6.5 Furniture, Fixtures, Equipment and Contents

6.5.2 Bookcases, shelving

6.5.2.2 Library and Other Shelving

Library shelving typically consists of many rows of tall back-to-back shelving units that are heavily loaded. There have been many costly failures of library shelving in earthquakes; this includes failures of both unrestrained and poorly restrained shelving units.

Provisions

BUILDING CODE PROVISIONS

Bookshelves are considered force controlled, and the principal objective of the code provisions is to prevent them from sliding or overturning.

- The seismic design requirements of ASCE/SEI 7-10, *Minimum Design Loads for Buildings and Other Structures*, (ASCE, 2010), Chapter 13 apply to permanent floor-supported library shelving, book stacks, and bookshelves over 6 feet tall in Seismic Design Categories C, D, E, and F. The weight of the contents must be included.

RETROFIT STANDARD PROVISIONS

- ASCE/SEI 41-06, *Seismic Rehabilitation of Existing Buildings*, (ASCE, 2007) requires bookshelves 4 feet in height comply with the anchorage provisions of the standard when the performance level is Life Safety or higher.

Typical Causes of Damage

- Unrestrained or poorly restrained library shelving can slide or overturn resulting in damage to the contents, damage to the shelving units, and damage to partition walls or other contents. Shelving failures may result in personal injuries. It may be costly and time consuming to repair the shelving units and reshelf all of the books.
- Unrestrained or poorly restrained library shelving has failed in a variety of ways. If the base anchorage is inadequate, the bolts can fail and the units may slide or tip. If overhead transverse ties are provided between many shelving units, but no longitudinal bracing or ties are provided, the units may collapse in their longitudinal direction. If undersized transverse ties are provided, or they are attached at the extremes to walls or partitions with insufficient capacity or with inadequate connectors, the units may all

topple in their transverse direction like dominos. If individual or back-to-back shelving units are braced to the structure above, these restraints may fail or buckle if they are undersized.

- Damage to rare books or irreplaceable museum collections can be devastating. These materials may need to be rebound or restored at great expense to the institution. Where water leakage from failed sprinkler piping is also an issue, these items may be beyond restoration.

DAMAGE EXAMPLES

Figure 6.5.2.2-1 Photo showing collapsed library shelving in the 2010 magnitude-7.1 Canterbury New Zealand Earthquake (Photo courtesy of University of Canterbury).

Figure 6.5.2.2-4 Shelving units with longitudinal ties did not fall over but all of the contents spilled to the floor in the 2010 Canterbury Earthquake. The use of lips or wires would have prevented the damage.(Photo courtesy of University of Canterbury).

Figure 6.5.2.2-3 Longitudinal failure of library shelving units (Photo courtesy of NISEE-PEER, U.C. Berkeley). Transverse ties used to tie units together but this was not enough to prevent longitudinal failure.

Figure 6.5.2.2-2 Failure of overhead transverse bracing for bookshelves were anchored to gypsum board partition in the 1984 magnitude-6.2 Morgan Hill Earthquake (Photo courtesy of Santa Clara County Office of Emergency Services). The anchors were not attached to wall studs, only to gypsum board.

Figure 6.5.2.2-5 These shelving units remained in place but all of the contents spilled in the 2010 magnitude-6.5 Eureka, California Earthquake (Photo courtesy of Steve Mahin, PEER).

Seismic Mitigation Considerations

- Following damage to library collections in the 1994 Loma Prieta Earthquake, the California Library Association developed a library shelving standard, ANSI/NISO Z39.73, *Single-Tier Steel Bracket Library Shelving* (ANSI/NISO, 1994) for single-tier steel bracket library shelving.
- Large library collections may contain rare or valuable items that need to be preserved; such library shelving should be engineered to prevent costly downtime and damage to the collection.
- For new library installations, it is important to procure heavy duty shelving that has cross bracing or solid sides and backing that will prevent longitudinal collapse. In addition, for units that will receive additional overhead bracing, the unit should be strong enough to receive the attached ties and bracing. Light duty steel shelving or weak wood shelving units may require strengthening. Steel shelving may require additional cross bracing. Wood shelving units could be strengthened with the addition of corner brackets or hardware to tie the top, back and sides more securely together.
- Anchor the shelving units to the floor. Where shelving units are located against a structural wall, anchor the top of the units to the structure. Tie freestanding back-to-back units together to create a larger base. A one-way transverse grid or two-way grid may be installed, either at the top of the units or above the ceiling surface, to tie many units together. This grid in turn should be anchored to structural walls at the perimeter of the grid or to the structural slab or framing above. However, if the shelving units are anchored to the floor and braced to the framing above, the shelving and brace assembly must accommodate story drift through distortion of the shelving. While bracing to the structure above will prevent the units from toppling, it may result in damage to the shelving itself, if the story drifts are significant.
- Any connections to stud walls must engage the structural studs. Stud walls and partitions typically do not have adequate lateral capacity to support many shelving units unless they have been engineered with heavy gauge studs and braced to resist the imposed lateral loading from the shelving. Anchorage to structural concrete or masonry walls is preferred.
- The location of the library shelving will influence the design loading. Floor accelerations typically increase as you go higher in a building and may also be higher at locations such as poorly braced mezzanine floors.
- See Section 6.5.6.1 for recommendations regarding edge restraints and the arrangement of shelf-mounted items. Especially rare or valuable items may need to be stored in

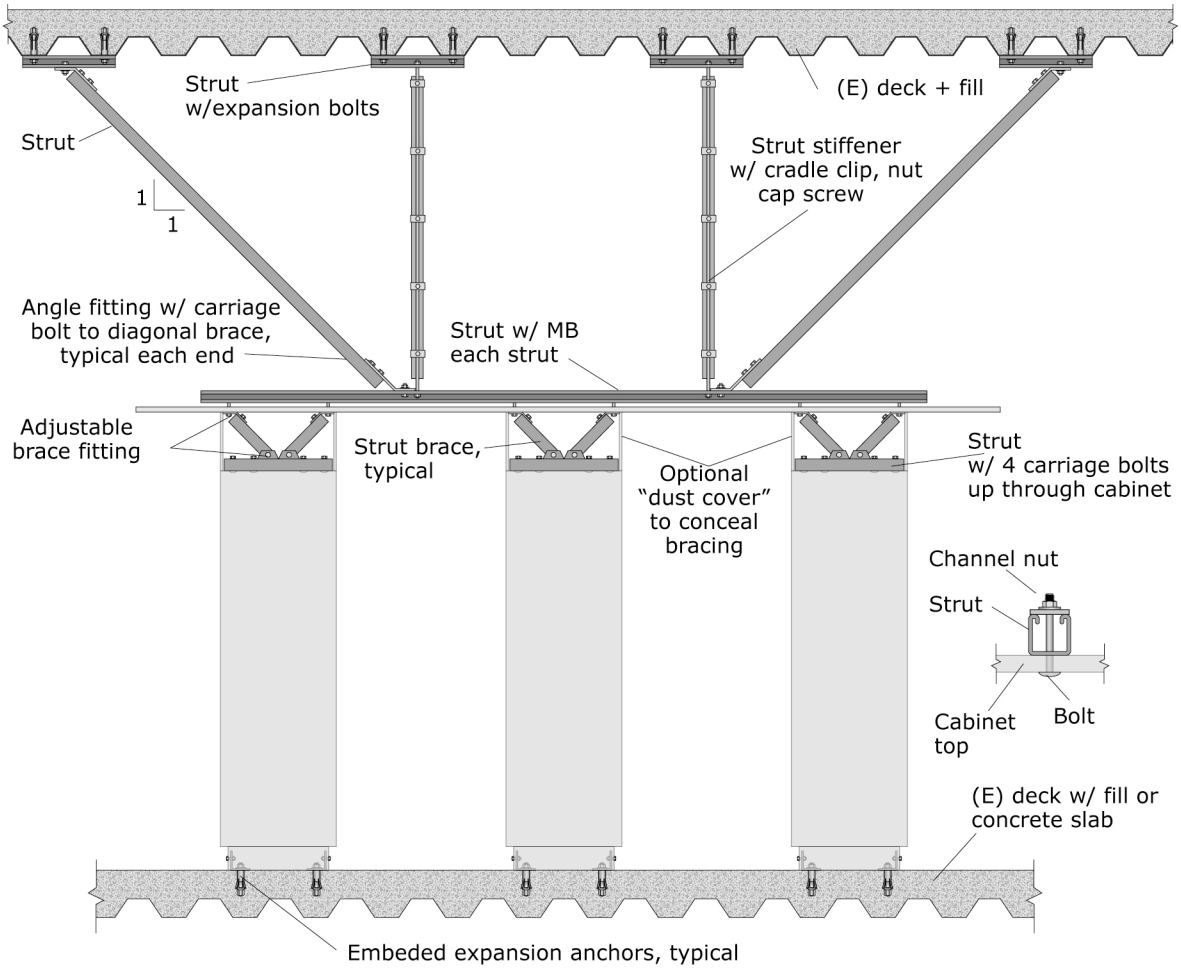
well-anchored temperature controlled and water tight cabinets to protect them from deterioration, dust, sprinkler damage, or from falling.

- Do not locate shelving adjacent to doors or exits if their failure would block the exit.

MITIGATION EXAMPLES

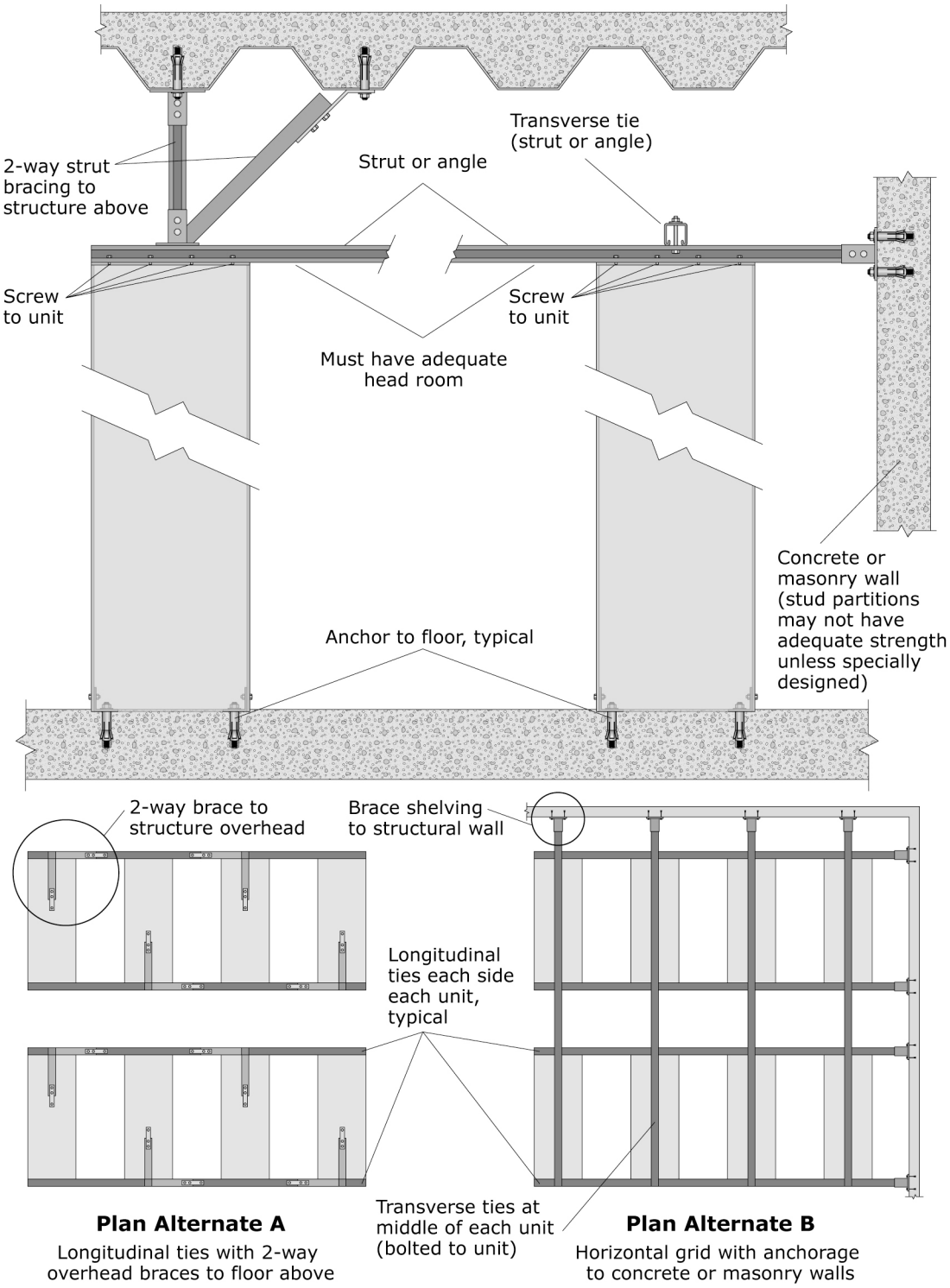
Figure 6.5.2.2-6 Examples of struts and hardware used to retrofit library shelving at the University of California, Berkeley (Photos courtesy of Mary Comerio, Dept. of Environmental Design, University of California Berkeley).

MITIGATION DETAILS



Note: since the shelving system is anchored to the floor below and the floor above, use of this detail should be limited to structures with limited interstory drift such as those braced with concrete or masonry shear walls.

Figure 6.5.2.2-7 Concealed overhead restraints for library and other shelving (ER).



Note: since the shelving system is anchored to the floor below and the floor above, use of this detail should be limited to structures with limited interstory drift such as those braced with concrete or masonry shear walls.

Figure 6.5.2.2-8 Overhead restraints for library and other shelving (ER).

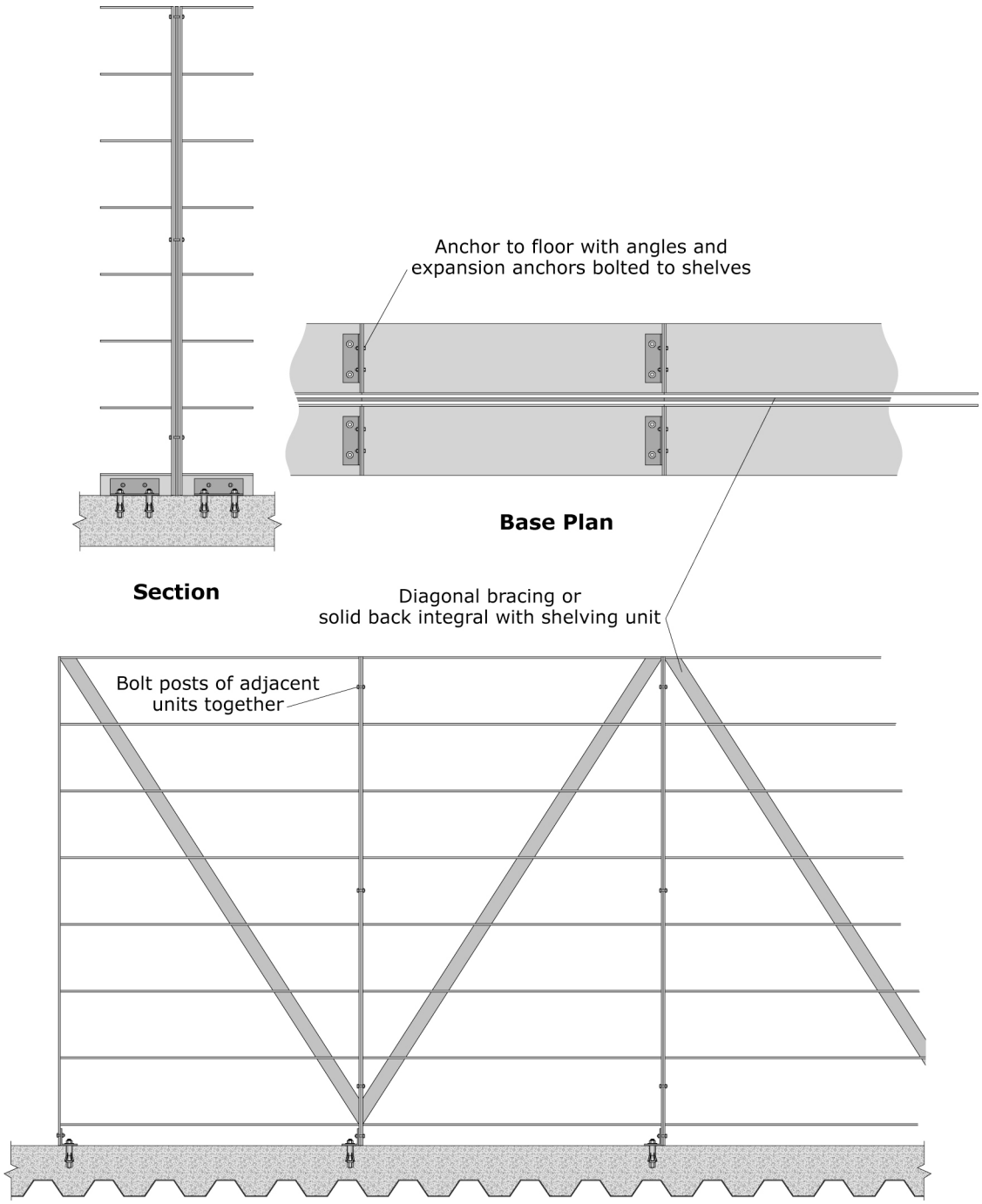


Figure 6.5.2.2-9 Freestanding library and other shelving units (ER).