

## 6.4 Mechanical, Electrical, and Plumbing Components

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### 6.4.3 Pressure Piping

#### 6.4.3.8 Penetrations

This section addresses locations where pressure piping passes through floor, roof, or wall penetrations in either architectural or structural components. Penetrations usually fall into one of three categories: 1) the penetration is sufficiently oversized to prevent impact between the pipe and surrounding wall or slab; 2) a seismic restraint is located at or near the penetration so the pipe and surrounding wall or slab are constrained to move together; or 3) the penetration is not properly detailed and becomes an unintended restraint in the piping run which may result in damage to the piping, wall, slab, or finishes. Structural and nonstructural elements may require strengthening around penetrations or may need special detailing to provide fire-proofing, sound-proofing, and weather-proofing or improve the appearance of architectural finishes.

### Provisions

#### BUILDING CODE PROVISIONS

ASCE/SEI 7-10, *Minimum Design Loads for Buildings and Other Structures*, (ASCE, 2010), Chapter 13, Nonstructural Components states that when seismic design is required, interaction between the components and the supporting structures, including other mechanical and electrical components, shall also be considered. Pressure piping with an Importance Factor  $I_p$  greater than 1.0 must be designed to eliminate seismic impact for:

- Components vulnerable to impact,
- Components constructed of nonductile materials, and
- Cases where material ductility will be reduced due to service conditions (e.g., low temperature applications).

#### RETROFIT STANDARD PROVISIONS

ASCE/SEI 41-06, *Seismic Rehabilitation of Existing Buildings*, (ASCE, 2007) classifies pressure piping systems as force and deformation sensitive. Compliance with the requirements of the standard is necessary when the performance level is Immediate Occupancy or Life Safety in areas of High and Moderate seismicity. There are no specific requirements for pipe

penetrations in ASCE/SEI 41–06. Retrofit in accordance with prescriptive standards is permitted.

### **Typical Causes of Damage**

- Pipe movement at penetrations often results in damage to architectural finishes, fire-proofing, and insulation. Failure of joints at or near penetrations may result in leakage causing further damage to these components.
- Where pipes pass through unreinforced masonry walls, the opening may create a point of weakness resulting in crack propagation from the opening. Lightweight partitions or ceilings are also frequently damaged by movement of unrestrained piping. Pipe movement at penetrations may also result in damage to electrical lines in the wall or ceiling space.

## DAMAGE EXAMPLES

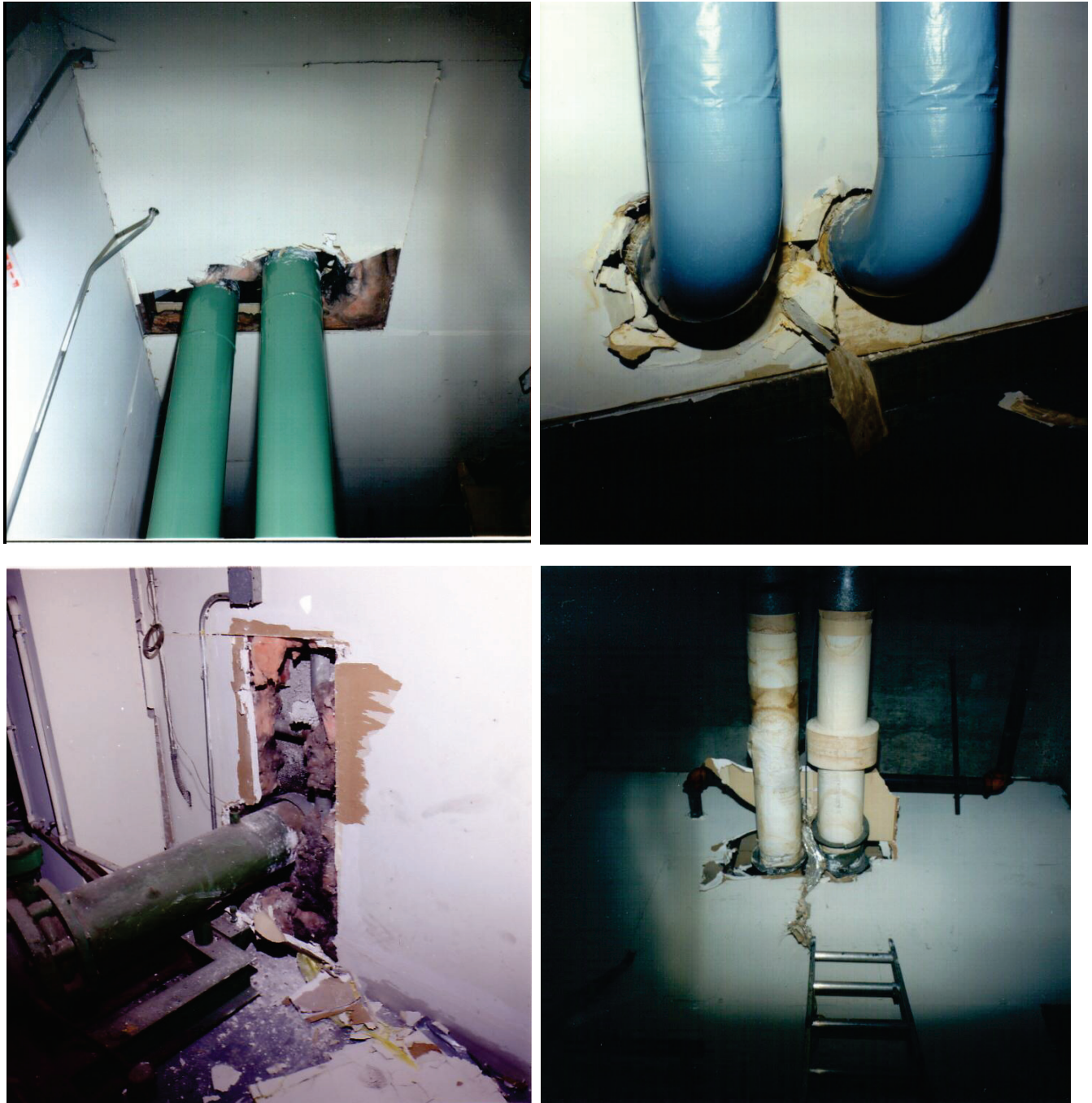


Figure 6.4.3.8-1 Damage to ceilings, gypsum board partitions, fire-proofing, and insulation in the 1994 magnitude-6.7 Northridge Earthquake (Photo courtesy of Mason Industries). Note that the blue piping has joints located in the wall space which leaked, resulting in additional damage.



Figure 6.4.3.8-2 Exterior stucco damage at wall penetration for fire protection piping in the 2001 magnitude-8.4 Peru Earthquake (Photos courtesy of Eduardo Fierro, : BFP Engineers).



Figure 6.4.3.8-3 Wall penetrations for piping and ducts contributed to damage to unreinforced masonry walls at an industrial facility in the 2010 magnitude-7 Haiti Earthquake (Photos courtesy of Eduardo Fierro, BFP Engineers). The piping and ducts were not damaged but the walls cracked and will need to be repaired.

## Seismic Mitigation Considerations

- As described above, there are two different approaches for avoiding damage at pipe penetrations. Either the penetration should be designed to be oversized to avoid contact between the pipe and the wall or slab, or the pipe should be restrained at or near the penetration so the pipe and wall or slab are constrained to move together.
- Penetrations should be oversized wherever possible to allow for differential movement of pipe supports and the structural elements they are attached to on either side of the wall, floor, or roof slab. Alternatively, lateral restraints for the piping should be provided close to the penetration to prevent impact between the pipe and the opening. Where piping crosses from one building to another, flexible connections may also be required near the penetration.
- Pipes often fail or leak at joints; pipe joints should not be located within penetrations where they will leak into a wall cavity or are inaccessible for inspection and repair.
- Penetrations through structural walls, slabs, or framing must be coordinated with a structural engineer; structural walls, slabs, or framing elements may require strengthening around penetrations. For large openings such as a pipe chase, this may involve extra trim steel around the opening or additional framing members beneath a slab. Penetrations in a structural steel girder may require welded reinforcement plates around the opening. For locating penetrations in existing concrete or masonry walls or concrete slabs, care must be taken to locate rebar or post-tensioned tendons prior to drilling holes for pipe penetrations so these elements are not cut.
- Penetrations through nonstructural walls should be coordinated with an architect to ensure that fire-proofing, sound-proofing, weather-proofing, insulation requirements and finishes on either side of the opening are not compromised. Roof penetrations have particular issues related to weather-proofing and corrosion protection; care must be taken to avoid leakage at roof penetrations. Where penetrations pass through weak materials such as unreinforced masonry or lightweight partitions, these elements may require strengthening.
- Detailing at penetrations often involves several layers of material and finishes each of which require attention; penetrations through structural elements may involve both the engineer and the architect. For instance, a penetration through a masonry wall with interior plaster and exterior stucco will require detailing for all three of these materials. The damage shown in Figure 6.4.3.8-2 occurred because although the masonry penetration was oversized and filled with packing, the exterior stucco was placed flush with the pipe resulting in stucco damage during the earthquake.

- Pipe risers that pass through floor and roof penetrations must be detailed so the seismic restraints can also accommodate longitudinal thermal movement of the pipe. If allowance for thermal movement is not included in the design, the seismic restraints may be damaged under operating conditions and fail to perform properly in an earthquake.
- Penetrations in exit corridors needed for emergency egress may warrant special care; similarly, penetrations in boiler rooms or locations with fuel lines or hazardous materials may also warrant special detailing to maintain the fire-proofing of the space in the event of a post-earthquake fire.
- FEMA 414, *Installing Seismic Restraints for Duct and Pipe* (2004), provides additional precautions regarding the installation of anchor bolts and general guidance on pipe restraints.

#### MITIGATION EXAMPLES

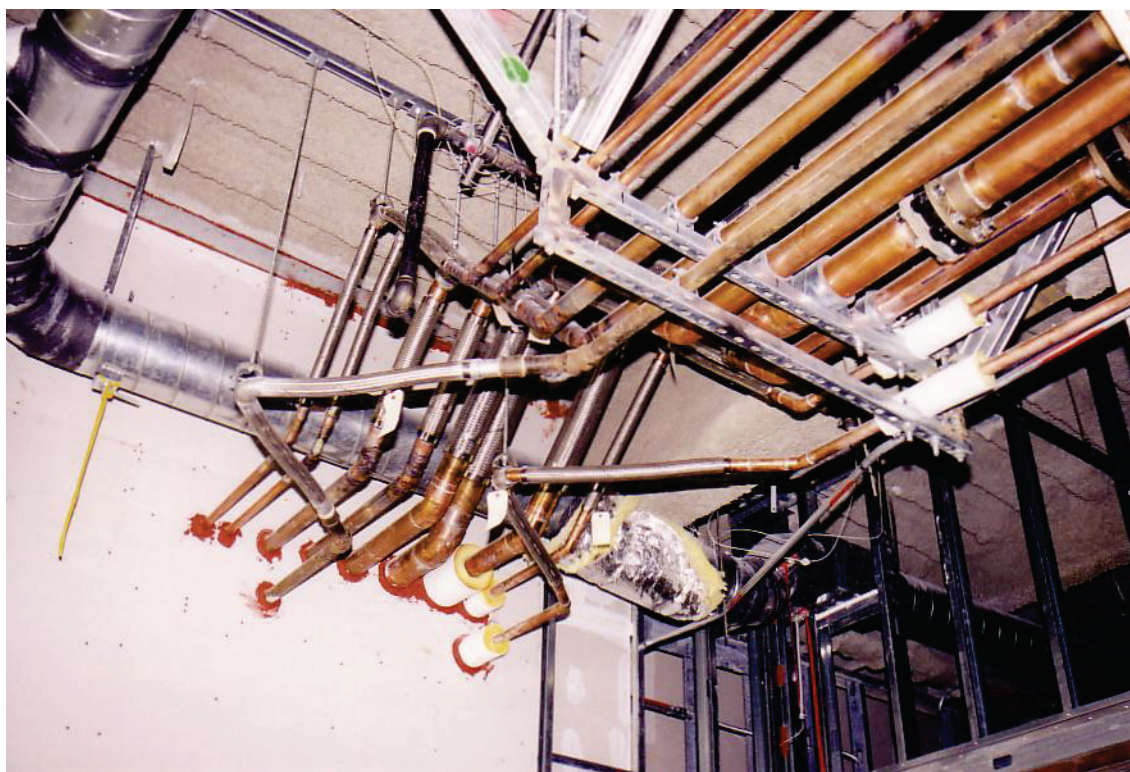


Figure 6.4.3.8-4 Wall penetrations with lateral restraints at trapeze in foreground, flexible couplings with independent vertical supports, and sealant at each wall penetration (Photo courtesy of Mason Industries).

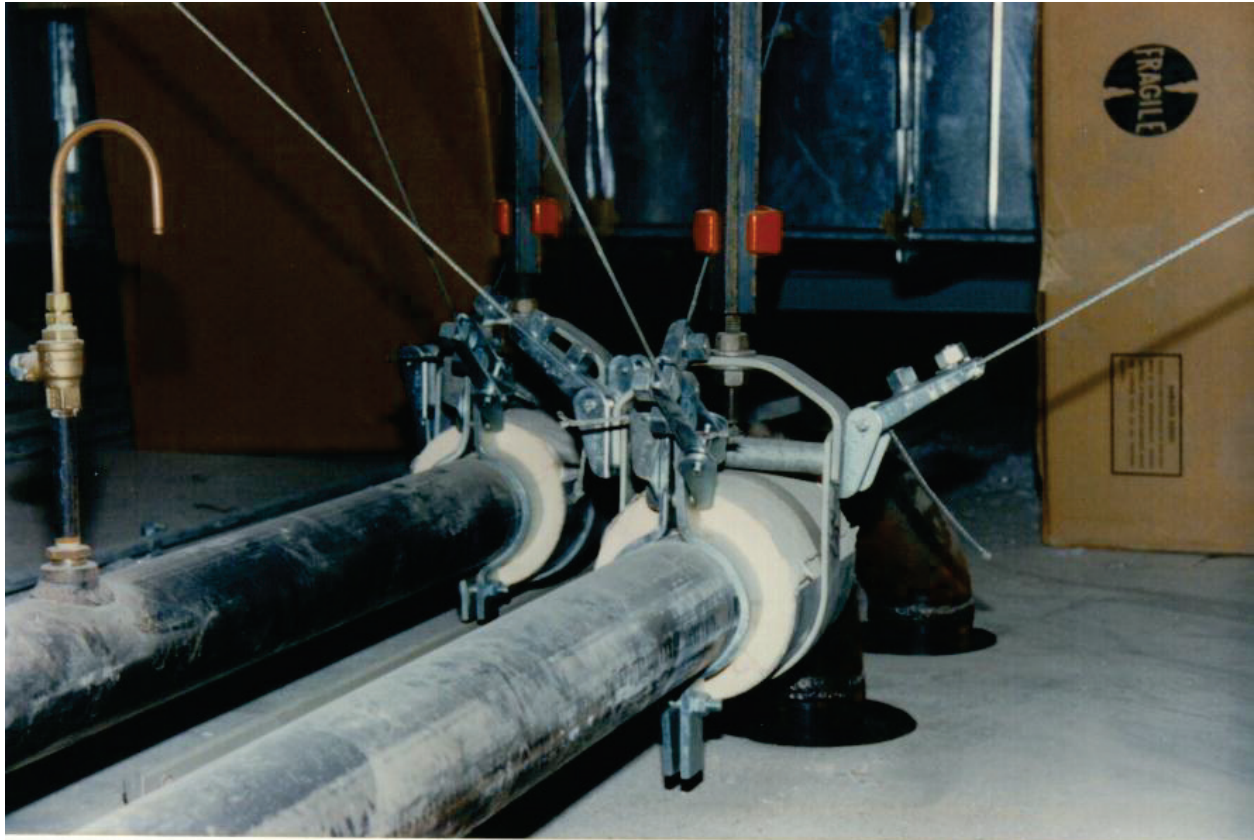


Figure 6.4.3.8-5 Floor penetration with oversized opening and vertical and lateral restraints immediately above floor (Photo courtesy of Mason Industries).



Figure 6.4.3.8-6 Series of pipe penetrations through a full-height CMU partition wall. Note pipe suspended from floor above; partition anchored to floor below and detailed with steel clip angles intended to provide lateral restraint for the wall but allow relative slip between the wall and slab above. The hangers will move with the floor above and the pipe at penetration will move with the wall. Lateral restraints are located immediately above floor (Photo courtesy Cynthia Perry, BFP Engineers).

## MITIGATION DETAILS

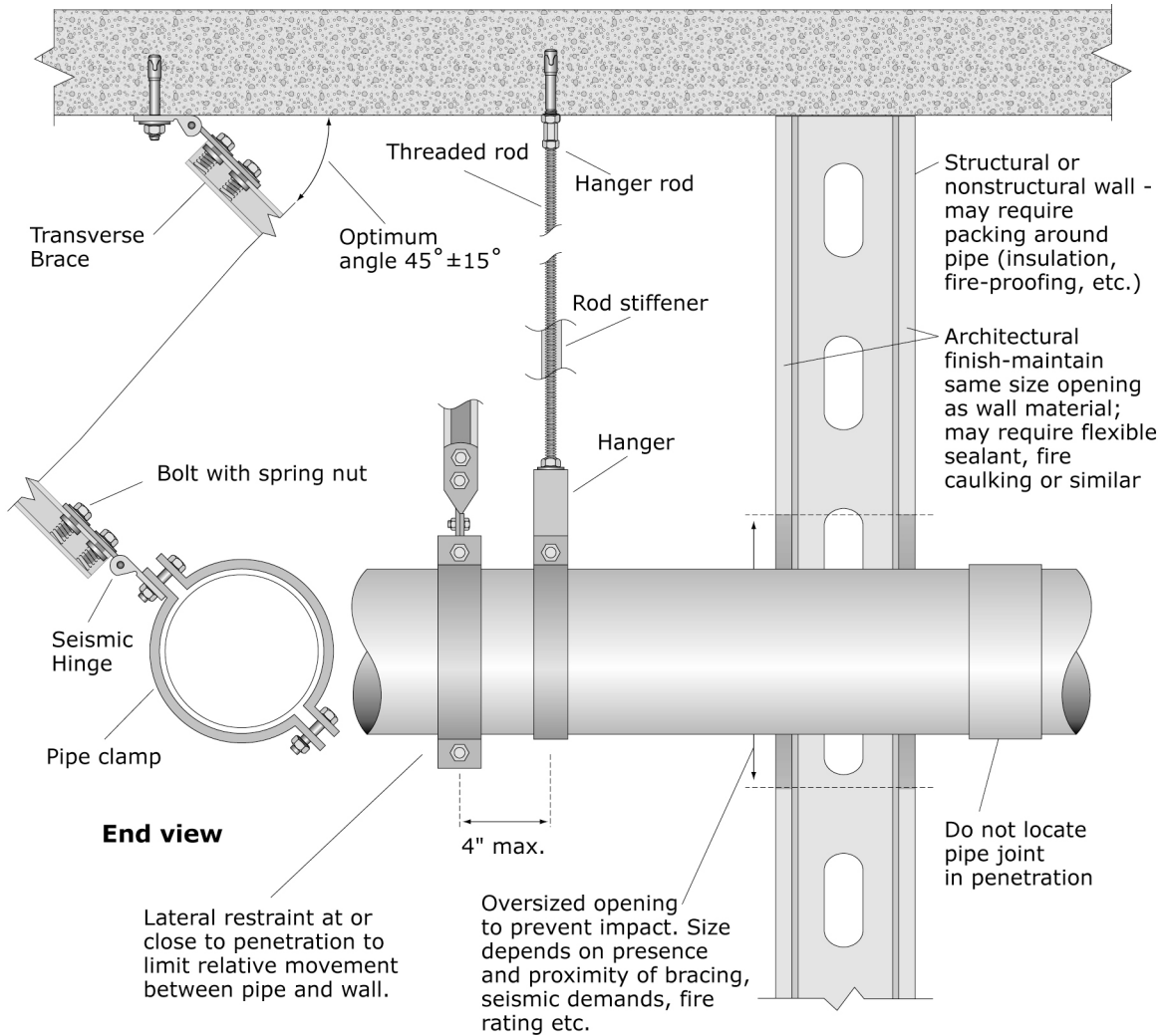


Figure 6.4.3.8-7 Wall penetration (ER).

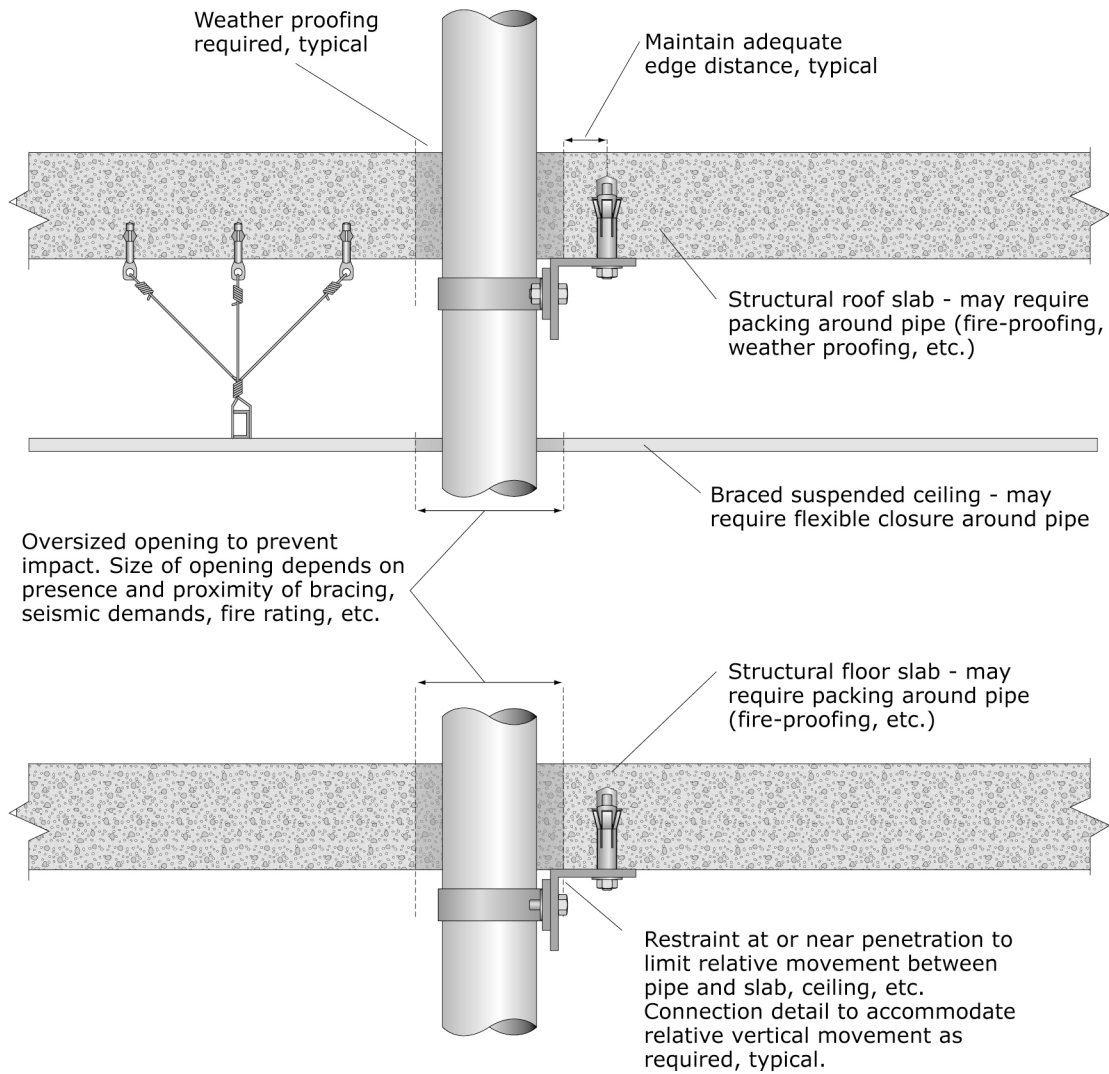


Figure 6.4.3.8-8 Floor or roof penetration (ER).