CHAPTER 17

Structural Insulated Panel Construction

CHAPTER OUTLINE

17.1 Basics of the Structural Insulated Panel (SIP) System

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The structural insulated panel system of construction described in this chapter is an alternative to the conventional WLF system. It is a panelized system that reduces on-site construction time and allows the use of less skilled labor. Panelization, however, necessitates the use of hoisting equipment such as cranes, fork lifts, booms, and so on during construction, Figure 17.1, whose use in WLF construction is generally limited.

Because insulation is part of the panels, the insulation subtrade is eliminated, which further increases construction efficiency. Several other advantages of the system, as well as its limitations, are described at the end of this chapter. Because the structural insulated panel is a relatively new system that is still evolving, its current market share is small compared with that of the well-established conventional WLF system that dominates the residential and light commercial construction market in the United States.

In addition to all structural insulated panel construction, structural insulated panels are used as wall and roofing panels in timber frame buildings (see the Expand Your Knowledge section in Chapter 15) and low-rise steel frame buildings.

17.1 BASICS OF THE STRUCTURAL INSULATED PANEL (SIP) SYSTEM

The structural insulated panel (SIP) system consists of panels of sandwich composition. Each panel comprises two facing boards bonded to a core consisting of rigid plastic foam insulation, Figure 17.2. The core generally consists of expanded polystyrene (EPS). (Extruded polystyrene and polyisocyanurate cores may also be used, but they are more expensive.) The material used for the facings may be oriented strandboard (OSB) or plywood. OSB is commonly used because of its lower cost and its availability in much larger sizes. The most common thickness of OSB facing is $\frac{1}{2}$ in.

Panels are manufactured by applying structural-grade adhesive on both faces of the core and then laminating the OSB to it. The assembly is kept under pressure for the required

FIGURE 17.1 Two examples of typical structural insulated panel buildings under construction. (Photos courtesy of the Structural Insulated Panel Association [SIPA])

duration. Because insulation is included in the panels, SIPs are used only in the building envelope. Therefore, in a SIP building, the interior walls are generally framed with 2-by lumber and the intermediate floors are also framed with 2-by lumber or engineered wood members. The use of SIPs for an intermediate floor is, in fact, discouraged because of its lower structure-borne sound insulation. The foam in SIPs functions as an efficient acoustical bridge. SIPs may, however, be used in a floor that is required to be insulated if its lower sound-insulation value is of no concern, such as a floor over a crawl space or basement.

Although there are many similarities between the characteristics of the SIP systems of various manufacturers, SIP is a proprietary system that differs somewhat from manufacturer to manufacturer. The discussion and illustrations provided here are generic. Most SIP manufacturers have details that have been carefully developed and approved by the code authorities and should be strictly followed.

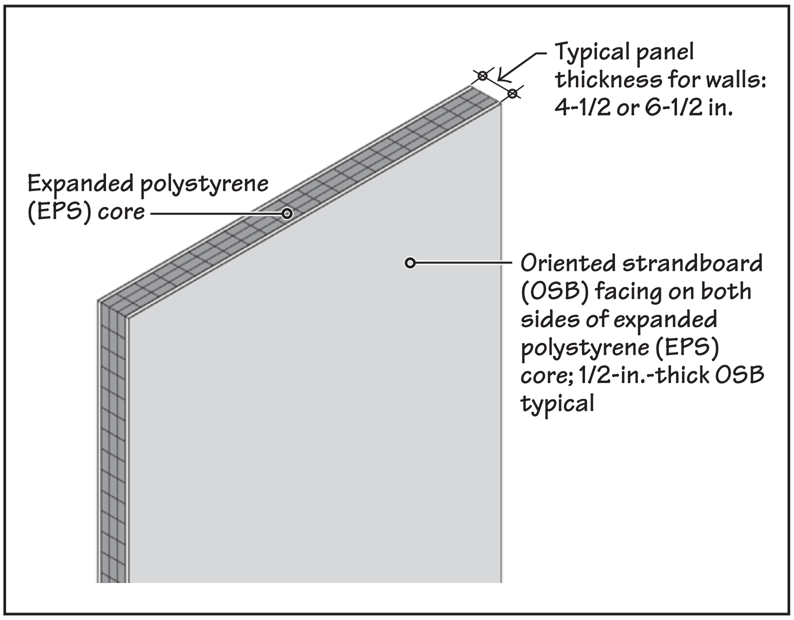

FIGURE 17.2 Composition of a typical structural insulated panel.

In considering the use of a SIP system, the general procedure is to send the architectural drawings of the project to the selected SIP manufacturer. Based on the analysis of the drawings, the manufacturer determines the size, shape, configuration, and thickness of the panels and prepares the necessary shop drawings for their fabrication.

After the approval of the shop drawings by the architect and the constructor, the manufacturer fabricates the panels. Each panel is uniquely identified as to its location in the building. All panels required for the project are packaged and sent to the construction site for assembly.

Because almost no cutting is required on site, the panels are shipped to the site when needed, eliminating the need for elaborate site storage facilities. The plant typically packages the panels in reverse order of their use, increasing the builder's productivity. The entire fabrication work, that is, the analysis of architectural drawings, preparation of shop drawings, and fabrication of panels, is generally computerized.

STRUCTURAL BEHAVIOR OF A SIP PANEL

Structurally, a SIP panel functions as a composite panel in which the core integrates the two facings. Thus, under an axial compressive load, even if the load is initially delivered to one facing, both facings combine to resist the load because the core transfers the load to the other, initially unloaded facing through shear mechanism.

Similar behavior comes into play when the panel is subjected to bending. Under bending, one facing is subjected to compressive stresses and the other facing is under tensile stresses. The core resists the shear stresses generated by bending. The behavior of a SIP panel is, therefore, identical to that of an I-section, where the facings function as the flanges of the I-section and the foam core functions as the section's web, Figure 17.3.

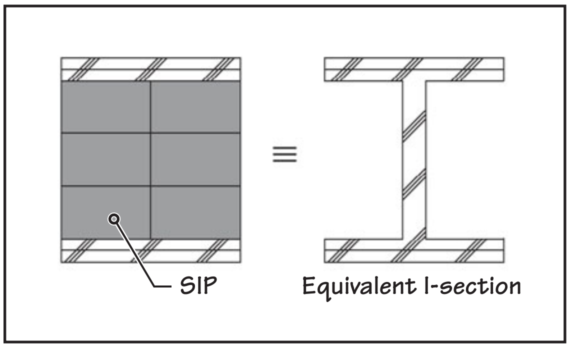

FIGURE 17.3 In carrying both axial and lateral loads, a SIP behaves as an I-section where the core functions as the web of the section and the facings as its flanges.

The core also helps to prevent the buckling of thin facings under compressive stresses, created either by the bending of the panels (in a floor or roof) or under compressive loads (in a wall). In other words, all three elements of a SIP are stressed under axial or lateral loads.

The facing-core composite behavior also comes into action in providing racking resistance to the structure where the facings and the core act together as shear walls. In a conventional wood frame building, only the exterior sheathing and the studs provide racking resistance.

Panel Sizes

Panels are produced in various thicknesses, depending on whether they are used in walls, floors, or roofs. Wall panels are generally $4\frac{1}{2}$ in. or $6\frac{1}{2}$ in. thick. A $4\frac{1}{2}$-in.-thick SIP consists of a $3\frac{1}{2}$-in.-thick core, matching a wood light-frame wall made of 2×4 studs. A $6\frac{1}{2}$-in.-thick panel (with a $5\frac{1}{2}$-in.-thick core) corresponds to a wood frame wall comprising 2×6 studs. Panel thicknesses of $8\frac{1}{4}$ in., $10\frac{1}{4}$ in., and $12\frac{1}{4}$ in. are used for floors or roofs.

The surface dimensions (length and width) of panels vary, depending on whether lifting and placing the panels in position at the site is done manually or using hoisting equipment. Panels of up to 8 ft × 24 ft can be produced by fabricators.

17.2 SIP WALL ASSEMBLIES

In general, SIP wall panels are either 4 ft or 8 ft wide. They may be continuous over the entire height of the building or they may be only one floor tall, requiring floor-by-floor installation. The floor-by-floor installation of panels is similar to the construction of walls in a conventional WLF building, where the upper floor walls are installed over the subfloor at that level.

The details of the connection of wall panels to the foundation, between adjacent panels, at wall corners, and to the floors and roofs are critical. Figure 17.4 provides an

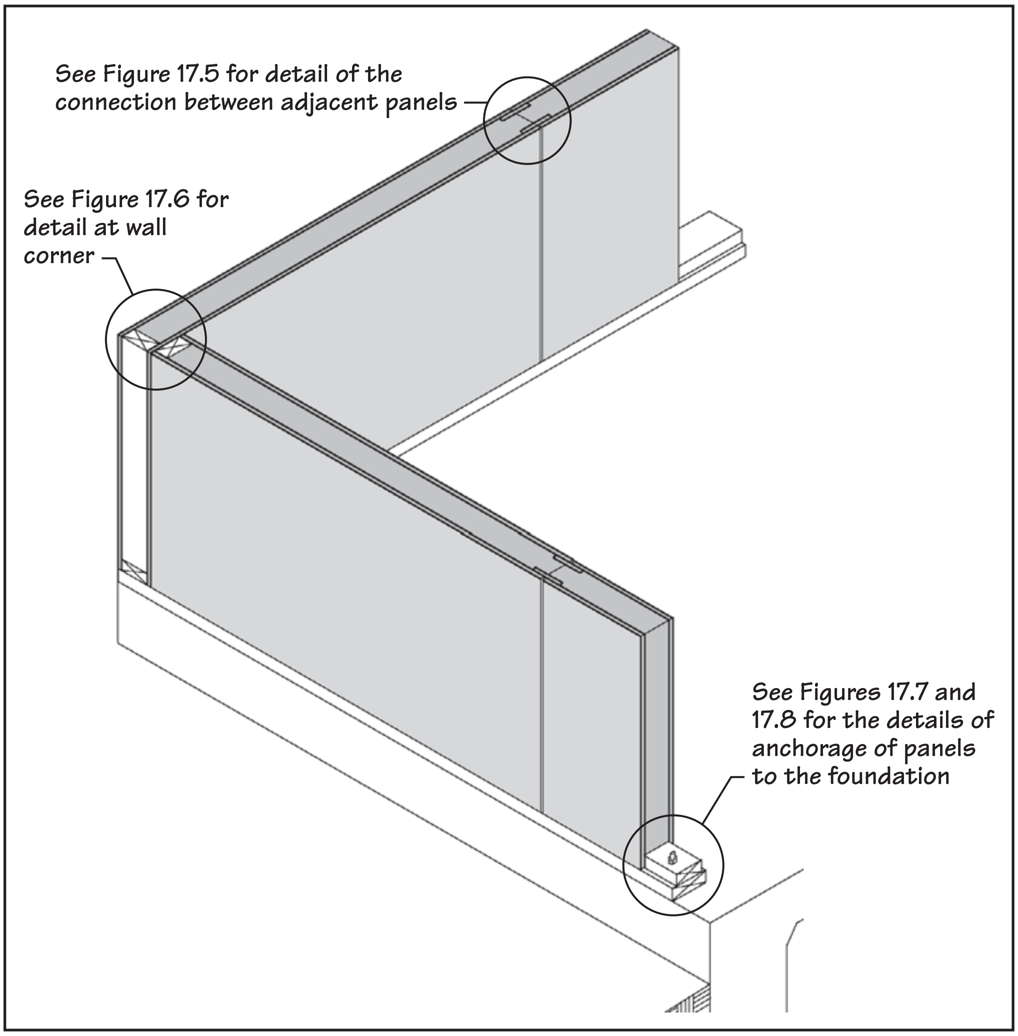

FIGURE 17.4 General layout of exterior walls in a SIP structure.

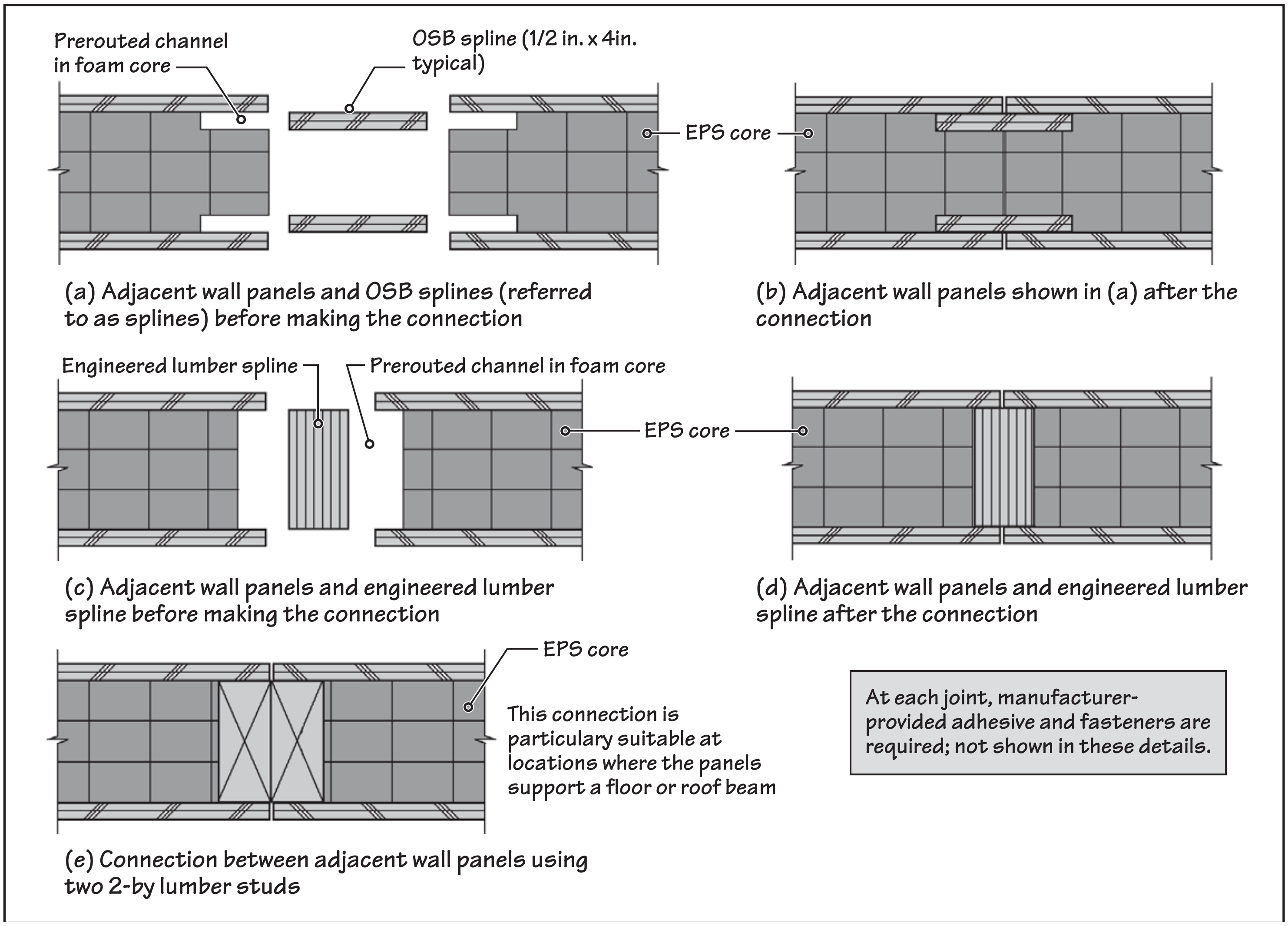

FIGURE 17.5 Three commonly used alternative ways of connecting adjacent wall panels. These details are keyed to Figure 17.4.

overall view of a typical panel layout. The adjacent wall panels are connected together with splines, Figure 17.5.

The splines may consist of $\frac{1}{2}$-in.-thick OSB strips (referred to as *surface splines*), engineered wood studs, or double 2-by studs, depending on the requirement of the connection. Nails, screws, and adhesives are used in a connection per the manufacturer's details.

The use of connecting splines requires the foam core to be routed and grooved to accept the splines. This operation is performed at the panel-fabrication plant so that the panels arrive at the site already routed. Chases for electrical wiring (generally $1\frac{1}{2}$ in. in diameter) are also routed before the panels are shipped to the site. Chases for other utility pipes are not included in SIPs because these pipes typically occur in the interior walls.

Figure 17.6 shows the connection between panels at a wall corner. Figures 17.7 and 17.8 show the details of the anchorage of wall panels to foundations. A two-sill-plate assembly at the foundation is commonly recommended by the manufacturers. The lower sill plate consists of preservative-treated lumber. The upper sill plate functions as a connecting spline. The details of Figures 17.7 and 17.8 ensure that the OSB facings bear directly over the lower sill plate so that the gravity load on the wall is transferred through the facings to the foundations in bearing.

There are various ways in which windows and doors can be detailed in a SIP wall. A commonly used method is shown in Figure 17.9. As stated previously, the interior partitions in a SIP building are framed by using conventional 2-by studs. Figure 17.10 shows the detail of the junction between an exterior SIP panel and an interior wall.

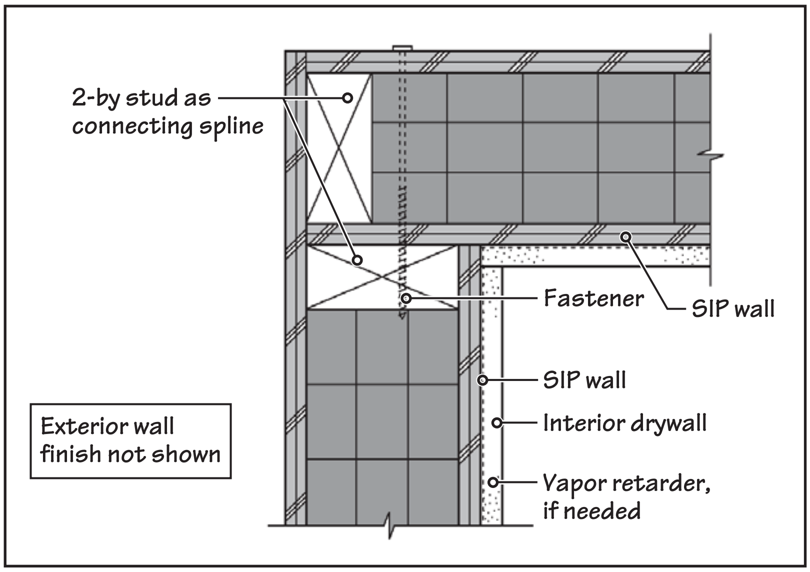

FIGURE 17.6 Typical connection at the corner of two structural insulated wall panels. This detail is keyed to Figure 17.4.

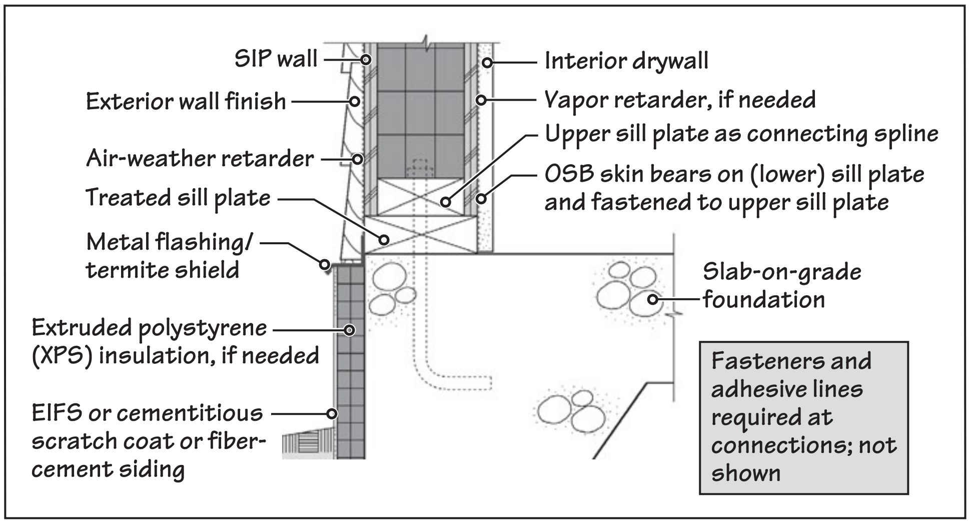

FIGURE 17.7 Typical detail of the anchorage of structural insulated wall panels to a slab-on-grade foundation. This detail is keyed to Figure 17.4.

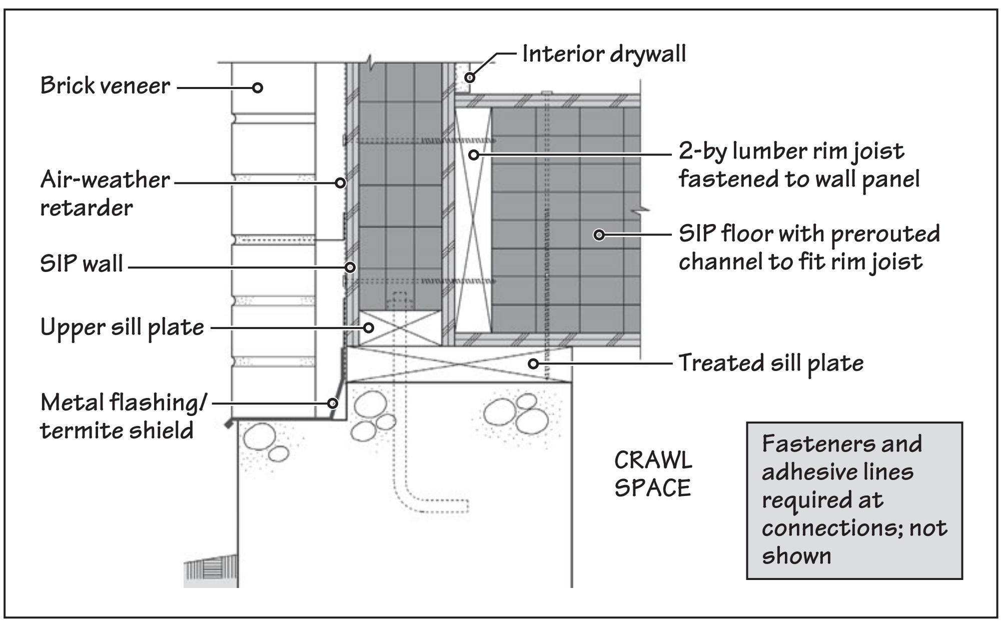

FIGURE 17.8 Typical detail of the anchorage of structural insulated wall panels to a foundation with a crawl space.

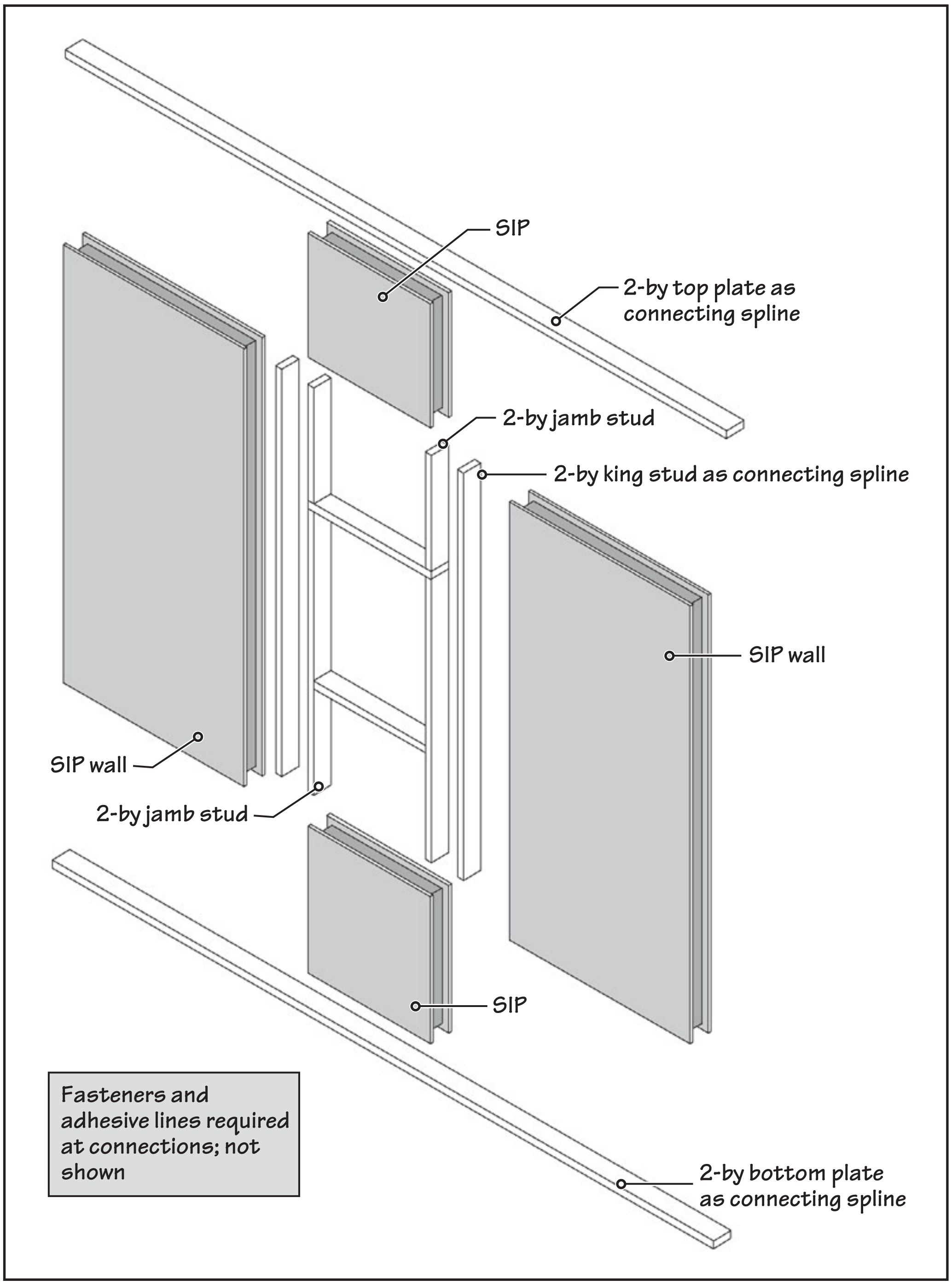

FIGURE 17.9 A typical detail of framing around a window. Framing around a door is similar.

17.3 SIP FLOOR ASSEMBLIES

As stated earlier, an intermediate floor in a SIP building is framed with 2-by lumber joists, engineered wood members (e.g., wood I-joists), or trussed joists. The floor joists may be placed on the wall panel and fastened to the top plate spline using a detail similar to that used in a conventional wood frame building, Figure 17.11.

The detail of Figure 17.11 creates a thermal bridge at the rim joist. Therefore, some SIP manufacturers recommend the detail shown in Figure 17.12, in which the floor joists are hung off the top plate spline using joist hangers. The joist hangers are top-supported, that is, fastened to the top plate in the SIPs. Where the SIPs are continuous, that is, two floors high, the floor joists are supported on joist hangers that are fastened to a ledger beam, Figure 17.13.

17.4 SIP ROOF ASSEMBLIES

Two alternative roof assemblies can be used in a SIP building. One alternative is to use any one of the various assemblies that are used in a conventional wood frame building—that is, a stick-frame rafter-ceiling assembly or wood roof truss assembly. In these assemblies, insulation is placed in the attic.

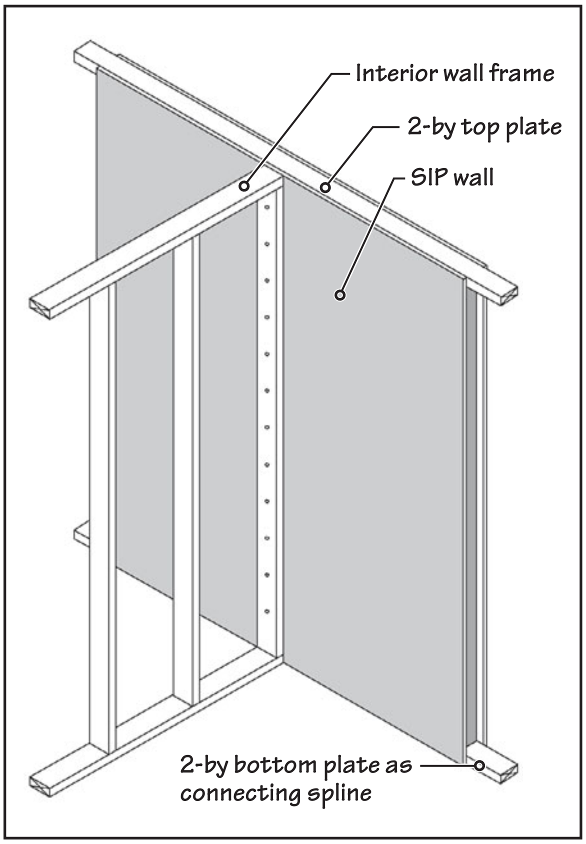

FIGURE 17.10 Connection of an interior wall to a SIP wall.

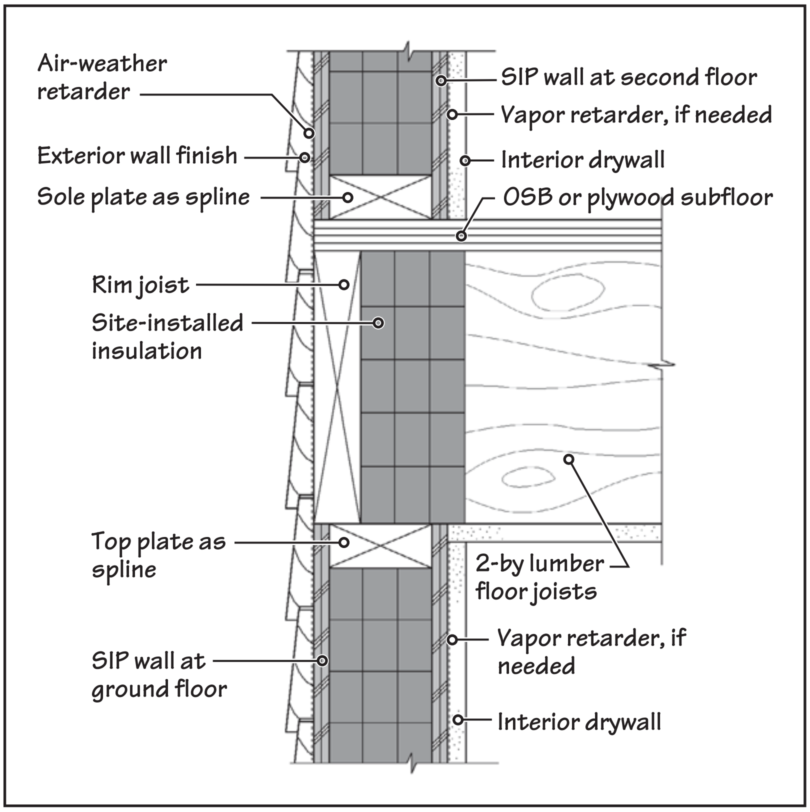

FIGURE 17.11 Detail at the junction of a SIP floor and a SIP wall. The detail is similar to that used in a conventional wood frame building. Site-installed insulation is needed behind the rim joist.

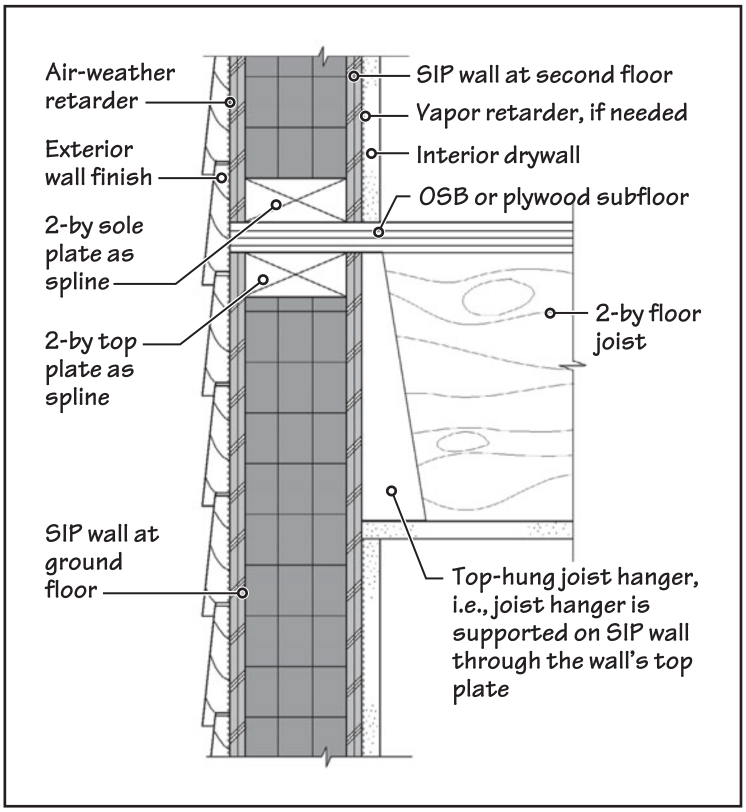

FIGURE 17.12 Detail at the intersection of a floor and a SIP wall—an alternative to the detail in Figure 17.11. In this detail, site-installed insulation is not needed.

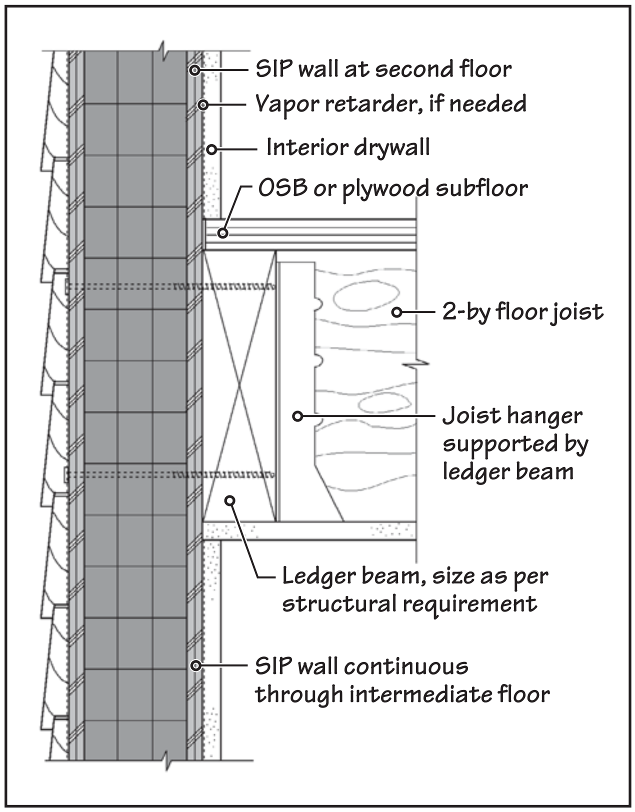

FIGURE 17.13 Detail at the intersection of a floor and a SIP wall where the SIP wall is continuous through the floor.

The second alternative is to use a SIP roof, where the roof SIPs span from the ridge beam to the exterior wall, creating a cathedral ceiling. Typical details of such an alternative are shown in Figure 17.14.

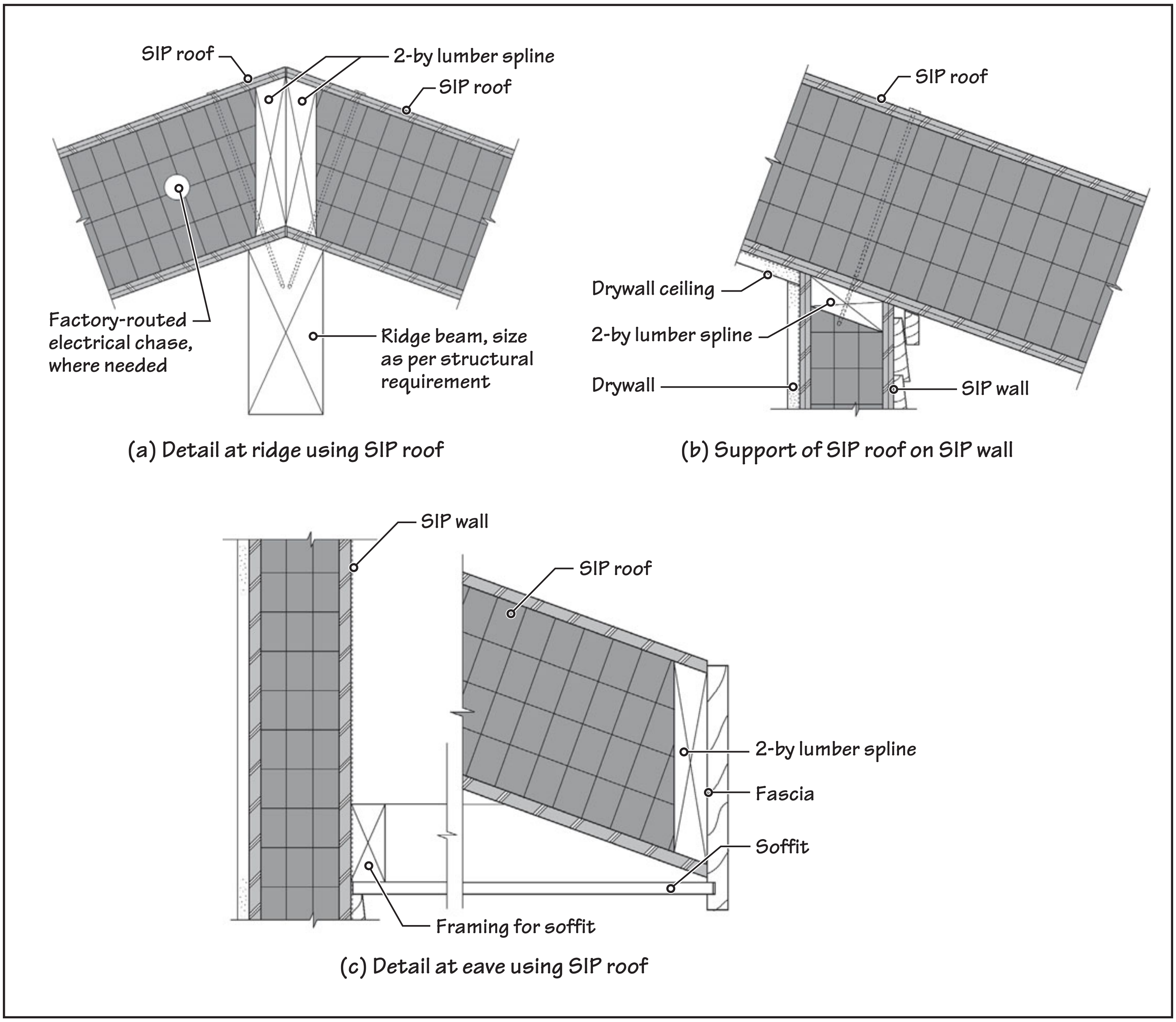

FIGURE 17.14 Details at the ridge and eave using roof and wall SIPs.

17.5 ADVANTAGES AND LIMITATIONS OF SIPS

The SIP system of construction has several advantages and limitations compared with the conventional WLF system.

ADVANTAGES

- *Panelization and Deletion of Insulation Subtrade:* As stated at the beginning of this chapter, panelization and deletion of the insulation subtrade in a SIP structure increase the speed and efficiency of construction.
- *Air-Weather Retarders:* Because the panels are relatively airtight, air-weather retarders are needed only for their water-resistive properties.
- *Continuous Nailable Surface:* Because OSB facings provide a continuous nailable surface, interior drywall and exterior wall finishes can be applied without having to locate the studs.
- *Pneumatic Nailers:* Although several details require the use of screws, pneumatic nailers are used extensively.
- *On-site Waste:* Very little on-site waste is produced in a SIPs structure because most members arrive at the site precut to size.
- *Energy Efficiency:* One of the major advantages of SIP is their energy efficiency. A SIP structure has virtually no thermal bridges in the envelope. The use of foam core allows no air movement within the insulation, unlike that in fiberglass insulation.

- *Fire Endurance:* SIP manufacturers claim that the fire endurance of a SIP structure matches that of a conventional wood frame structure. The absence of concealed spaces in walls and roofs deprives the fire of the oxygen required for burning.

LIMITATIONS

- *Chases:* Because the electrical chases must be prerouted in the panels, a greater amount of preplanning is necessary.
- *Squareness of Panels:* Panels must be absolutely square for a successful installation.
- *Termites and Insect Attack:* Termites and insects boring through foam insulation, which can seriously impact the structural performance of the system, must be checked with the manufacturer.
- *Long-term Performance:* Long-term structural performance of the system depends on the long-term performance of the adhesives.

PRACTICE QUIZ

Each question has only one correct answer. Select the choice that best answers the question.

1. In a SIP, the insulation generally consists of
a. fiberglass.
b. extruded polystyrene.
c. polyisocyanurate.
d. polyurethane.
e. expanded polystyrene.

2. The facing in a SIP generally consists of
a. OSB on both faces.
b. OSB on the exterior face and gypsum board on the interior face.
c. plywood on the exterior face and gypsum board on the interior face.
d. plywood on the exterior face and OSB on the interior face.
e. none of the above.

3. In a SIP structure, the interior walls are constructed of 4 ft × 8 ft SIP panels.
a. True
b. False

4. In a SIP building, exterior wall panels are typically
a. 6 in. or 7 in. thick.
b. $5\frac{1}{2}$ in. or 6 in. thick.
c. 5 in. or 6 in. thick.
d. 4 in. or 6 in. thick.
e. $4\frac{1}{2}$ in. or $6\frac{1}{2}$ in. thick.

5. Adjacent structural insulated wall panels in a SIP building are connected through
a. 2-by lumber studs.
b. engineered lumber splines.
c. OSB splines.
d. any one of the above.
e. special sheet metal connectors.

6. A corner between structural insulated wall panels in a SIP building requires a minimum of
a. four 2-by lumber studs.
b. three 2-by lumber studs.
c. two 2-by lumber studs.
d. one 2-by lumber stud.
e. 2-by lumber studs are not required.

7. The connection of a wall panel to a concrete foundation, as shown in this text, requires the use of
a. one treated sill plate.
b. two treated sill plates.
c. two sill plates, one of which is treated.
d. a sill plate is not needed in a SIP structure.

8. In a SIP structure, an intermediate floor may be framed with any one of the following except
a. 2-by lumber members.
b. wood I-joists.
c. wood trussed joists.
d. SIP panels.
e. all of the above (without exception).

9. In a SIP structure, the roof may be framed with any one of the following except
a. a rafter-and-ceiling-joist assembly consisting of 2-by lumber members.
b. a rafter-and-ceiling-joist assembly consisting of wood I-joists.
c. wood roof trusses.
d. SIP panels.
e. all of the above (without exception).

10. A SIP manufacturer generally supplies standard-size panels, which must be cut to size at the site as required by project drawings.
a. True
b. False

11. Similar to the conventional WLF structure, the interior gypsum board wall finish must be nailed to the studs in a SIP structure.
a. True
b. False

12. The maximum size of available SIP panels is
a. 4 ft × 8 ft.
b. 4 ft × 10 ft.
c. 8 ft × 8 ft.
d. 8 ft × 16 ft.
e. 8 ft × 24 ft.

REVIEW QUESTIONS

1. Using a sketch and notes, explain the anatomy of a SIP. In what thickness are the panels commonly used?
2. Using sketches and notes, show two alternative ways in which two adjacent SIP wall panels are joined.
3. Using a sketch and notes, explain the support of SIP walls on a slab-on-grade foundation.
4. Explain why SIPs are not recommended for an intermediate floor but can be used for roofs.
5. List the two most important advantages and the two most important disadvantages of SIP construction in comparison with WLF construction.