6.4 Mechanical, Electrical, and Plumbing Components

6.4.1 Mechanical Equipment

6.4.1.2 General Manufacturing and Process Machinery

This category covers a wide range of equipment of various shapes and sizes. It includes isolated pieces of equipment as well as manufacturing lines that consist of numerous components requiring precise alignment. Mechanical components may be constructed of deformable materials and attachments or rigid components and attachments; they may be floor-, wall-, or roof-mounted.

Provisions

BUILDING CODE PROVISIONS

General manufacturing and process machinery may be subject to the requirements of ASCE/SEI 7-10, *Minimum Design Loads for Buildings and Other Structures* (ASCE, 2010), Chapter 13, Nonstructural Components, or Chapter 15, Nonbuilding Structures. Components housed in or supported by a building are typically assumed to be nonstructural components and are covered by Chapter 13. Larger or significant components not enclosed or supported by a building are considered Nonbuilding Structures and are covered by Chapter 15. For example, the components in Figures 6.4.1.2-1 and 6.4.1.2-2 would be classified as Nonbuilding Structures. The distinction between the nonstructural components and Nonbuilding Structures is sometimes difficult to determine. When uncertainty exists, one approach is to use the larger of the seismic demands determined by either method.

The principal objective of the requirements in ASCE/SEI 7-10 is to prevent the component from sliding or overturning. However, depending on the nature of the machinery, it may also be sensitive to building displacements if the system is connected to multiple levels of the same structure, or is connected to adjacent structures.

Requirements for general manufacturing and process machinery classified as Nonbuilding Structures:

- ASCE/SEI 7-10 Chapter 15 classifies Nonbuilding Structures into two broad groups, those that are similar to buildings and those that are not similar to buildings.
- Nonbuilding Structures similar to buildings may be designed or strengthened using the same general approach as those used for buildings. The most significant difference is

that in areas of high seismicity, a broader range of structural systems are permitted for Nonbuilding Structures, although higher design forces are required.

- ASCE 7-10 Chapter 15 provides extensive provisions for Nonbuilding Structures not similar to buildings, including tanks, vessels, silos, and cooling towers.

Requirements for general manufacturing and process machinery classified as nonstructural components:

- ASCE/SEI 7-10 requires anchorage for all equipment in Seismic Design Categories D, E, and F for all equipment weighing over 400 pounds, and items weighing over 20 pounds that are mounted over 4 feet above the floor. Lighter items may be exempt if the component Importance Factor $I_p = 1.0$.
- Items that are exempt from the anchorage requirements noted above are still required to be positively anchored to the structure. The anchorage need not be designed or detailed on the construction documents. They must also be provided with flexible connections between the equipment and associated pipes, ducts, or conduits or alternate means for protecting the connections.

RETROFIT STANDARD PROVISIONS

ASCE/SEI 41-06, *Seismic Rehabilitation of Existing Buildings* (ASCE, 2007) classifies general manufacturing and process machinery as force controlled. For general manufacturing and process machinery that can be classified as a nonstructural component, ASCE/SEI 41-06 requires compliance with the anchorage 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 gas-fired.
    - The item is part of an emergency power system,
    - The items 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.

For general manufacturing and process machinery classified as a nonbuilding structure, the provisions of ASCE/SEI 41-06 are not directly applicable. However, the procedures of the document may be extrapolated to apply to many Nonbuilding Structures similar to structures such as pipe racks and structural towers that support tanks, vessels and bins.

Typical Causes of Damage

- Unanchored or poorly restrained equipment can slide, tilt, overturn, or fall. Poorly reinforced housekeeping pads may slide or fail.
- Components may be damaged by shaking or pounding, or may be crushed by other fallen components. Failure of large nonstructural components may result in damage to structural elements due to impact or falling.
- Items crossing seismic joints, attached to adjacent floors, penetrating structural elements, or connections between flexible and rigid components may be particularly vulnerable.
- Machinery may cease to function due to misalignment or internal damage.
- Contents, fluids, or hazardous materials may slosh, mix, or spill.
- Connections of fuel lines, electrical lines, optical cable, piping, or ductwork may be damaged; runs of piping, ducts, or cable may be damaged.
- Loss of function of manufacturing equipment can cause significant business interruption losses.

DAMAGE EXAMPLES

Figure 6.4.1.2-1 Damage to conveyors and equipment at a cement plant in the 2010 magnitude-7 Haiti Earthquake (Photos courtesy of Eduardo Fierro, BFP Engineers).

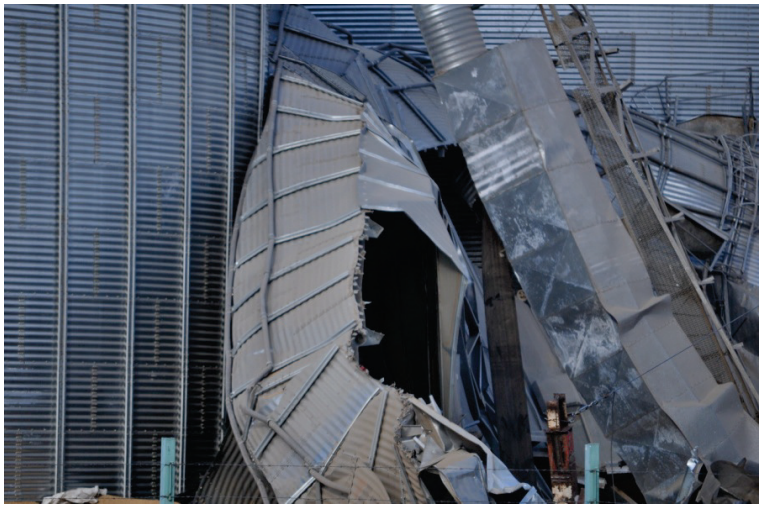

Figure 6.4.1.2-2 Damage to silos, conveyors and equipment at a grain operation in the 2010 magnitude-8.8 Chile Earthquake (Photos courtesy of Eduardo Fierro, BFP Engineers).

Seismic Mitigation Considerations

- In addition to requirements in ASCE/SEI 7-10 *Minimum Design Loads for Buildings and Other Structures* (ASCE, 2010), anchorage design for equipment may be governed by specialty codes and standards such as ASME, ASHRAE, IEEE, API.
- See Sections 6.4.1.1 and 6.4.1.3 for sample details for floor-mounted equipment and see FEMA 412 *Installing Seismic Restraints for Mechanical Equipment* (2002), FEMA 413 *Installing Seismic Restraints for Electrical Equipment* (2004) and FEMA 414 *Installing Seismic Restraints for Duct and Pipe* (2004) for example details for MEP equipment, piping and ductwork. Many of the attachment details in these documents could be adapted for use with other types of equipment.
- Some equipment has been shake table tested and is rated for seismic loading by their vendors; inquire about seismic load ratings and seismic anchorage details when any new equipment is purchased.
- For vulnerable items that require a long lead time to replace, it may be prudent to stock replacement parts or equipment in order to reduce an outage following an earthquake.
- Special attention is required for control rooms and emergency generators to ensure that a facility may be shut down safely after an earthquake.
- Flexible connections should be provided for fuel lines and piping where they connect to rigidly mounted equipment.
- Design of seismic bracing and anchorage for complex manufacturing systems is a significant engineering challenge and should be handled by design professionals with specific expertise in this area. Nonstructural bracing should be checked regularly to ensure that the anchorage has not been compromised. It may be prudent to have a standing agreement with a design professional familiar with the facility to perform postearthquake inspections in order to facilitate speedy repairs and reduce the outage time.