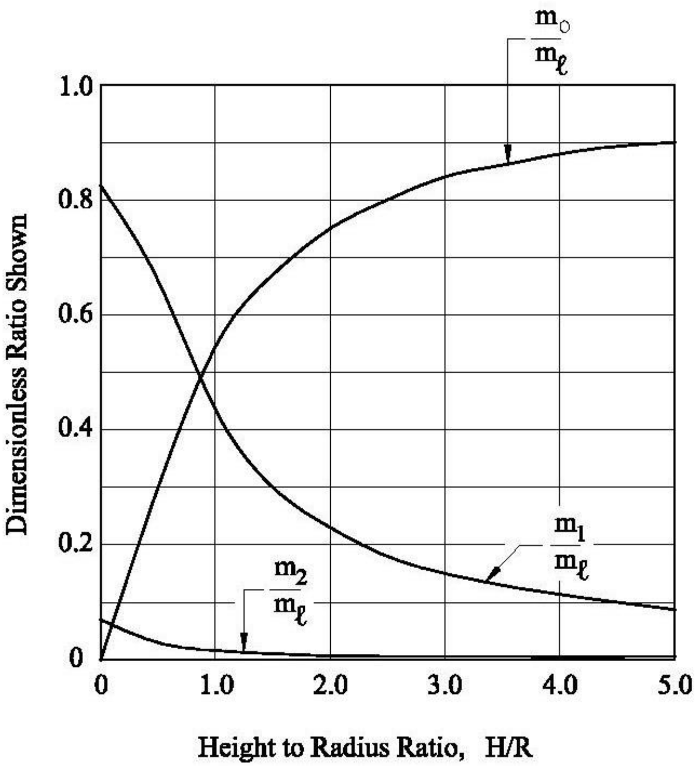
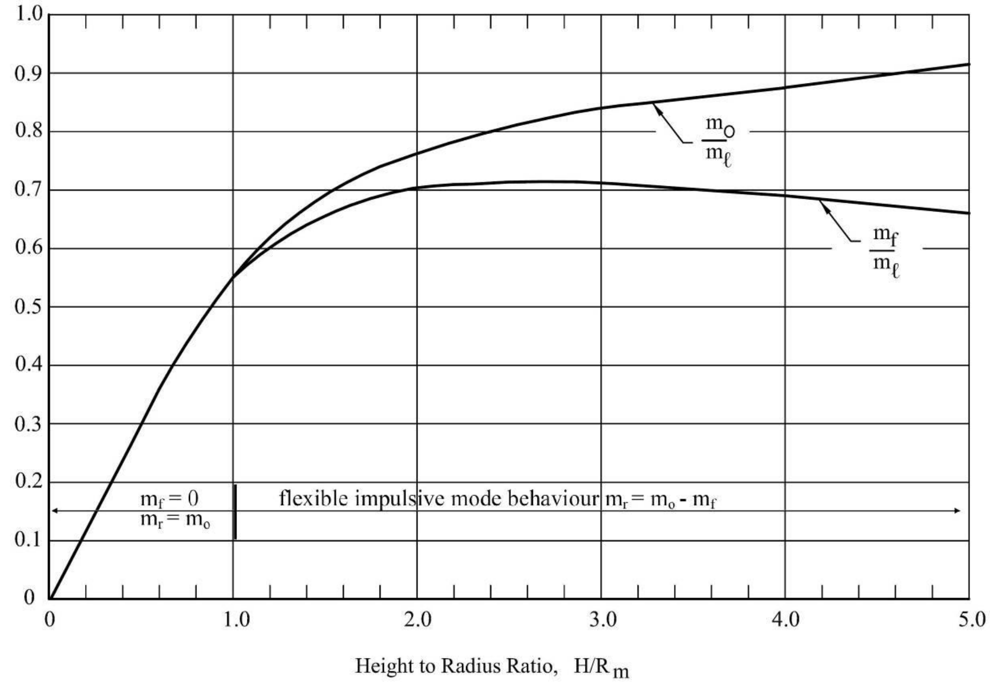
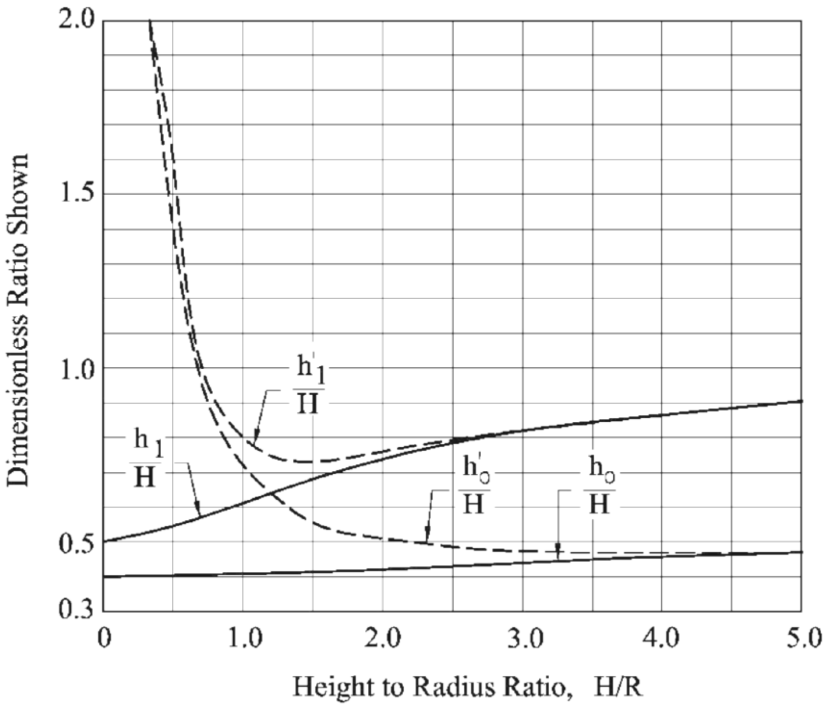
Liquid Mass Distribution

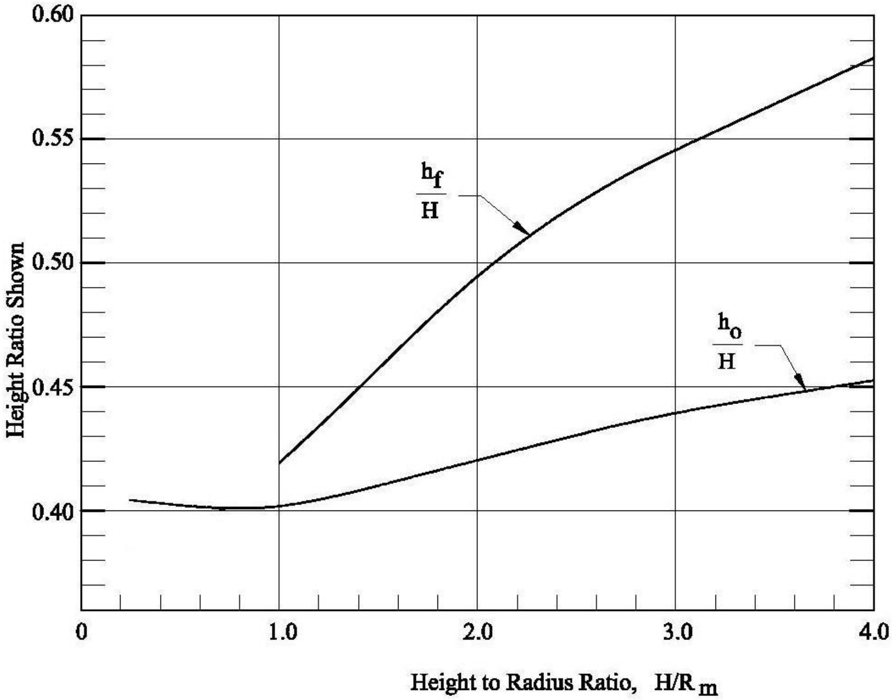




Note: Wine tanks typically full confining the liquid and supressing any convective mode action. In this case M_o = 100% of the mass.

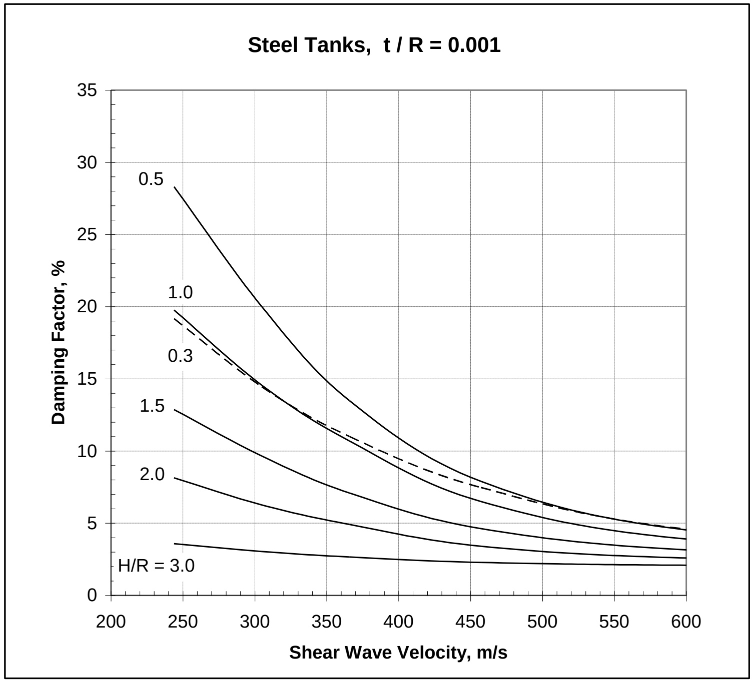
Mass Lever Arms





Damping and Ductility

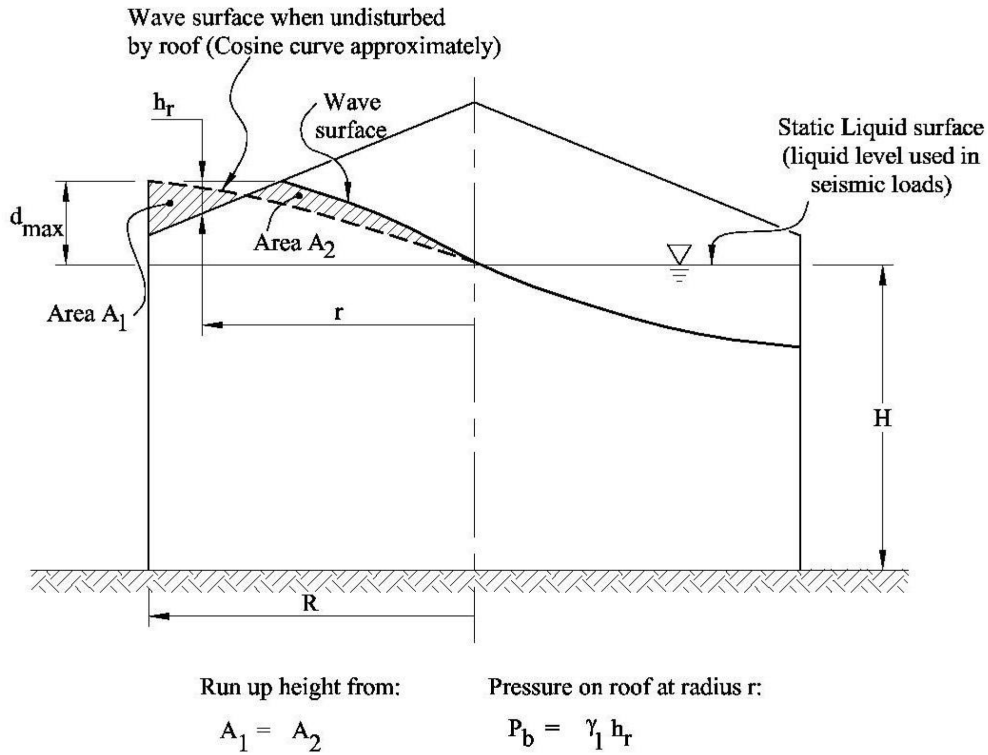
Type of Tank		Ductility Factor μ[1]
Steel Tanks on Grade		
	Elastically responding	1.25
	Unanchored tank with limited ductile behaviour (e.g. elephant's foot shell buckling or uplift)	2.0 [2][4]
	Unanchored tank elastically designed or with a non-ductile mechanism (e.g. elastic, diamond shaped shell buckling)	1.25
	Anchored with non-ductile holding down bolts	1.25
	Anchored with ductile tensile yielding holding down bolts	2.0 [3] [4]
	Ductile skirt pedestal	2.0 [3] [4]
	On concrete base pad designed for rocking	2.0 [3] [4]



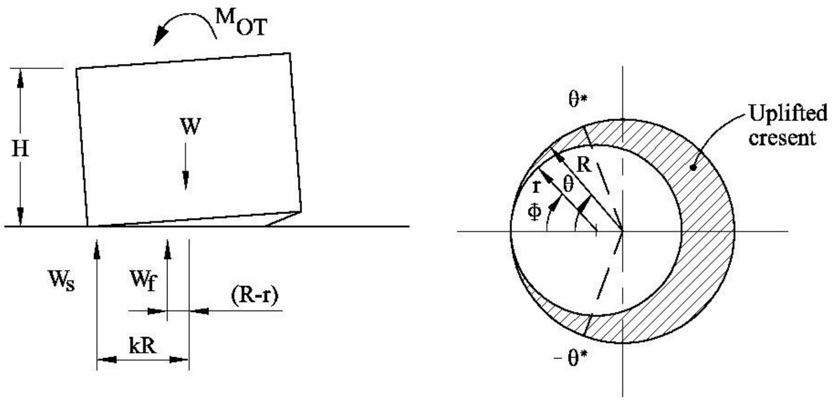
Ductility μ	Teq/T[1]	ξ_h [2] (%)	$k_f(\mu, \xi_i)$[4]							
			ξ [3] = 0.5 %	ξ = 1 %	ξ = 2 %	ξ = 5 %	ξ = 10 %	ξ = 15 %	ξ = 20 %	ξ = 30 %
1.0	1.000	0.0	1.67	1.53	1.32	1.00	0.76	0.64	0.56	0.47
1.25	1.033	3.5	1.08	1.04	0.96	0.82	0.67	0.58	0.52	0.44
2.0	1.120	5.9	0.91	0.89	0.84	0.74	0.63	0.55	0.50	0.43

Convective (Sloshing) Actions

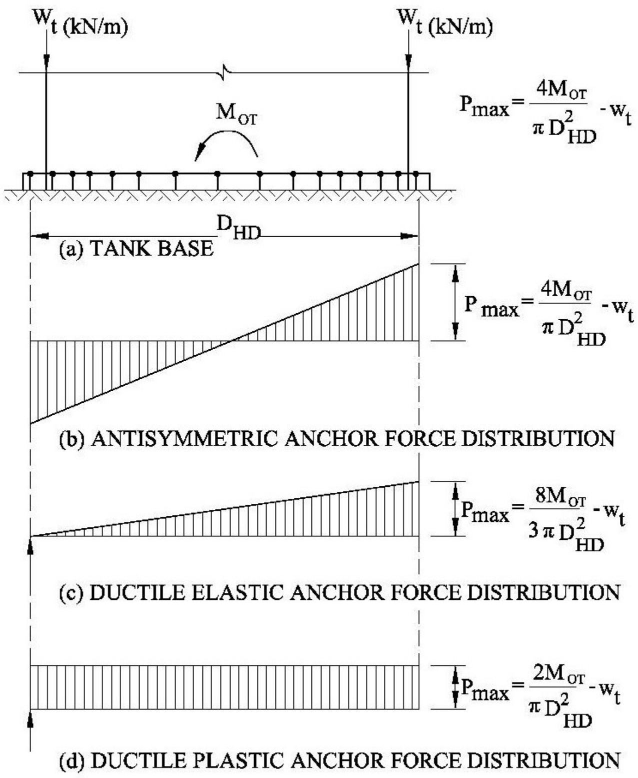
$$d_{max} = R\sqrt{[0.84C_d(T_1)]^2 + [0.07C_d(T_2)]^2}$$



Design of Anchorage



Self-anchorage (rocking)



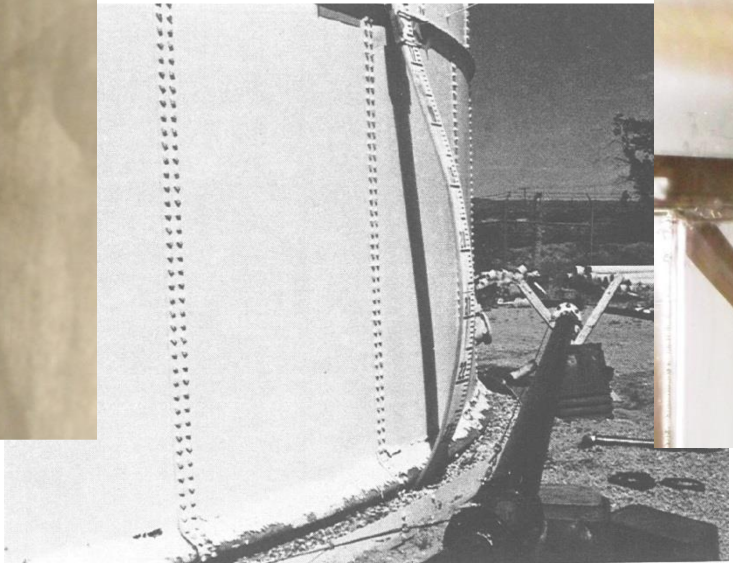
Hold-down brackets

Components of Design to Check

- Sliding at the base of the tank
- Global overturning of the tank
- Wall yielding under hoop tension
- Wall yielding under bending stresses
- Wall buckling, both ‘Elephants foot’ and ‘Diamond shaped’
- Base or wall yielding if the tank uplifts
- Buckling of the roof/wall joint from wave loading on the roof
- Roof loading, live load, snow load, internal pressures, wave impact
- Differential settlement of foundations (larger diameter tanks)
- Anchorage if required and foundation design
- Wind girders

Expected Performance in EQ Shaking

- ‘Elephants Foot’ wall buckling



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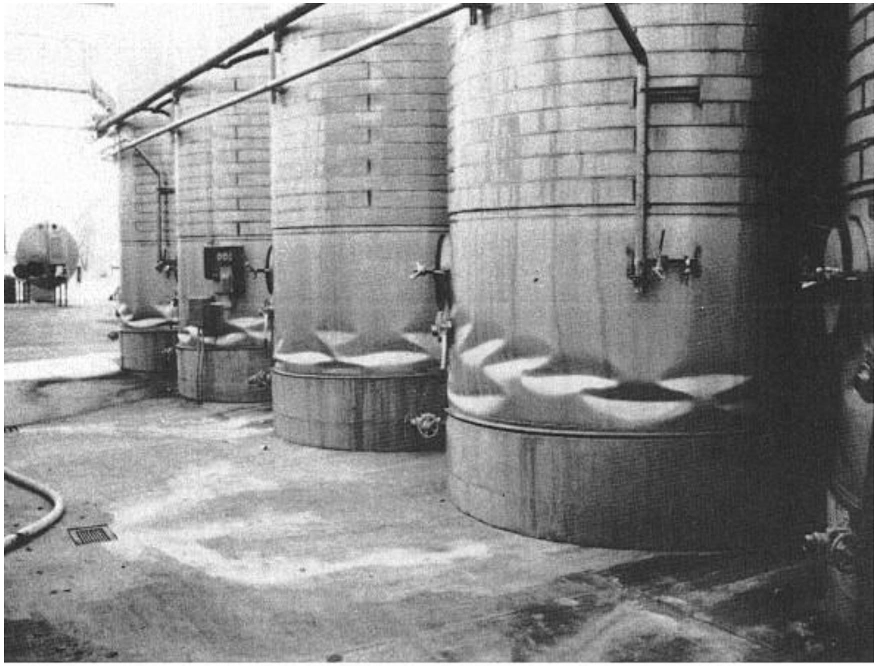
Expected Performance in EQ Shaking

- Elastic ‘Diamond’ wall buckling



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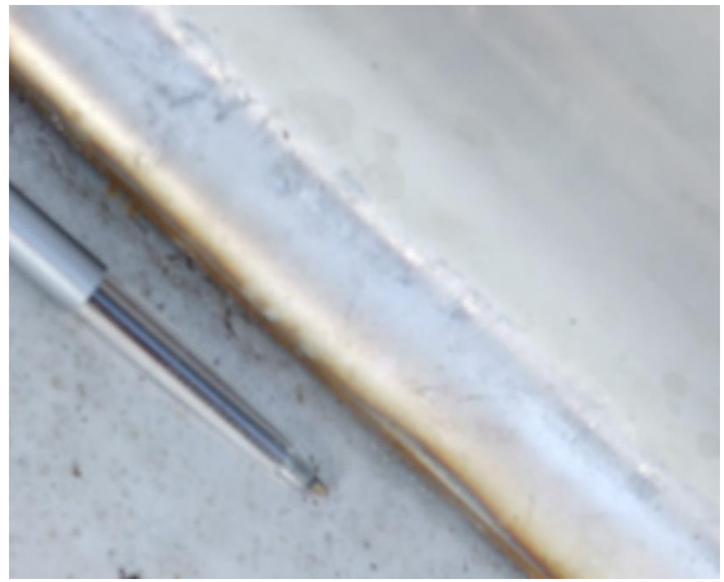
Expected Performance in EQ Shaking

- Knuckle squash ‘Guttering’ (an early onset damage form)



Expected Performance in EQ Shaking

- Leg damage (an early onset damage form)

Expected Performance in EQ Shaking

- Base Distortion & Strap Damage (an early onset damage form)

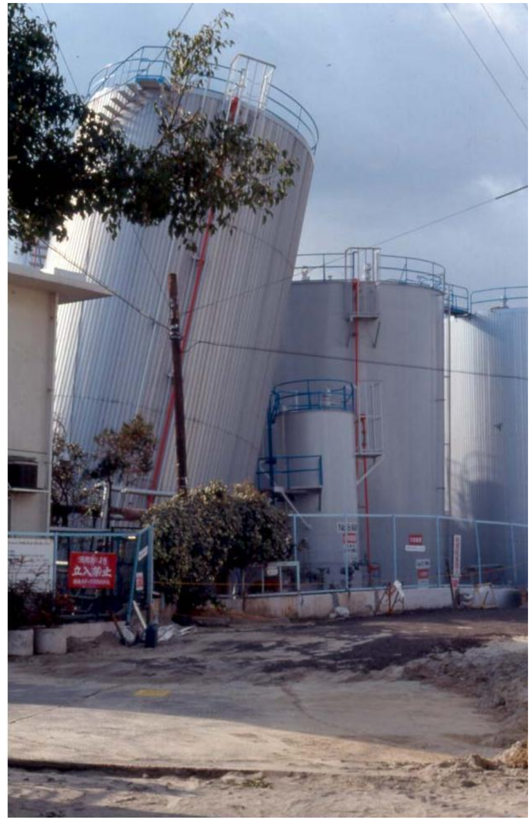
Expected Performance in EQ Shaking

Suck-in from content loss

Hold-down pullout or failure

Expected Performance in EQ Shaking

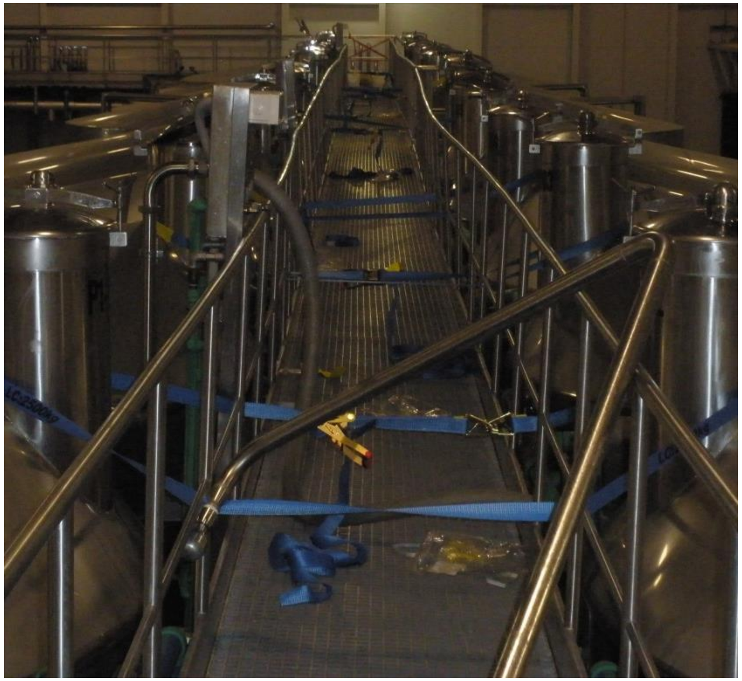
Roof buckling from pressurisation



Foundations

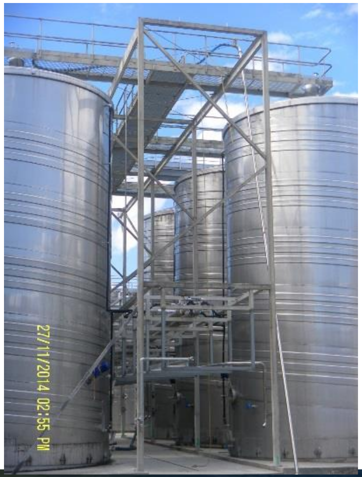
Sliding

Walkways



Modern Detailing

- All designs are limited to the capacity to which they are designed. *We have no say in which earthquake turns up*.
- Walkways
  - Sliding seating on tanks
  - Over better than between (collapse limitation)
  - Telescopic supports between tanks
  - Independent support frames
  - Fixing of walkway grating to frames (fall-through prevention)



Modern Detailing

- Knuckle squash ‘Guttering’ protection
  - Post-installed plinths – skirt bearing to the foundation slab
  - Compression/tension brackets

VS

Modern Detailing

- Hold-down bolts and brackets
  - Waste-able portions
  - Capacity design

- Design Criteria (owner selected)
  - Design Basis statements for Requests for Tender
    - Importance level
    - Design Life
    - Ground conditions / soil type (NZS 1170.5)
    - Acceptable ductility for wall buckling

Thank You

Questions

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