6.3 Architectural Components

6.3.4 Ceilings

6.3.4.1 Suspended Lay-in Tile Ceiling Systems

Suspended modular ceiling systems are used widely in many types of buildings. These ceilings consist of light gauge metal inverted T-sections in a grid pattern, usually 2' x 2' but sometimes 2' x 4', hung from the structure with wires. The ceiling panels are most commonly designed for acoustics and are lightweight, typically weighing 1 psf or less. However, the same suspension system is often used for metal or other custom designed panels, sometimes resulting in a total system weight of up to 4 psf. Suspended lay-in tile ceiling systems typically support lighting and air diffusers, and have penetrations for sprinkler heads. Diagonal bracing wires, when present, extend from the hanger wire locations to the structure above to reduce swaying of the ceiling. Modern ceilings also have a "compression post" at each bracing location to prevent uplift of the ceiling.

Provisions

BUILDING CODE PROVISIONS

Suspended acoustic ceiling systems are subject to the requirements of ASCE/SEI 7-10, *Minimum Design Loads for Buildings and Other Structures*, (ASCE, 2010) Chapter 13, Nonstructural Components. Two options for establishing compliance are available:

- Suspended acoustic ceiling systems may be designed as an integral system, considering the mass and flexibility of elements including the ceiling, lights, HVAC air diffusers, and sprinklers.
- Suspended acoustic ceiling systems may be installed in accordance with the prescriptive requirements of ASTME E580, *Standard Practice for Installation of Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels in Areas Subject to Earthquake Ground Motions* (ASTM, 2010), as modified by ASCE/SEI 7-10, Chapter 13.

RETROFIT STANDARD PROVISIONS

ASCE/SOU 41-06, *Seismic Rehabilitation of Existing Buildings*, (ASCE, 2007) classifies ceilings into one of four types. Suspended acoustic ceiling systems are classified as "Category d", an integrated ceiling that includes lighting fixtures and mechanical items (air diffusers). Compliance with the requirements of the standard is necessary when:

- The performance level is Immediate Occupancy.
- The performance level is Life Safety in high, moderate, or low seismicity areas and the weight of the ceiling panels exceeds 2 psf.

Note that even if the ceiling system is exempt, light fixtures and air diffusers in the ceiling system may still be subject to support and bracing requirements.

Suspended acoustic ceiling systems are classified as both force and deformation controlled. Evaluation and rehabilitation of these ceilings is performed using prescriptive requirements such as ASTM E580, as modified by ASCE/SEI 7-10, Chapter 13.

Typical Causes of Damage

- The panels are supported by the metal Tee grid, but the metal Tee grid is stabilized by the panels. If one or the other system is damaged, the entire ceiling could become unstable and collapse as shown in Figure 6.3.4.1-1 through 6.3.4.1-3. Such general instability often starts at the perimeter of the ceiling, particularly where there is no wire hanger on the first span of Tees next to the wall. If the Tees fall off the wall angles without additional wire support, tiles will fall, the perimeter Tees become unstable, and the ceiling system will have uncontrolled sway, usually leading to collapse. Bracing will somewhat control the sway in this case but if the perimeter of the ceiling starts to fall apart, braces are only partly effective.
- Any differential movement of the ceiling relative to structural elements, such as structural columns or walls, partitions, sprinklers heads, or fixed lighting may locally damage the ceiling. Similarly, movement of unrestrained piping, mechanical ducts, or lighting in a tightly braced ceiling can also damage the ceiling.
- Recent laboratory tests (University of Buffalo, NEES Nonstructural Grand Challenge) have shown that in ceilings with a 50 foot dimension, the tees in between braced lines (12 feet spacing) were not sufficiently restrained by the braces and pulled away from the perimeter walls. Added braces, or staggering braces on different tee lines, may avoid this failure mode.
- Where lights, diffusers and other services within the ceiling do not have independent safety wires, these items can fall and create a hazard for occupants.
- Conflicts between ceilings and sprinkler heads are a common occurrence causing damage to both the ceiling and sprinkler heads, potentially setting off the sprinkler system or causing local leaks..
- Ceiling failures may result in building evacuations and loss of functionality until the ceiling and utilities are repaired. In a hospital setting or clean lab, the failure of the

ceiling system may introduce dust and debris, including asbestos, into the room below compromising its functionality. In the case of asbestos contamination, this may involve costly removal before functionality can be restored.

DAMAGE EXAMPLES

Figure 6.3.4.1-1 Failure of suspended ceiling system including lights, air diffusers, and insulation in control room of an industrial plant in the 2001 magnitude-8.4 Peru Earthquake (Photo courtesy of BFP Engineers).

Figure 6.3.4.1-2 Failure of suspended ceiling system including lights and air diffusers in the 1994 Northridge Earthquake (Photo courtesy of Wiss, Janney, Elstner Associates).

Figure 6.3.4.1-3 Generalized failure of ceiling grid, tiles, lights, and diffusers at the Los Angeles Hospital in the 2010 magnitude-8.8 Chile Earthquake (Photo courtesy of Bill Holmes, Rutherford & Chekene).

Figure 6.3.4.1-4 Fallen ceiling tiles at Talca Hospital in the 2010 Chile Earthquake, in spite of the use of clips as shown in detail at right. Most ceilings observed in Chile did not have seismic detailing (Photos courtesy of Bill Holmes, Rutherford & Chekene).

Figure 6.3.4.1-5 Damage to suspended metal panel ceiling system and fire sprinklers at Concepción airport, primarily at far end and around column obstructions in the 2010 Chile Earthquake (Photos courtesy of Rodrigo Retamales, Rubén Boroschek & Associates). The metal panel was strong enough to fail the sprinkler head shown at lower left.

Seismic Mitigation Considerations

- Standard practice for the seismic design of suspended acoustic lay-in tile ceilings is described in ASTM E580, *Standard Practice for Installation of Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels in Areas Subject to Earthquake Ground Motions* (ASCE, 2010), which is referenced in ASCE 7-10 Section 13.5.6. This standard supersedes several previous Ceilings and Interior Systems Construction Association (CISCA) standards.
- For ceilings in Seismic Design Category C, the objective of these standards is to provide an unrestrained ceiling that will accommodate the movement of the structure during a seismic event. This is achieved by specifying the strength of grid connectors, frequency of hangers, perimeter closure angles, edge clearances, etc.
- For ceilings in Seismic Design Category D, E, and F, the objective of these standards is to provide a restrained ceiling with connection to the perimeter wall and with rigid or non-rigid bracing assemblies. This is achieved by specifying the strength of grid elements, grid connections, frequency of hangers and lateral bracing assemblies, 2" minimum perimeter closure angles, minimum edge clearances, etc. For Seismic Design Category D, E & F, lateral bracing assemblies are required for all ceiling areas greater than 1000 sq. ft. There are several exemptions as follows:
  - Seismic detailing is not required for suspended ceilings less than or equal to 144 sq. feet that are surrounded by walls or soffits that are laterally braced to the structure (this exemption applies to heavy or light suspended ceiling systems).
  - For ceilings in Seismic Design Category C weighing less than 2.5 psf, special seismic perimeter closure details are required to provide an unrestrained ceiling; bracing assemblies are not required.
  - Ceilings weighing above 2.5 psf in Seismic Design Category C and ceilings in Seismic Design Categories D, E, and F are detailed to provide a restrained ceiling; nevertheless, ASTM E580 does not require bracing assemblies unless the ceiling area is larger than 1000 sq. ft. However, recent shake table testing indicates that long lengths of unbraced Tees cannot deliver the tributary seismic load to the fixed walls. Based on previous testing, it is estimated unbraced tees of greater than 30 feet should be avoided.
- For Seismic Design Category D, E, and F, these details typically include requirements for perimeter closure that provides fixity along two adjacent sides and allows ¾" of slip on the opposite sides as well as periodic bracing assemblies in ceilings larger than 1000 sq. ft. ASTM E580 includes requirements for the strength of connections between grid elements, minimum size (2") for the closure angle, requirements for seismic separation

joints for ceilings larger than 2500 sq. ft., requirements for the support of lighting and mechanical services, and other requirements. See also Figures 6.3.4.1-8, 9, and 10.

- Where lights and diffusers and supported by the ceiling grid, either an intermediate duty or heavy duty grid must be used and supplementary framing and hanger wires may be required to provide direct support for such items. For instance, ASTM E580 requires heavy duty main runners with a load carrying capacity of 16 lb/ft for Seismic Design Category D, E and F. If cross runners with a load carrying capacity less than 16 lbs/ft are specified, and the corner of any light fixture is supported on two adjacent sides by these intermediate duty cross runners, then a supplementary hanger wire must be attached to the grid within 3" of each such corner. ASTM E580 includes several figures showing examples where these supplementary wires are required. These supplementary hanger wires are not required where heavy duty cross runners are specified. See Examples 6.4.6.2 and 6.4.9 for additional requirements for ail diffusers and lights, respectively.
- Seismic bracing assemblies for suspended ceilings typically include a vertical compression strut and diagonally splayed wire braces as shown in Figure 6.3.4.1-9. Rigid bracing assemblies, such as those shown to brace overhead piping in Section 6.4.3 may also be used.
- ASTM E580 includes other requirements for clear openings for sprinkler heads, seismic separation joints, ceiling penetrations, and consideration of consequential damage and seismic interaction effects.
- The Division of the State Architect sets forth special ceiling standards for California schools in DSA IR 25-5 (California Department of General Services, 2009c),. This reference is a useful tool for designing in areas of potentially severe seismic shaking. In California, schools require ceiling bracing assemblies at a spacing of not more than 12 feet in each direction; essential services buildings require bracing assemblies at a spacing of not more than 8 ft. by 12 ft. on center. DSA requirements differ slightly from those in ASTM E580; check the applicable jurisdiction for specific requirements.
- Ceiling details in Figures 6.3.4.1-7, 8, 9 and 10 are for Seismic Design Category D, E and F where the total ceiling weight does not exceed 4 psf or Seismic Design Category C where the total ceiling weight is between 2.5-4 psf. These details and diagrams are adapted from CA DSA IR 25-5 and ASTM E580. These figures are shown with heavy duty main runners and cross runners as required by DSA IR 25-5. Check the applicable jurisdiction; in some cases, ceilings heavier than 4 psf, or those with a plenum larger than a certain threshold, may require engineering. See references for additional information, updates, or for connection details and special conditions not shown.

- There are shake table tests of ceilings which show that systems perform better when the tile almost nearly fills the available space and has ample overlap on the runners. These systems also have fewer tiles drop in tests than systems with smaller tiles.
- ASCE/SEI 7-10 Section 13.5.6.3 includes a discussion of "integral construction" where the grid, panels, lights, piping, and other overhead services are shop assembled in modules and bracing is provided for the whole assembly. These are included as an alternative to the details shown here. Check the internet for proprietary systems or systems pre-approved for use in your jurisdiction.
- Safety wires are required for lights and mechanical services in suspended acoustic tile ceilings to prevent them from falling. Refer to Sections 6.4.9 and 6.4.6.2 for additional information. As noted above, supplementary hanger wires for the ceiling grid may also be required. The weight of supported items should never exceed the carrying capacity of the ceiling grid. Special details are required for heavy lighting or heavy mechanical items; these should be supported directly from the structure above and not depend on the ceiling grid for vertical or lateral support. For such fixed items, perimeter closure details may be required for the ceiling to prevent impact with the ceiling system.
- Although not required by code, some manufacturers offer slide-on metal fabrications to clip the panels to the runnersfor enhanced stability. The main problem with such clips is that they defeat the purpose of an accessible ceiling space. In the case shown in Figure 6.3.4.1-4, the clips were installed but extreme shaking and ceiling movement at the walls still caused panels to fall.

MITIGATION EXAMPLES

Figure 6.3.4.1-6 Compression struts and diagonal splayed wires are used to limit the movement of suspended acoustic tile ceilings. Per ASTM E580, this type of bracing assembly is required for ceiling areas larger than 1000 sq. ft. in Seismic Design Category D,E, and F (Photo courtesy of Maryann Phipps, Estructure).

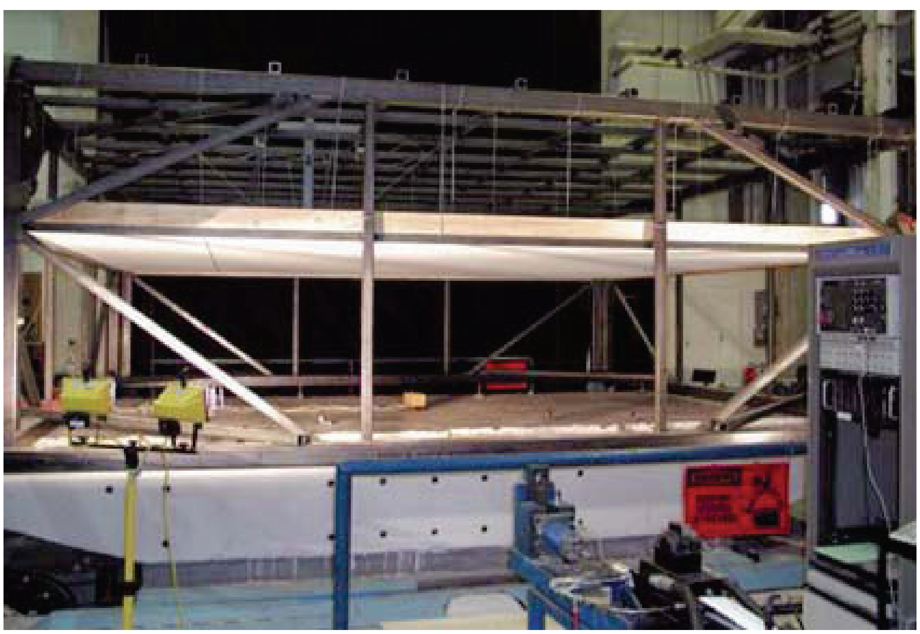


Figure 6.3.4.1-7 Shake table testing of a proprietary suspended acoustic lay-in tile ceiling at MCEER (Photo courtesy of University of Buffalo, SUNY). Additional testing of these systems will help improve our understanding of their failure modes and help inform the design of more resilient systems.

MITIGATION DETAILS

Ceiling details in Figures 6.3.4.1-8, 9, 10 and 11 are for Seismic Design Category D, E and F where the total ceiling weight does not exceed 4 psf or Seismic Design Category C where the total ceiling weight is between 2.5-4 psf. These are adapted from DSA IR 25-5 and ASTM E580. These figures are shown with heavy duty main runners and heavy duty cross runners as required by DSA IR 25-5; see discussion in text regarding the requirement in ASTM E580 for supplementary hanger wires at light fixtures supported by intermediate duty cross runners. Check the applicable jurisdiction; in some cases, ceilings heavier than 4psf, or those with a plenum larger than a certain threshold, may require engineering. See sources for additional information, updates, or for connection details and special conditions not shown.

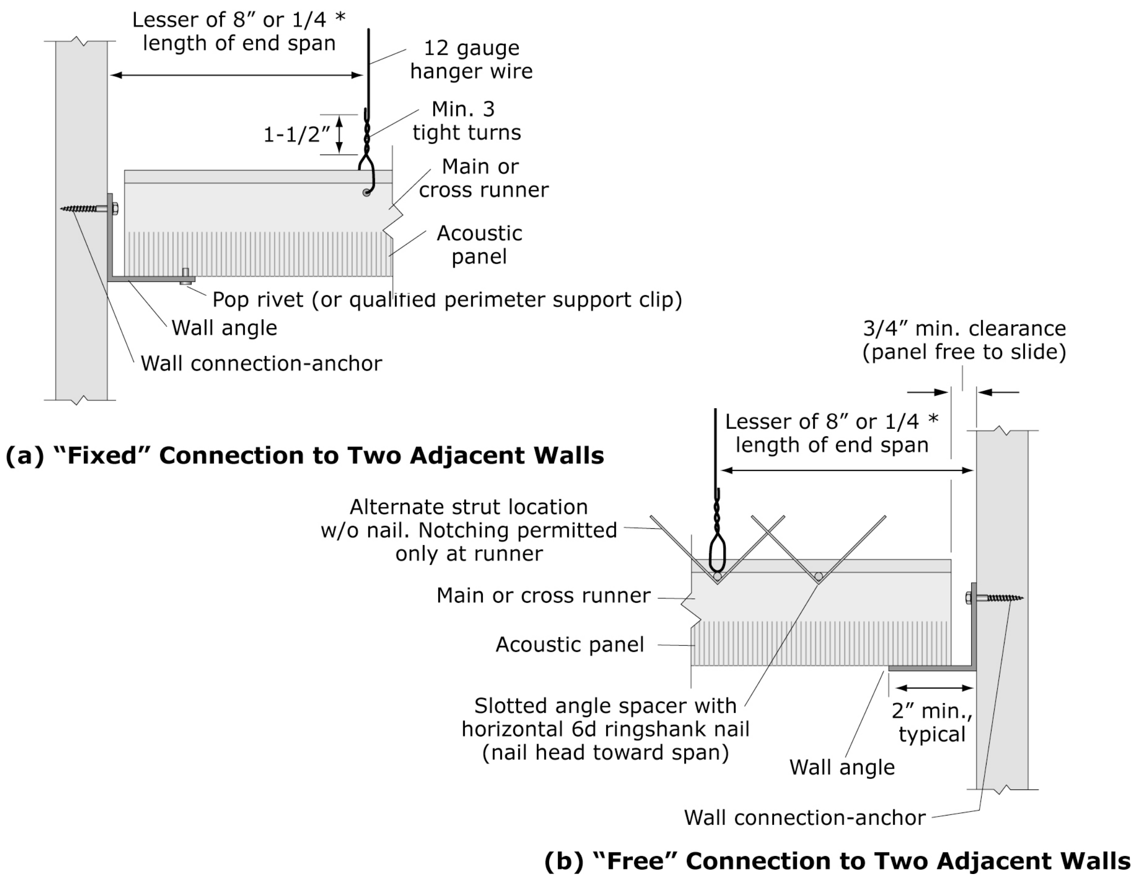
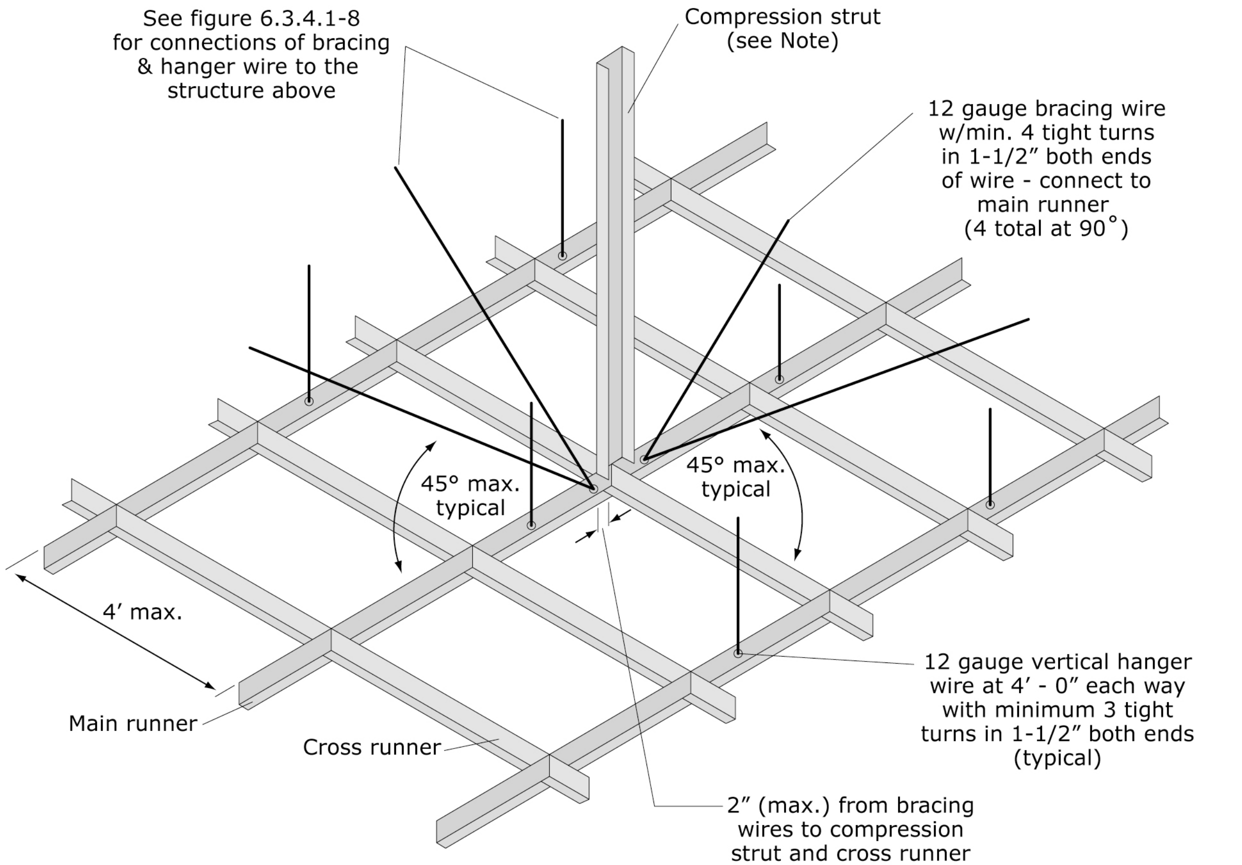


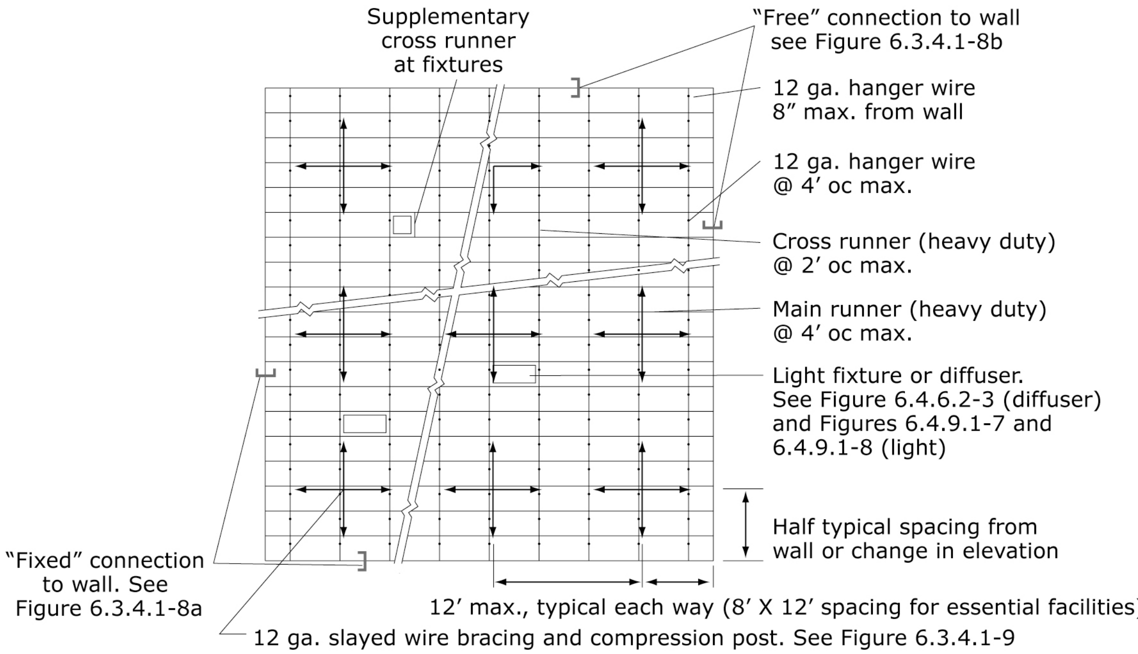
Figure 6.3.4.1-8 Suspension system for acoustic lay-in panel ceilings – edge conditions (PR).



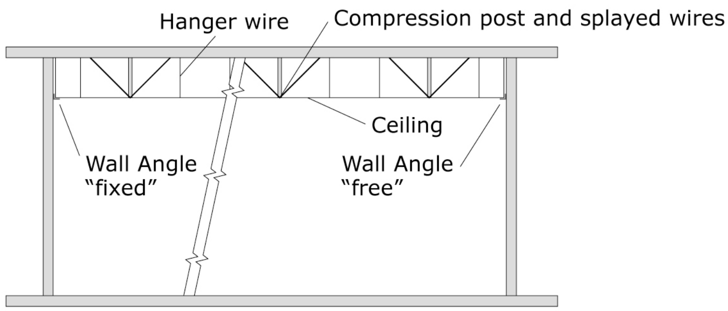
Note: Compression strut shall not replace hanger wire. Compression strut consists of a steel section attached to main runner with 2 - #12 sheet metal screws and to structure with 2 - #12 screws to wood or 1/4″ min. expansion anchor to structure. Size of strut is dependent on distance between ceiling and structure (l/r ≤ 200). A 1″ diameter conduit can be used for up to 6′, a 1-5/8″ X 1-1/4″ metal stud can be used for up to 10′

Per DSA IR 25-5, ceiling areas less than 144 sq. ft, or fire rated ceilings less than 96 sq. ft., surrounded by walls braced to the structure above do not require lateral bracing assemblies when they are attached to two adjacent walls. (ASTM E580 does not require lateral bracing assemblies for ceilings less than 1000 sq. ft.; see text.)

Figure 6.3.4.1-9 Suspension system for acoustic lay-in panel ceilings – lateral bracing assembly (PR).

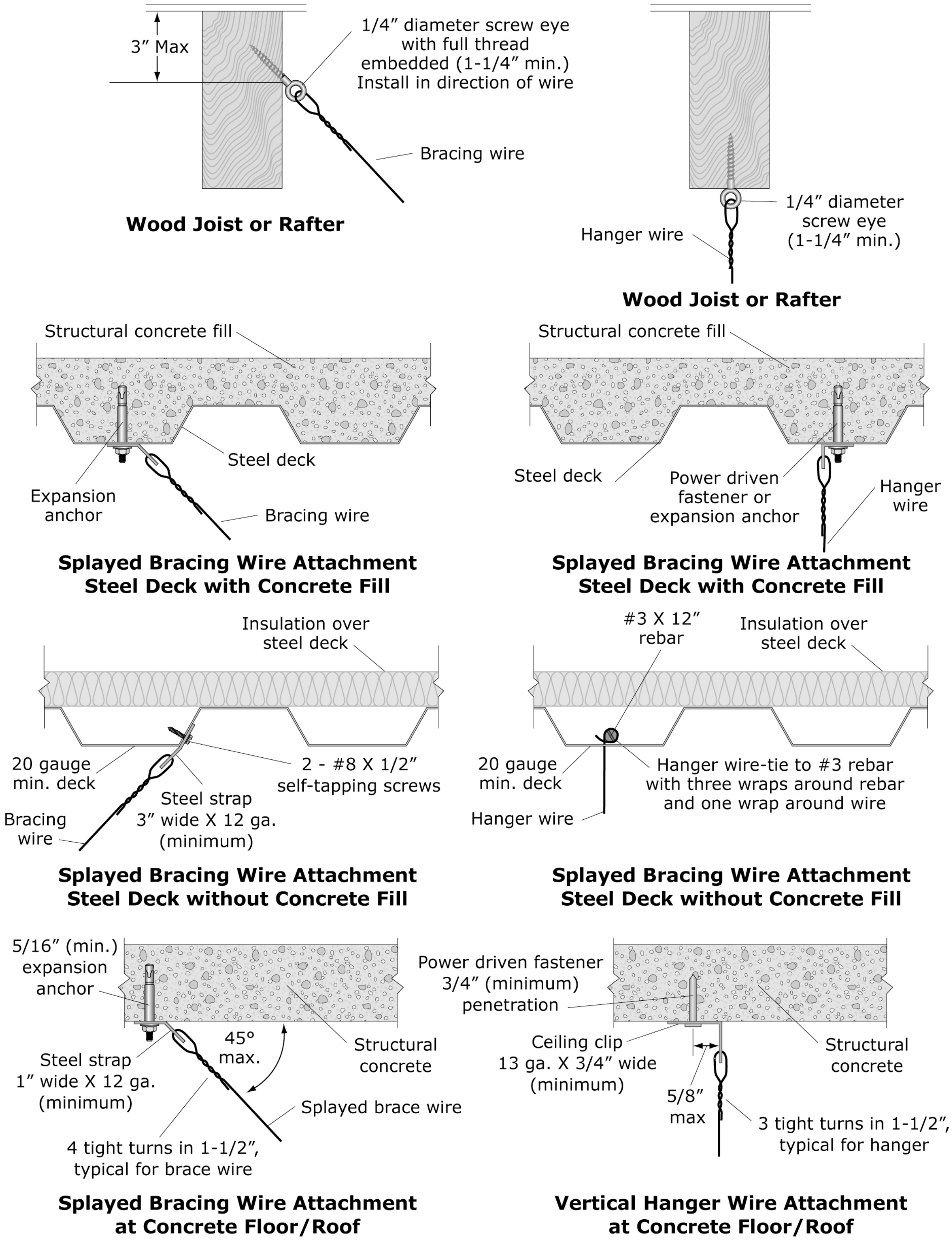


Plan



Section

Figure 6.3.4.1-10 Suspension system for acoustic lay-in panel ceiling – general layout. Although installation standards suggest alignment of brace locations, intermediate tees (particularly with a 12 foot brace spacing), may not be sufficiently restrained in large ceilings (greater than 30 foot dimension). In order to follow the current standard and alleviate this problem, braces must be added in between the 12 foot spacing. Another solution, not in complete compliance with the standard, would include staggering brace locations so more tee lines are braced (PR).



Note: See California DSA IR 25-5 (06-22-09) for additional information.

Figure 6.3.4.1-11 Suspension system for lay acoustic lay-in panel ceiling – overhead attachment details (PR).