6.4 Mechanical, Electrical, and Plumbing Components

6.4.10 Elevators and Escalators

Elevators are the most common type of transportation system to move people or cargo from one floor to another in buildings. Since the first passenger elevator was installed in New York in 1857 by Elisha Otis, elevators have become a ubiquitous mode of vertical transportation in buildings and they are found in practically all modern buildings around the world. An elevator is a machine that either pulls or pushes a car (or cab) located in a shaft (also referred to as hoistway). There are two main types of elevators which vary depending on the mechanical means in which the car is lifted or lowered. In hydraulic elevators a pressurized fluid in a piston is used to lift and lower the car whereas in traction (sometimes referred to as roped) elevators the car is pulled by steel ropes moved by a pulley system.

6.4.10.1 Hydraulic Elevators

The primary components of the hydraulic elevator system are the elevator cab, cab guides, doors and door mechanism, piston, cylinder, fluid reservoir, hydraulic fluid, rotary pump, valve, solenoid switch, and electrical control panel. Figure 6.4.101-1 shows a schematic view of a typical hydraulic elevator. Hydraulic elevators consist of relatively simple mechanical systems but failure of any of the component parts could disable the functionality of the entire system. The system may be tied to a seismic switch or a smoke detector which would facilitate safe shutdown in the event of an earthquake or fire.

These elevators are typically less expensive but are limited in height since they require a cylinder beneath the elevator equal to the height of the elevator cab's vertical travel. Typical heights are two to six stories.

Provisions

BUILDING CODE PROVISIONS

Seismic loads for elevators are determined using ASCE/SEI 7-10, *Minimum Design Loads for Buildings and Other Structures*, (ASCE, 2010), Chapter 13. Elevators are classified as mechanical components, and are sensitive to both story drift and acceleration. Elevators designed in accordance with the seismic requirements of ASME A17.1 *Safety Code for Elevators and Escalators* (ASME, 2007a) are deemed to meet the requirements of ASCE/SEI 7-10, provided the forces and displacements used in the design meet the provisions of ASCE/SEI 7-10.

- Elevators, hoistway structural systems, elevator equipment supports and attachments, and controller supports and attachments must be designed to meet the force and displacement requirements of ASCE/SEI 7-10.
- Bracing exemptions for small diameter piping and piping supported on hangers less than 12 inches long do not apply to elevator piping.
- Elevators that operate at speeds greater than 150 feet per minute must be provided with seismic switches that are triggered by earthquake shaking. The seismic switch will prevent a potentially damaged elevator from being used.

RETROFIT STANDARD PROVISIONS

ASCE/SEI 41-06, *Seismic Rehabilitation of Existing Buildings*, (ASCE, 2007) classifies components of elevators as acceleration sensitive. Shafts and hoistway rails that rise through several floors are both acceleration and deformation sensitive.

- Elevators are subject to the requirements of ASCE/SEI 41-06 when the performance level is Immediate Occupancy, or in regions of high and moderate seismicity when the performance level is Life Safety.
- The evaluation must consider the anchorage of the equipment and controllers, as well as the construction of the elevator shafts.
- Acceptance criteria may be based on prescriptive procedures, or the elevator components may be analyzed for the force and displacement demands.

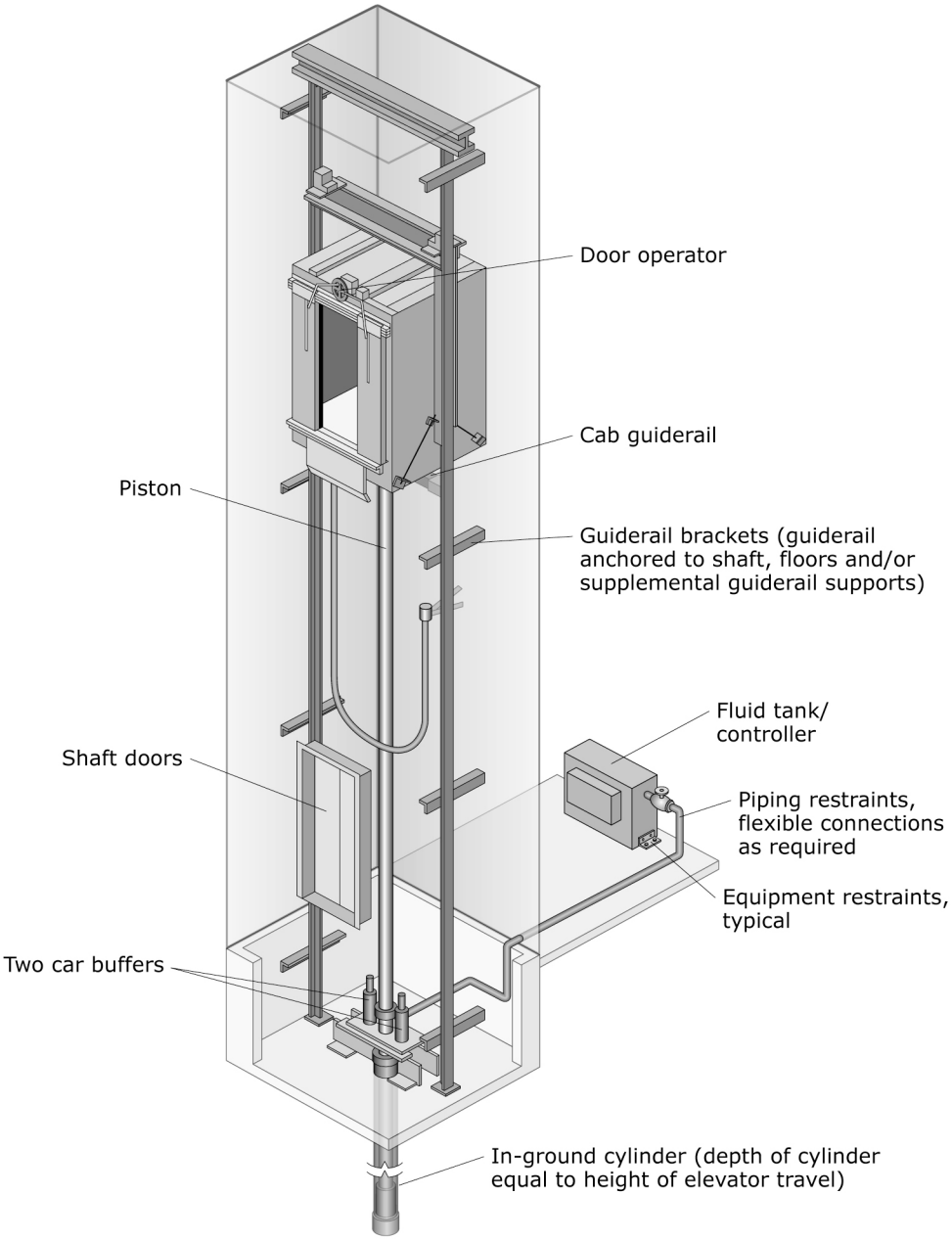
Typical Causes of Damage

- Common modes of elevator damage includedeformed door frames impeding the adequate operation of doors, failure of door rails, damaged to pump, oil leakage in hydraulic lines, and damage to hoistway switches.
- According to survey responses collected by the Division of Occupational Safety and Health Elevator, Tramway, and Ride unit, following the 1994 Northridge Earthquake 897 hydraulic elevators suffered damage such as leaks in underground feed lines, separated pipes, and failed gaskets and fittings. In addition, numerous guide rails were bent and several cars came out of rails. Tie downs on several oil tanks failed and hold-down bolts sheared and pulled out.
- In addition to property damage, passengers may become trapped in the cab following an earthquake and may need to await extraction by qualified elevator technicians.

Seismic Mitigation Considerations

- All components of the hydraulic system need to be restrained, anchored or detailed to accommodate movement to prevent damage in an earthquake. The system must be designed to accommodate the anticipated inter-story drift over the height of the elevator travel and the depth of the cylinder below. Components such as cab guides, door frames, and cylinder supports must all be detailed to accommodate lateral deformations. All mechanical and electrical equipment, sensors, piping, tanks, valves, and guides need to be properly anchored or restrained.
- All elevators should be inspected by qualified elevator technicians following an earthquake. Elevators should have a seismic switch or safety features that allow for safe shutdown in an earthquake.
- Elevator safety is governed by the prescriptive requirements in ASME A17.1/CSA B44, *Safety Code for Elevators and Escalators* (ASME, 2007a) a document that is continually evolving to reflect new elevator technologies. In addition, ASME A17.7/B44.7, *Performance Based Code for Elevator Safety* (ASME, 2007b), is the next step in the evolution of elevator safety codes in the United States and Canada. Local or state jurisdictions may have other elevator requirements.
- The internet provides information regarding hydraulic elevators. A few websites are linked below:
    - The website http:science.howstuffworks.com/elevator1.htm describes the workings of hydraulic elevators and provides links to other resources
    - Jobsite safety in the elevator industry is discussed on http://safety.elevator-world.com/disaster.htm
    - The websites of the Elevator and Escalator Safety Foundation, http://eesf.org/, and major elevator suppliers such as The Otis Elevator Company and Schindler Elevators provide additional resources.
    - The National Elevator Industry, Inc. has other resources including a discussion of the performance based code for elevator safety (http://www.pbc-elevators.com/).

MITIGATION DETAILS



Notes: Provide lateral restraints for guiderails to resist design forces and accommodate anticipated interstory drift.

Elevators should be installed, maintained, inspected and repaired by qualified elevator technicians.

Inappropriate seismic restraints may compromise the safe operation of these systems.

Figure 6.4.10.1-1 Schematic view of hydraulic elevator (ER).

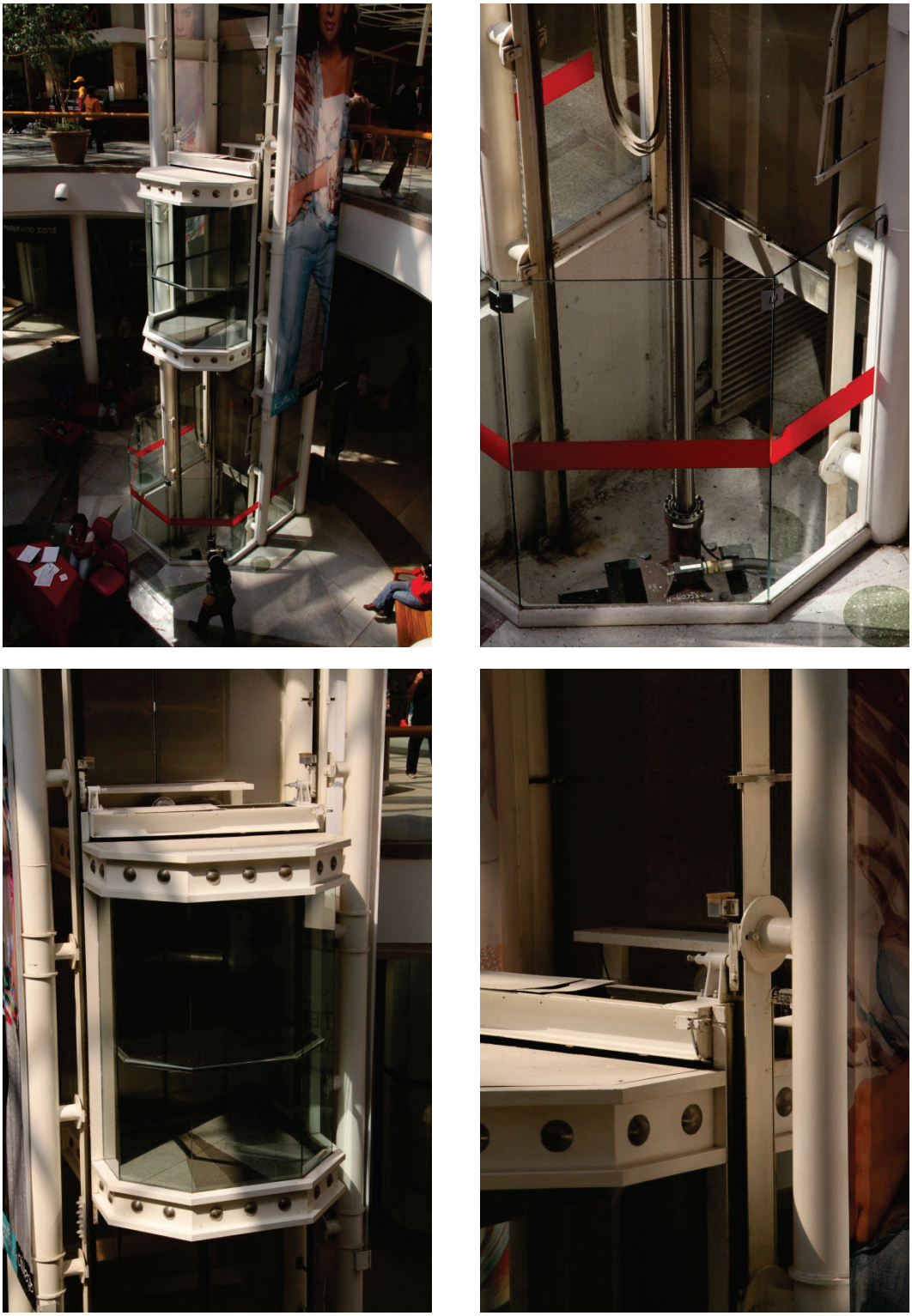


Figure 6.4.10.1-2 Hydraulic elevator that performed well during the 2010 magnitude-8.8 Chile Earthquake (Photo courtesy of Eduardo Miranda, Stanford University).