## 6.4 Mechanical, Electrical, and Plumbing Components

### *6.4.2 Storage Tanks and Water Heaters*

#### 6.4.2.1 Structurally Supported Tanks and Vessels

This category covers any type of tank or vessel supported on legs or a structural frame and may be either vertical or horizontal. Tanks may be made of steel, stainless steel, polyethylene, polypropylene, fiberglass reinforced plastic (FRP), or concrete.

### Provisions

BUILDING CODE PROVISIONS

Seismic loads for structurally supported tanks and vessels are determined using ASCE/SEI 7-10, *Minimum Design Loads for Buildings and Other Structures,* (ASCE, 2010), Chapter 13, or Chapter 15 (Nonbuilding Structures) for large tanks that are not within buildings.

For tanks considered nonstructural components, ASCE/SEI 7-10 Chapter 13 requires anchorage for tanks in Seismic Design Categories D, E, and F weighing over 400 pounds. Lighter tanks may be exempt if the component Importance Factor $I_p = 1.0$.

- Tanks or vessels that are exempt from the anchorage requirements noted above are still required to be positively anchored to the structure or ground. The anchorage need not be designed or detailed on the construction documents. The components must be provided with flexible connections between the equipment and associated pipes or conduits or alternate means of protecting the connection should be implemented.
- ASCE/SEI 7-10 requires design of component supports and component anchorage where:
    - Component supports for the tank or vessel include the legs and attachment of the legs to the base plate and the tank or vessel wall, and
    - Component anchorage includes the attachment or anchors of the tank or vessel to the structure (e.g., anchor bolts to a concrete slab or bolts to a steel platform).

Requirements for structurally supported tanks and vessels classified as nonbuilding structures:

- ASCE/SEI 7-10 Section 15.7 contains extensive design requirements for elevated tanks on legs, saddles and skirts.

RETROFIT STANDARD PROVISIONS

ASCE/SEI 41-06, *Seismic Rehabilitation of Existing Buildings* (ASCE, 2007) classifies structurally supported tanks and vessels as force controlled, meaning that the principal objective is to prevent the component from sliding or overturning. These components are subject to the provisions of the standard when:

- The performance level is Immediate Occupancy.
- The performance level is Life Safety in high seismicity areas, if
    - The item is part of an emergency power system.
    - The item weighs more than 400 pounds and is 6 feet or more in height.
    - The item is unanchored, weighs over 100 pounds, is 6 feet or more in height, and is subject to overturning. These items may be exempt if they have a factor of safety greater than 1.5 against overturning when design loads are applied.
    - The item weighs over 20 pounds and is mounted over 4 feet above the floor.

## Typical Causes of Damage

- If the tank is not anchored to the structural supports or the structural supports are not properly braced and anchored, the tanks may slide or fall. Poorly anchored tanks may damage the supports or damage the tank wall.
- The most common forms of damage are the following:
    - Failure of anchor bolts to the concrete deck or slab
    - Failure of the welds between the tank or vessel leg and the base plate
    - Buckling of the tank legs
    - Failure of the welds or connections between the supporting legs and the body of the tank or vessel
    - Buckling or local failure of the tank wall where the legs are attached
    - For saddle mounted tanks, failure of the straps or connectors that hold the tank in the saddle
- If the tank slides or rocks, the connections of supply lines or fuel lines may be damaged; contents may slosh or spill.

DAMAGE EXAMPLES

Figure 6.4.2.1-1 Tank shifted off support curb, Granada Hills Hospital in the 1994 magnitude-6.7 Northridge Earthquake (Photo courtesy of OSHPD).

Figure 6.4.2.1-2 A vertical tank at hospital overturned due to inadequate anchorage in the 1994 Northridge Earthquake (Photo courtesy of OSHPD).

Figure 6.4.2.1-3 Horizontal tank strapped to structural support frame on hospital roof; one strap failed and tank slid six inches in the 1994 Northridge Earthquake (Photo courtesy of OSHPD).

Figure 6.4.2.1-4 Wineries suffered extensive damage in the 2010 magnitude-8.8 Chile Earthquake with many barrels of wine spilled. This winery had damage to anchored tanks; tank anchorage failed, legs buckled, welds tore, anchor bolts pulled up, etc. The tank legs all have leveling bolts at the bottom, creating a weak zone between the bottom of the leg and the anchor plate. Similar unanchored tanks in this facility shifted position but were undamaged (Photos courtesy of Eduardo Fierro, BFP Engineers).


Figure 6.4.2.1-5 Damage to tanks at the Pioneer Memorial Hospital at the 2012 Brawley Earthquake (Photo courtesy of Chris Tokas, OSHPD)

## Seismic Mitigation Considerations

- Tanks must have adequate vertical and horizontal support. Provide anchorage and bracing for tank legs or support structure; provide positive attachment from tank to support structure. Provide concrete pad large enough to prevent tank from overturning.
- Provide flexible connections for fuel lines and piping.
- The details shown are for rigid connections; see also FEMA 412 *Installing Seismic Restraints for Mechanical Equipment* (2002) for attachment details.
- For some installations where tanks have a low aspect ratio (i.e., the tank is relatively wide compared to the height) and are unlikely to overturn, it may be preferable to allow the tank to slide rather than providing rigid anchorage. As shown in the photos in Figure 6.4.2.1-4 taken at a winery, many stainless steel tanks on legs with base anchorage were damaged while nearby unanchored tanks shifted slightly but were undamaged. Flexible connections designed to accommodate sliding would be required

for tanks left free at the base. Tanks classified as nonstructural components that are specifically designed and detailed to accommodate seismic demands by sliding would be considered an Alternative Means of Compliance subject to the approval of the Building Official, since ASCE/SEi 7-10 explicitly requires that tanks and vessels be anchored. Tanks classified as nonbuilding structures that accommodate seismic demands by sliding may be designed using the provisions of ASCE/SEI 7-10 Section 15.7.5.

## MITIGATION EXAMPLES


Figure 6.4.2.1-6 Braces added to four sides of tank support structure (Photo courtesy of Eduardo Fierro, BFP Engineers).


Figure 6.4.2.1-7 Gusset plates and cross bracing added at base of vertical tank on four legs following the 2001 magnitude-8.4 Peru Earthquake (Photo courtesy of Eduardo Fierro, BFP Engineers).

MITIGATION DETAILS

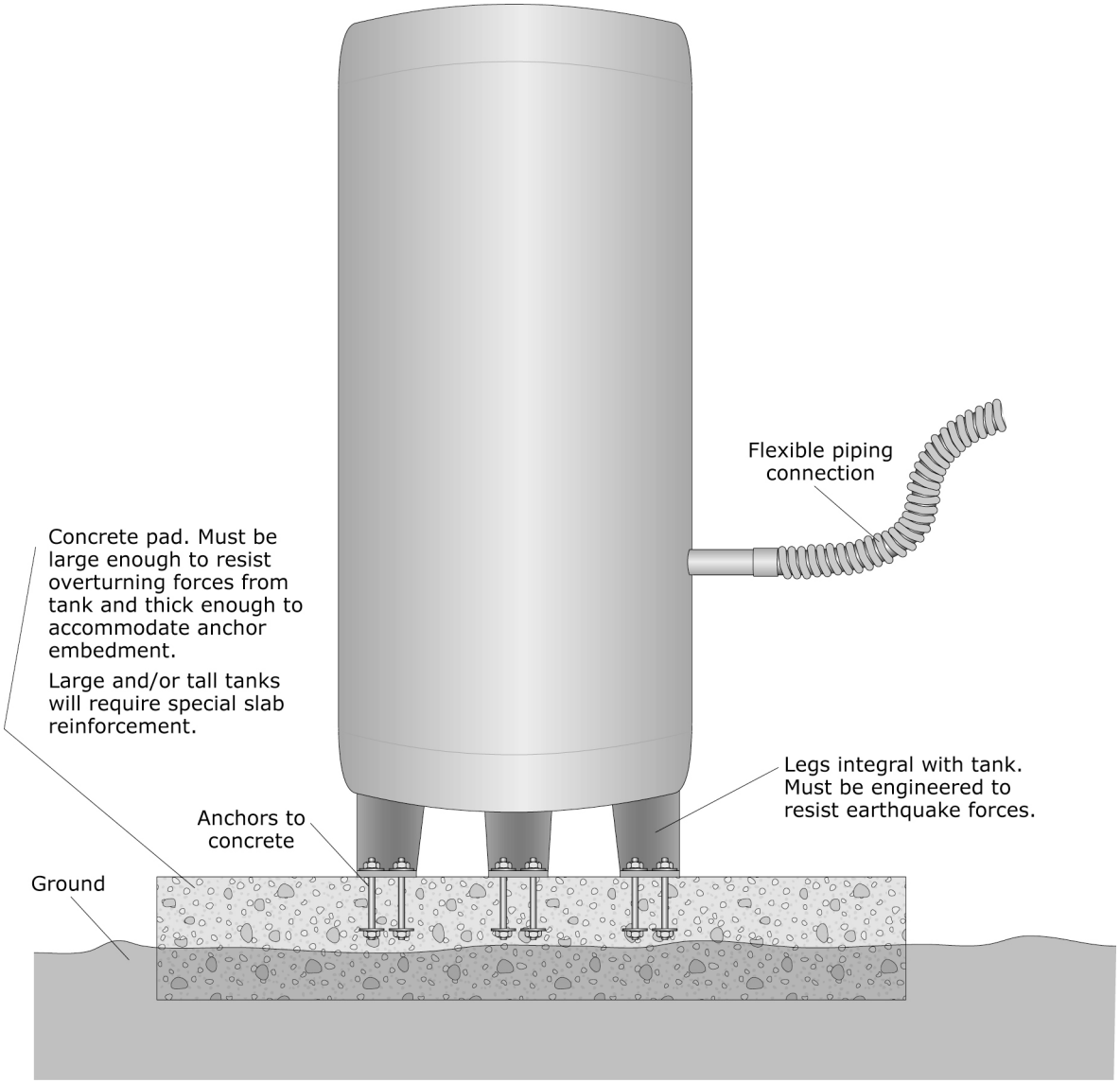


Figure 6.4.2.1-8 Vertical tank on legs (ER).