6.4 MECHANICAL, ELECTRICAL, AND PLUMBING COMPONENTS

6.4.10 ELEVATORS AND ESCALATORS

6.4.10.2 TRACTION ELEVATORS

Traction elevators have made high rise construction possible. These systems are continually evolving to achieve faster speeds, smoother and quieter operations. Currently there are geared traction elevators, gearless traction elevators, and "machine-roomless" elevators that use flat belts instead of steel cable. Traction elevators are complex mechanical systems that have many moving parts and electronic components and failure of any of the components could disable the functionality of the entire system. Maintaining limited functionality of some elevators following an earthquake is critical for continued operations of essential facilities or the evacuation of hospital patients.

TYPICAL CAUSES OF DAMAGE

- The primary components of the traction elevator system are the elevator cab, counterweight, cab guide rails, counterweight guide rails, guide rail support brackets, electric motor, electrical control panel, ropes, sheaves, safety braking mechanisms, door mechanisms, and a shock absorber at the bottom of the shaft. 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. Any of these components could be damaged if not properly restrained. Other possible failures are: misalignment of cab guides, deformed door frames impeding the operation of the doors, failure of door rails, misalignment of the cab or counterweight, and damage to the mechanical or electrical equipment. Failures of counterweights can result in falling hazards if the subweights can come loose of the counterweight assembly.
- According to survey responses collected by the Division of Occupational Safety and Health Elevator, Tramway, and Ride unit, following the 1994 Northridge earthquake, the following issues were observed:
    - Water damage-sprinkler pipes pulled apart flooding machine rooms and pits causing water on top of cars, damage to door operators and door detectors, and soaking car processors and car station. Several oil buffers had to be rebuilt.

  - Falling debris in hoistways, falling plaster, loose concrete blocks, broken glass resulted in damaged door interlocks and misalignment of hatch switches and bent fascias.
  - Building settlements bent elevator guide rails; structural damage, loose and bent divider beams shifted guide rails and bending support brackets.
  - 3,528 cabled elevators were removed from service by a seismic protective device. 710 devices did not operate as intended. Some devices were located in the elevator pits which were flooded.
  - 968 electric cabled elevators sustained earthquake damage.
  - 2 minor injuries were reported, one of which was sustained by a fireman trying to open hoistway doors.
  - 39 elevators required rescue.
  - 57 instances were reported where "unauthorized persons" reset earthquake devices. Fortunately, only 5 elevators sustained additional damages.
  - 688 counterweights came out of guide rails. 8-1b rails were inadequate even with additional intermediate guide rail bracket retrofit. Several counterweight frames were twisted and bent with a few dislodged subweights. Some counterweight roller guide shoe mountings disintegrated.
- Following the 2010 Chile Earthquake, it was reported that 50%-80% of hospital elevators were damaged. In a number of locations, patients had to be carried down many flights of stairs, often cluttered with fallen debris, in order to evacuate them to safety. The most common damage was due to unrestrained movement of the counterweights, resulting in damage to the guide rails. Movement of unrestrained mechanical equipment was another problem. One security camera at a military hospital in Santiago, Chile captured a sequence through the open door of an empty elevator cab where the counterweights derailed and then the subweights came crashing down on top of the cab. (Source: Bill Holmes, March 2010).
- 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.

Damage Examples

Figure 6.4.10.2-1 Damage to traction elevator in Chillán in the 2010 magnitude-8.8 Chile Earthquake (Photo courtesy of Gilberto Mosqueda, SUNY Buffalo). The unanchored sheaves and motor above the 6th floor slid nearly off the housekeeping pad. The counterweight guide rails are bent due to impact with the counterweights. The guide rail support brackets have horizontal slots, but the bolt went through a welded tab (photo at lower right) and pulled out of the wall.

Figure 6.4.10.2-2 Derailed car roller assembly of the guide rail at the Santiago airport in the 2010 Chile Earthquake (Photo courtesy of Gilberto Mosqueda, SUNY Buffalo). The three rollers are supposed to travel along three sides of the stem of the T-shaped steel guide rail.

Figure 6.4.10.2-3 Glazing failures caused additional hazards at Santiago airport elevator in the 2010 Chile Earthquake (Photo courtesy of Antonio Iruretagoyena, Rubén Borsochek & Associates).

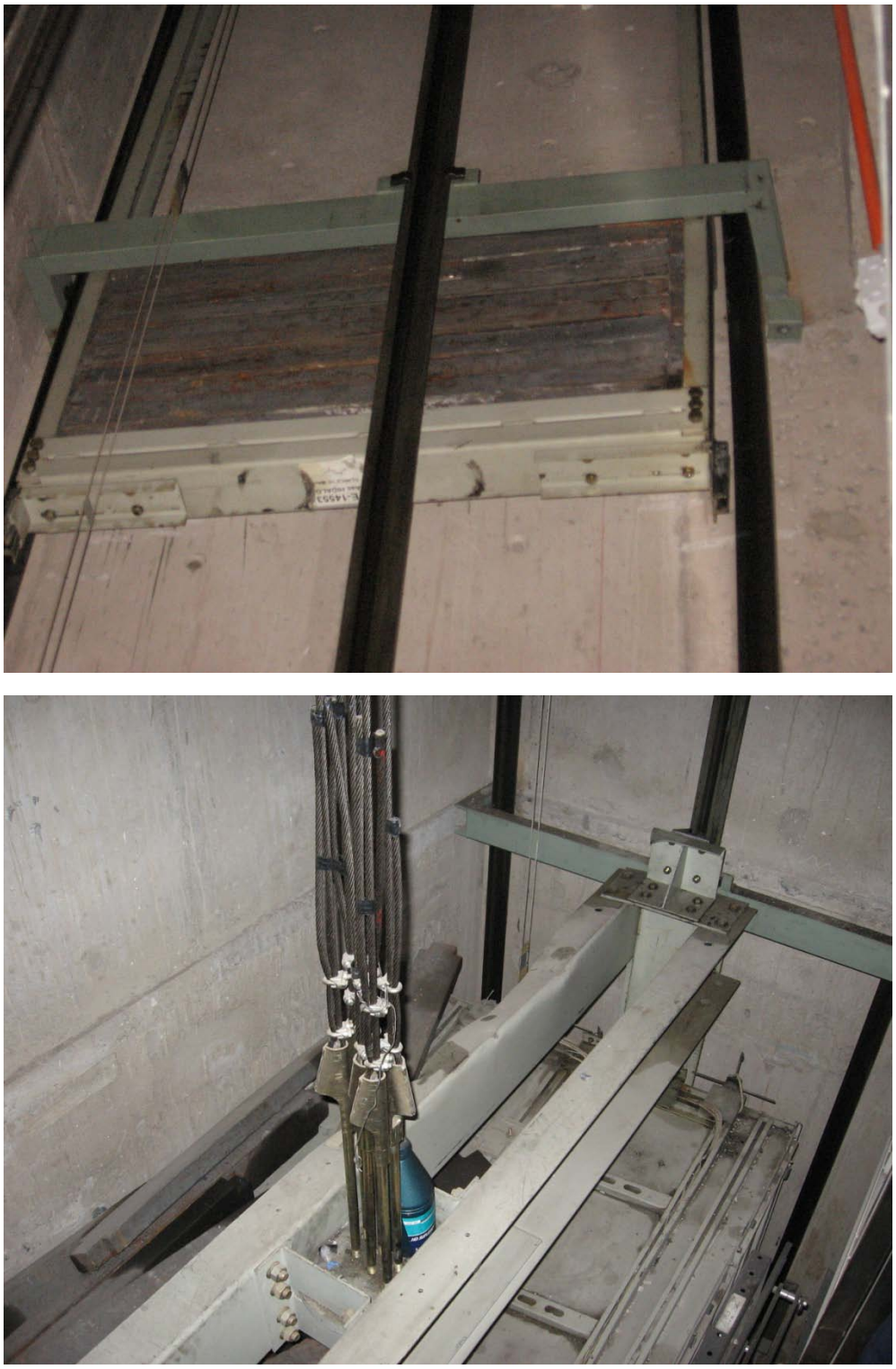


Figure 6.4.10.2-4 Unrestrained movement of the counterweights damaged the counterweight assembly and bent the counterweight guide rails; over half the subweights dropped onto the top of the cab and damaged the cab framing in the 2010 Chile Earthquake (Photo courtesy of Rodrigo Retamales, Rubén Borsochek & Associates).

Figure 6.4.10.2-5 Anchor bolt failure of the elevator generator set due to inadequate edge distance for the bolts at the Los Angeles Regional Public Hospital in the 2010 Chile Earthquake (Photo courtesy of Bill Holmes, Rutherford & Chekene).

SEISMIC MITIGATION CONSIDERATIONS

- All of the components of the traction system need to be restrained, anchored, or detailed to resist lateral forces in all directions and accommodate seismic movement. The system must be designed to accommodate the anticipated inter-story drift over the height of the elevator travel. Guide rails and door frames must all be detailed to accommodate lateral deformations. All of the mechanical and electrical equipment, sensors, 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* (2007a), a document that is continually evolving

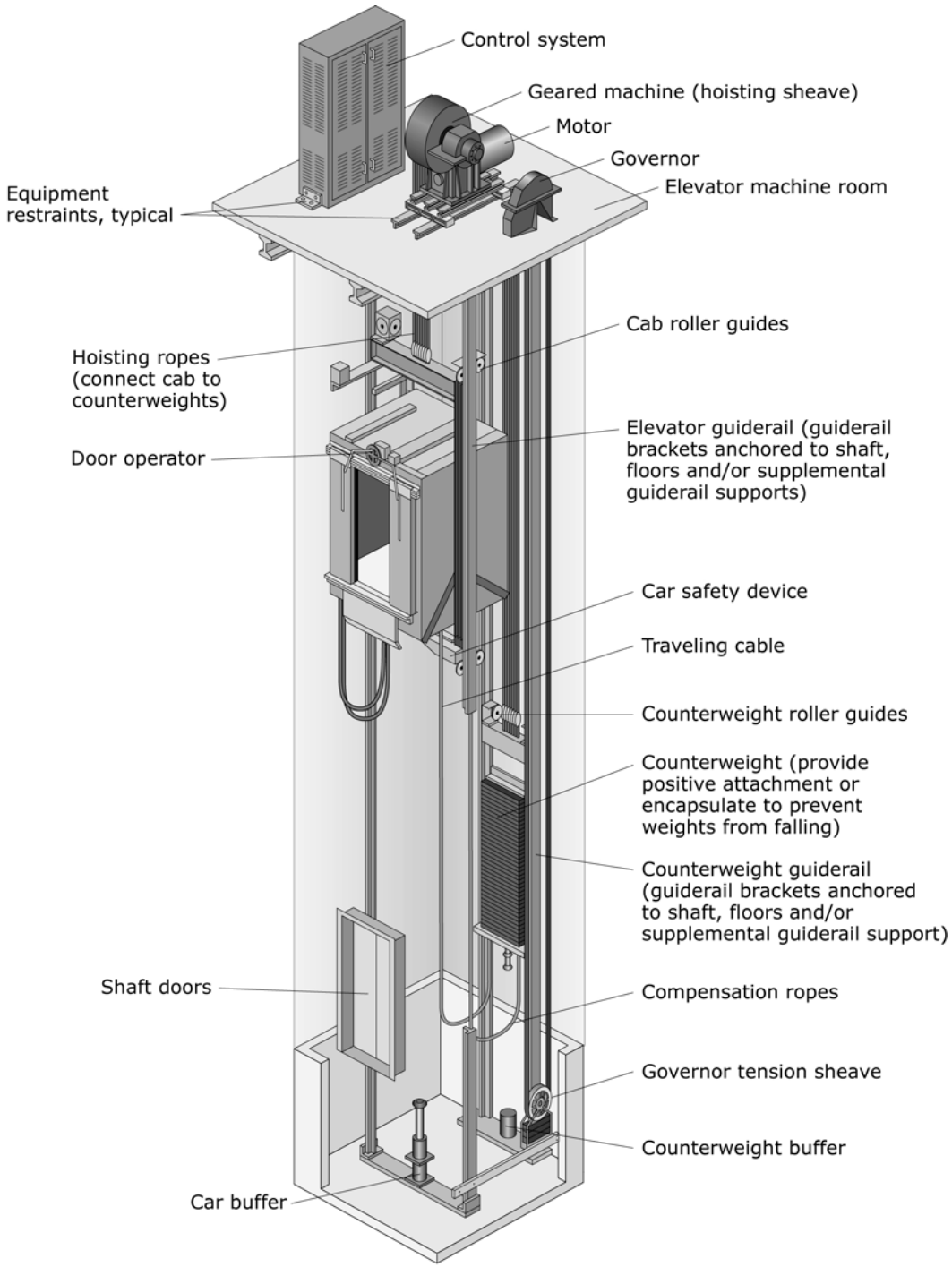
reflect new elevator technologies. In addition, ASME A17.7/CSA B44.7, *Performance Based Code for Elevator Safety* (ASME, 2007b), is the next step in the evolution of elevator safety codes in the United States and Canada. Local or state jurisdictions may have other elevator requirements.

- As an example of state jurisdictions, the California Office of Statewide Health Planning and Development (OSHPD) provides special requirements for elevators in California hospitals, such as Title 24, Section 3007. These include requirements for a seismic switch connected to the essential electrical system, a visible or audible alarm, the ability to function at a "go slow" speed of not more than 150 feet per minute until the elevator can be inspected, and an additional sensor that will disable the elevator if the governor tail sheave is dislodged. For these systems, the seismic anchorage, guards and switches all need to be inspected annually.
- The internet provides a resource of information regarding elevators. A few websites are linked below:
    - The website http:science.howstuffworks.com/elevator1.htm describes the workings of a traction elevator 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 Examples

Figure 6.4.10.2-6 Small "machine-roomless" traction elevator with flat belts at the Academy of Sciences, San Francisco, California (Photos courtesy of Eduardo Fierro, BFP Engineers). Clockwise: Overview of elevator at roof; view of guide rails and sheaves; top of cab showing belts; view down shaft at belts, counterweight, guide rails and guide rail brackets.

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 6.4.10.2-7 Schematic view of geared traction elevator system (ER).