6.3 Architectural Components

6.3.8 Stairways

6.3.8.1 Stairways

This includes stairs between floors, which may be independent of the structure, or integral with it. Stairs are needed for exiting following an earthquake and hence protecting them from damage and keeping them clear should be a high priority. Protecting a stair from damage is a structural concern that requires engineering expertise to address.

Provisions

BUILDING CODE PROVISIONS

ASCE/SEI 7-10, *Minimum Design Loads for Buildings* (ASCE, 2010), Section 13.1.3.1 specifies that systems required for life-safety purposes after an earthquake, including exit stairways, be classified as designated seismic systems and designed using a component importance factor, I_p, of 1.5. Designated seismic systems may require engineering calculations, special inspection, etc. Stairways must be designed to accommodate story drift, while having sufficient strength to resist inertial loads.

- The minimum lateral loads and seismic relative displacements on stairways are determined using ASCE/SEI 7-10, Chapter 13.
- Where the actual design drifts of the structure for displacement analysis are not known, the allowable story drifts of ASCE/SEI 7-10, Chapter 12 may be used.

RETROFIT STANDARD PROVISIONS

ASCE/SEI 41-06, *Seismic Rehabilitation of Existing Buildings* (ASCE, 2007) classifies stairs and stair enclosures as either acceleration or deformation sensitive, depending on the predominant behavior. Components of stairs that are attached to adjacent floors or the floor framing are considered deformation sensitive. All other stair components are considered acceleration sensitive.

- Stairs 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 stairs and their connection to the supports, supporting and adjacent walls, windows, and other elements of the stair shaft system.

- Acceptance criteria focus on verifying that the stairs have sufficient strength to resist out-of-plane forces, and the ability to accommodate the expected relative displacements.

Typical Causes of Damage

- Stairs are primarily damaged by interstory drift, i.e., differential movement of the adjacent floors, because the stairs must accommodate the differential movement. Stair damage is more likely to occur in flexible buildings with larger interstory drift and less likely to occur in stiffer buildings.
  - When stairs are rigidly attached to both floor levels, the stair structure will try to act like a diagonal brace and could be damaged as shown in Figure 6.3.8.1-3.
  - When one end or both ends of the stair have slip or sliding connections, the design differential movement could be exceeded causing failure of the connection and perhaps collapse of the stair as shown in Figures 6.3.8.1-4 and 6.3.8.1-5.
  - Steel and concrete stairs are vulnerable to inter-story drifts if not specially detailed for seismic resistance. Recent shake table testing of a full scale 5-story building at University of California, San Diego (project website is located at http://bncs.ucsd.edu/) revealed that standard prefabricated steel stairs can be badly damaged or even collapse at inter-drift levels less than expected in a Design Earthquake in flexible buildings.
- Damage to stairs will also vary depending on the material of construction, as follows:
  - Damage has been observed most often in stairs with concrete stringer assemblies, which, if not specifically detailed for movement, will naturally have very rigid connections. Concrete stairs are typically not detailed for ductility, so large tension or compression demands can lead to severe damage.
  - Single run stairs with steel stringers as shown in Figure 6.3.8.1-1, not detailed with slip connections, will provide stiff resistance to drift which could cause buckling of the stringers or failure of the connections.
  - Typical commercial steel exit stairways, often purchased on a “design-build” basis, are generally not provided with drift allowance on the basis that, with normal landing configurations, sufficient flexibility is provided. However, recent testing at the University of California, San Diego), has shown that these stairs can suffer dangerous damage if not specifically detailed for slip, or provided with ductile connection details.

  - Wooden stairs are generally in smaller, stiff buildings and have inherent flexibility in connections. Damage to wooden stairs has not been common, although configurations which provide direct bracing between floors (e.g., a straight run from ground to first floor)should be provided with a slip connection.
- The walls surrounding a stairway may be damaged during an earthquake causing debris to fall into the stairwell and rendering the stairs unusable. Brittle materials such as brick, hollow clay tile, or glass are particularly vulnerable and may create falling and debris hazards in stair enclosures as shown in Figure 6.3.8.1-2.

DAMAGE EXAMPLES

Figure 6.3.8.1-1 Stairway damaged by drift in the 1994 magnitude-6.7 Northridge, California earthquake (Photo courtesy of Wiss, Jenney, Elstner Associates).

Figure 6.3.8.1-2 View of stairway in the Banco Central Building, Managua, Nicaragua after the 1972 magnitude-6.2 Managua Earthquake. Most of the stairs were covered with debris that resulted from the failure of the hollow tile partitions surrounding the stairs. This photograph highlights the need to not only prevent direct damage to stairway framing and connections, but also to protect against damage to surrounding walls (Photo courtesy of PEER Godden Collection, No. J94).

Figure 6.3.8.1-3 Stairs damaged up the full height of this apartment building in Viña del Mar in the 2010 magnitude-8.8 Chile Earthquake (Photo courtesy of Santiago Pujol, Purdue University). The stairs were rigidly attached at adjacent floors and behaved like diagonal braces although they were neither designed nor detailed to function as structural braces.

Figure 6.3.8.1-4 Stair support condition at Forsyth-Barr Building in Christchurch, New Zealand. Precast stair runs have completely pulled off supports and collapsed into stairwell (Photo courtesy of Des Bull, Holmes Consulting Group).

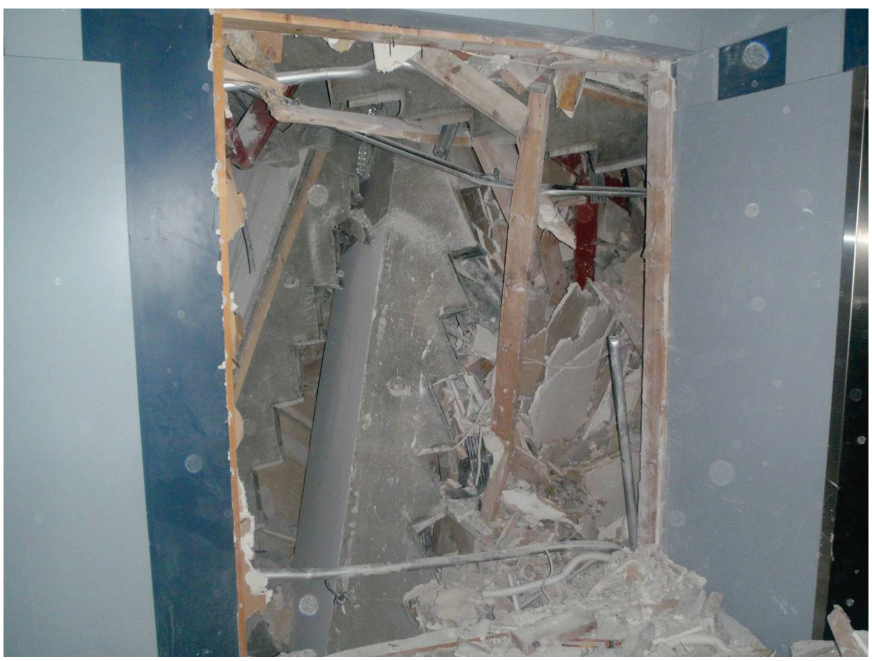

Figure 6.3.8.1-5 One story precast stair units stacked up at base of stairwell after falling off the sliding end supports and collapsing into stairwell (Photo courtesy of Des Bull, Holmes Consulting Group).

Seismic Mitigation Considerations

- Precast connection details in Christchurch, New Zealand often featured sliding joints in "pockets" that allowed only limited movement that tended to put the stair in compression. After stairs were compressed and shortened in one direction, the bearing length was reduced for sliding in the other direction. See Figure 6.3.8.1-6. Sliding joints on stairs can also cause collapse if the bearing length is simply too small. Guidelines in New Zealand recommend providing safe movement for 1.5 x the maximum expected drift.
- In order to prevent stairs from behaving like diagonal struts between adjacent floors, the stairs should be detailed with a fixed connection at one floor and a sliding connection at the other that allows movement parallel to the direction of the stair. Movement allowance must be adequate for the maximum possible drift, or connections provided with a fail-safe mechanism to prevent gravity failure. See Figures 6.3.8.1-7 (steel) and 6.3.8.1-8 (wood).
- Sliding "gang plank" connections or connections with slotted holes can also be used to isolate the stair from one of the attached floors and prevent damage due to interstory drift. The connection must be designed to accommodate the anticipated drift.
- If stair enclosures are built using brittle materials such as unreinforced masonry, hollow clay tile, glass block, or skylights, it is recommended that they be encapsulated or replaced to prevent falling hazards and debris in the stairwell. Provide bracing and anchorage for pipes, lighting, emergency lighting or ducts to prevent falling hazards and debris in the stairwell. Maintaining safe exits is a critical element of earthquake safety.

MITIGATION DETAILS

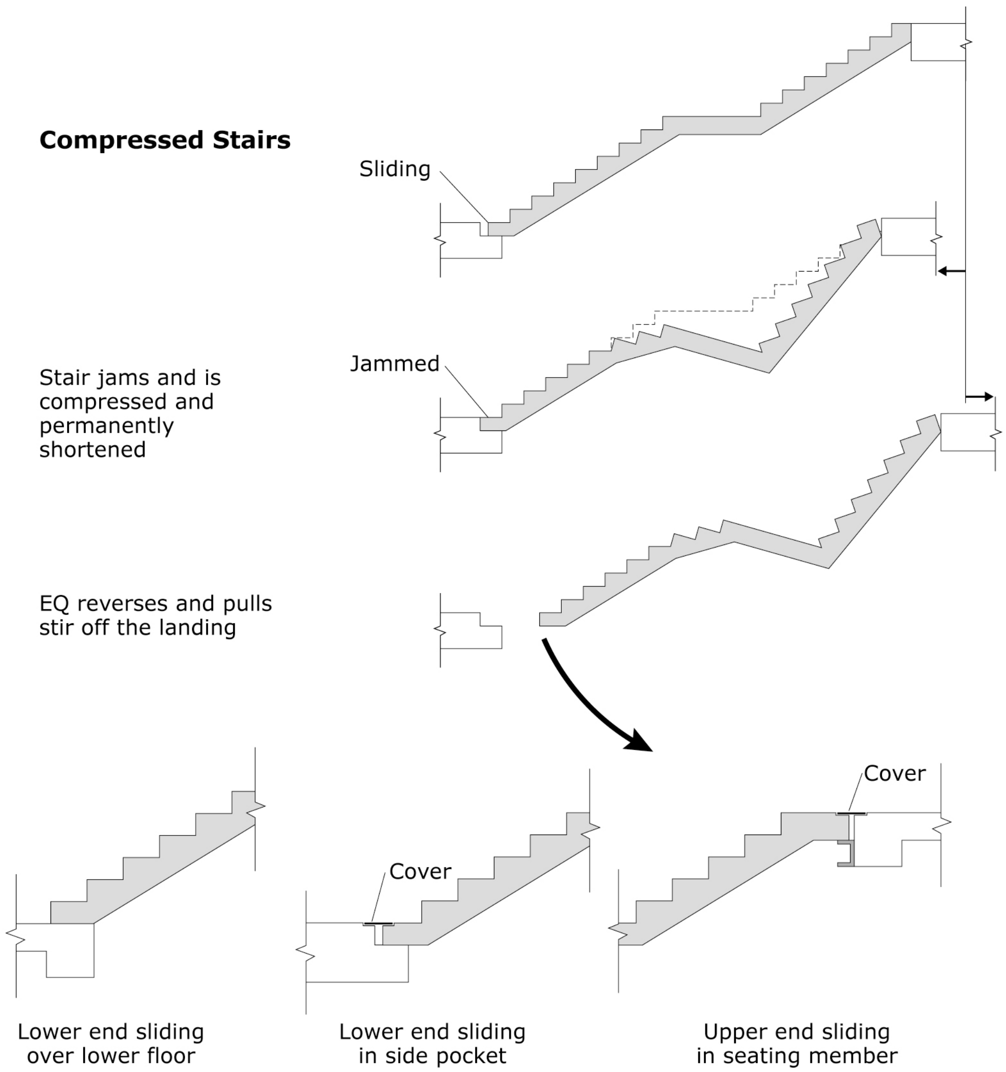

Figure 6.3.8.1-6 Figure showing how inadequate sliding surface can compress and then drop precast stair sections.

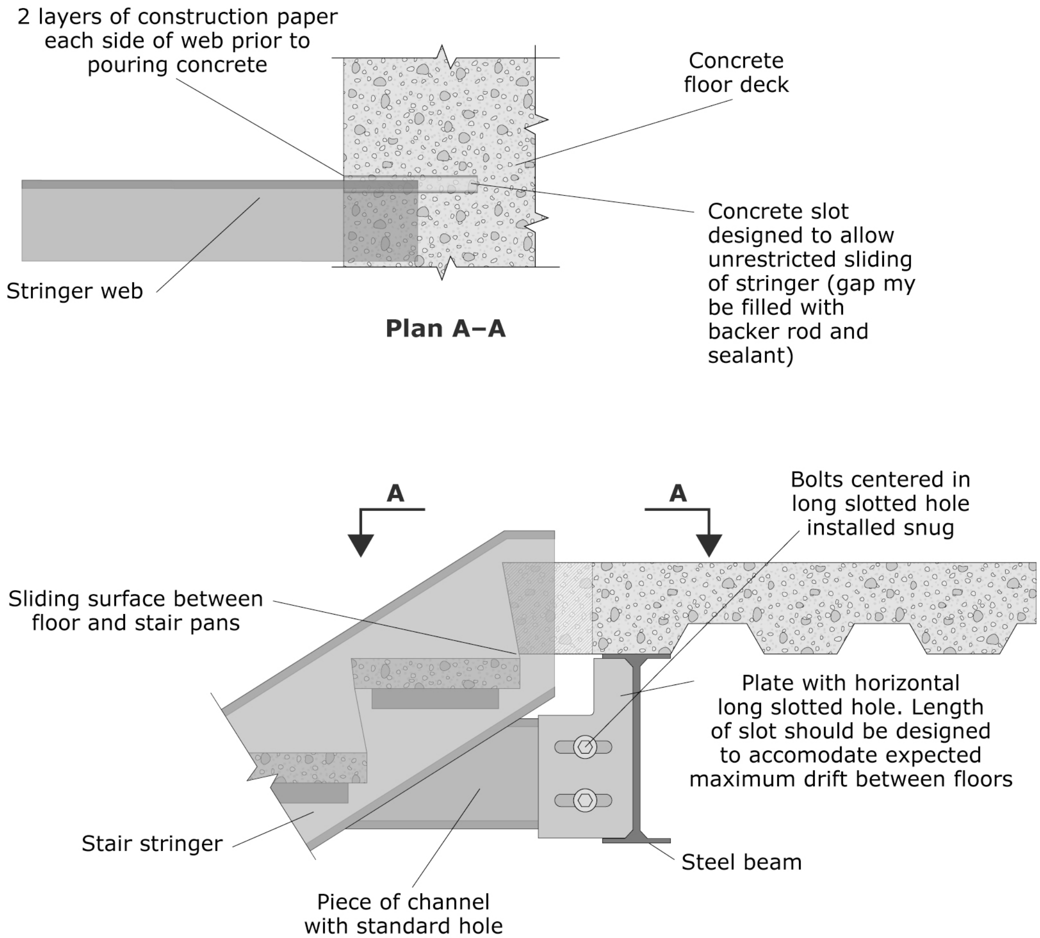

Figure 6.3.8.1-7 Example slip connection for steel stair stringer (ER).

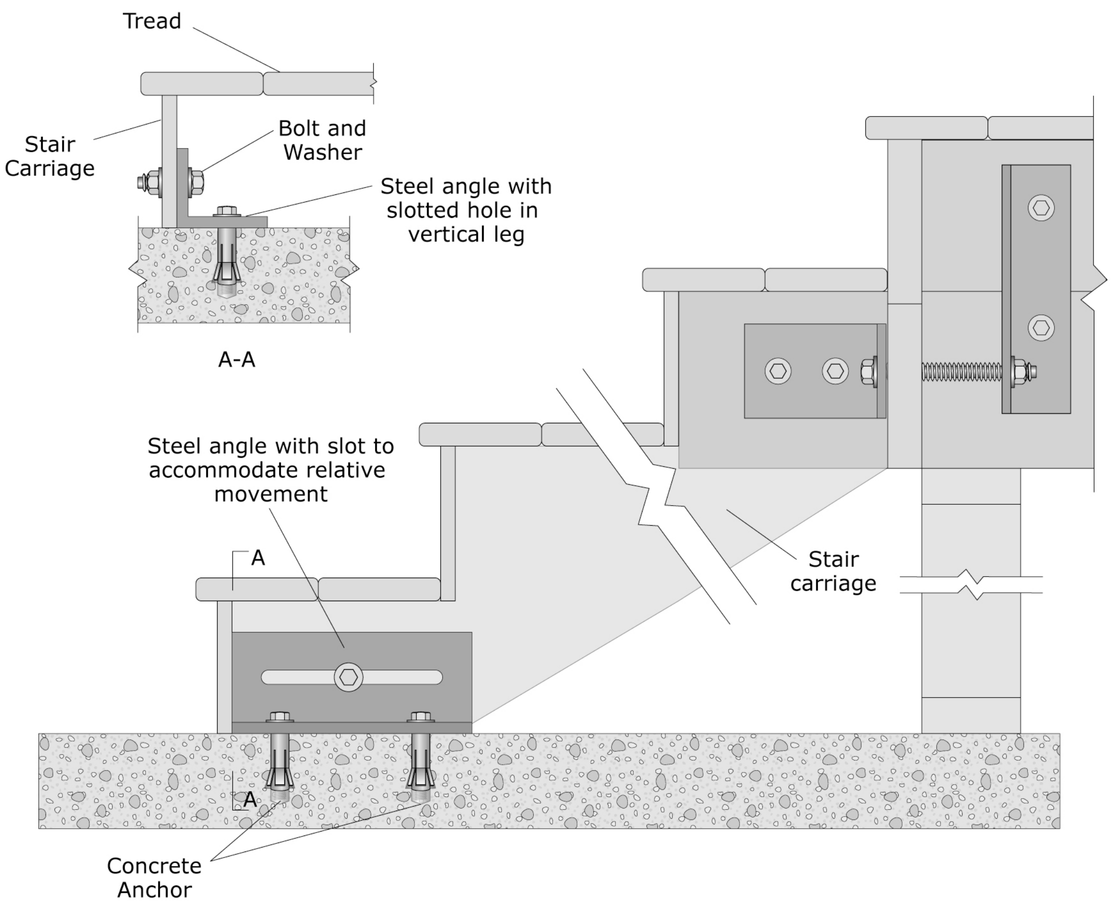

Figure 6.3.8.1-8 Example slip connection for wood stair with single run between floors (ER).