SIP Design Best Practices

SIP D-BP 3: Structural Capabilities

Introduction and How to Use This Document

This document is created specifically for design professionals by the manufacturing members of the Structural Insulated Panel Association (SIPA). It dives deeper and provides more background into each of the summarized topics presented in the *Design with SIPs: DESIGN CONSIDERATIONS* document which highlights important considerations during the design phase of a Structural Insulated Panel (SIP) structure. Decades of combined knowledge from SIPA manufacturers will help reduce the learning curve and leverage SIPs' exceptional qualities to achieve the high-performance results owners expect when building with SIPs. The considerations of how and why the best practices were developed as the common industry platform for SIP design are explored here.

The index below outlines ten topical areas, listed in sequence to match the order of design considerations and construction. The details in each chapter provide a deeper understanding of the subject matter to facilitate successful SIP design and later implementation. The current chapter is highlighted in bold and italic.

1. High-Performance Building Envelope
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3. ***Structural Capabilities***
    - 3.1. ***Manufacturers publish construction manuals and load design charts that can be accessed to understand structural capacities.***
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    - 3.6. ***SIPs are compatible with internal conventional framing.***
    - 3.7. ***Point loads may dictate the need for additional structural components to be embedded internally. Avoid point loads over openings to allow SIPs to act as the header without the need for additional structural elements.***
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    - 3.10. ***Wall SIPs may require a cap plate to meet high point load conditions.***

4. SIP Sizes

5. Shop Drawings
6. SIP Fabrication
7. SIP Installation
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9. Electrical
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SIP D-BP 3: Structural Capabilities

<u>SIP D-BP 3.1</u>**: Manufacturers publish construction manuals and load design charts that can be accessed to understand structural capacities.**

When a project does not meet the prescriptive requirements of the International Residential Code (IRC), Section R301.1.3 Engineered design applies. Section R301.1.3 Engineered design of the 2018 IRC states:

> *Where a building of otherwise conventional construction contains structural elements exceeding the limits of Section R301 or otherwise not conforming to this code, these elements shall be designed in accordance with accepted engineering practice. The extent of such design need only demonstrate compliance of nonconventional elements with other applicable provisions and shall be compatible with the performance of the conventional framed system. Engineered design in accordance with the International Building Code is permitted for buildings and structures, and parts thereof, included in the scope of this code.*

Since their inception back in the 1930's, SIPs (in former times also known as stress skin panels) have been well-tested and proven reliable. APA – the Engineered Wood Association published its 24-page *Structural Insulated Panels Product Guide* and the *ANSI/APA-PRS610.1-2018 Standard for Performance-Rated Structural Insulated Panels in Wall Applications* which can be found for free download on both the APA (www.apawood.org) and the SIPA (www.sips.org) websites.

The U.S. Department of Agriculture's Forest Products Laboratory has published numerous test reports as shown below. The *Builder's Guide to Structural Insulated Panels (SIPs)* by Building Science Corporation is available at www.sips.org. Numerous individual company code evaluation reports, load charts and construction manuals are also available to help the design professional design SIPs in accordance with accepted engineering practice.

- Lateral Load Performance of SIP Walls with Full Bearing FPL-GTR-251

- Lateral Load Performance of Structural Insulated Panel (SIP) Diaphragms FPL-RP-700
- Creep Behavior of Structural Insulated Panels (SIPs) Results from a Pilot Study FPL-RN-0332
- Evaluation of Creep Performance of Structural Insulated Panels (SIPs) Phase 2 FPL-RP-697
- SIP Shear Walls Cyclic Performance of High-Aspect-Ratio Segments and Perforated Walls FPL-RP-682
- Performance of Structural Insulated Panel Walls under Seismic Loading FPL RP 704
- Seismic Evaluation of Structural Insulated Panels in Comparison with Wood-Frame Panels
- APA Report T2011-73 Durability Testing for Structural Insulated Panels (SIPs)

While the above-mentioned resources are primarily used in North America, ISO standards prevail throughout the rest of the globe. Global ISO Standards for SIP walls and roofs are available for purchase at www.iso.org.

- ISO 18402 Timber Structures - Structural Insulated Panel Roof Construction - Test Methods
- ISO 22452 Timber Structures - Structural Insulated Panel Walls - Test Methods

SIP manufacturers' load design charts, evaluation reports and construction manuals provide design professionals with the resources to confidently design structures utilizing SIPs.

***SIP D-BP 3.2*: SIPs have been included in the IRC since the 2007 supplement to the 2006 IRC.**

SIPs can be used for the construction of homes in accordance with the prescriptive requirements of the IRC if they meet the general applicability limits of the IRC. These limitations, which cover the large majority of residential construction, are that the structure has a footprint of 40 feet by 60 feet or less, is two stories or less in height above the basement, and has a maximum building height of 35 feet. Structures adhering to these parameters do not require engineering since they follow prescriptive requirements. However, buildings that exceed these limitations would require specific project engineering.

SIPs were first introduced into the 2007 supplement of the 2006 IRC under Section R614, Structural Insulated Panel Wall Construction. This was changed to Section R613 of the 2009 IRC and is under Section R610 of the 2018 IRC. Section R610.1 General says:

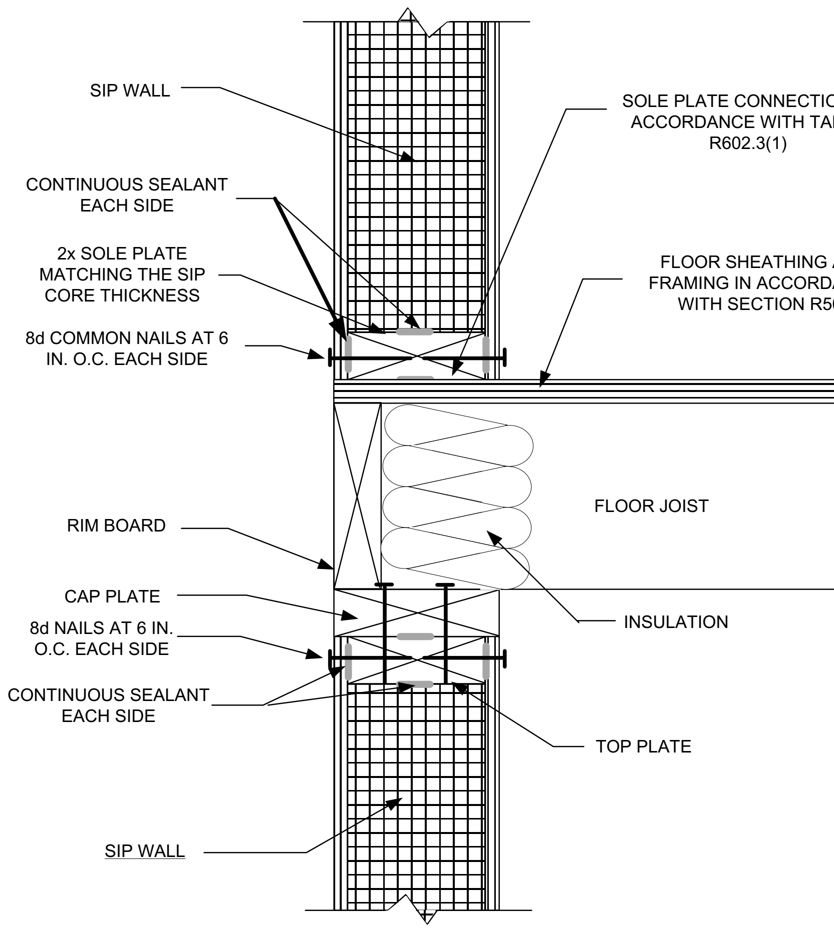
> *Structural insulated panel (SIP) walls shall be designed in accordance with the provisions of this section. When the provisions of this section are used to design structural insulated panel walls, project drawings, typical details and specifications are not required to bear the seal of the architect or engineer responsible for design, unless otherwise required by the state law of the jurisdiction having authority*.

One of the most complicated aspects of residential design and construction is determining the amount of wall bracing required to resist lateral loads induced by wind loads and seismic events. A key benefit of using the IRC is that it provides design professionals and builders with detailed information regarding the required wall bracing for residential construction. Section R602.10 establishes traditional stick frame construction using continuous wood structural panel sheathing (bracing Method CS-WSP) as the base to which all other wall framing systems are compared. Section R610.5.5 Wall Bracing says that "*SIP walls shall be braced in accordance with Section R602.10. SIP walls shall be considered continuous wood structural panel (bracing Method CS-WSP) for purposes of computing required bracing*."

Being able to equate SIP construction with traditional stick framing by applying the provision of Section R610.5.5 greatly simplifies the design professional's and builder's role in using SIPs in residential wall construction. SIPA Technical Bulletin No. 8 *Wall Aspect Ratios for SIPs* provides additional detailed prescriptive wall bracing guidance based on the IRC.

The IRC also provides numerous Figures showing installation recommendations for SIP walls. An example for a SIP Wall-to-Wall Platform Connection is shown in Detail 3.1 below. Note that the graphic details may differ based on geography or other design requirements or best practices.

Detail 3.1: IRC Figure R610.5(4) Showing SIP Wall-to-Wall Platform Frame Connection



For SI: 1 inch = 25.4 mm.
Note: Figures illustrate SIP-specific attachment requirements. Other connections shall be made in accordance with Tables R602.3(1) and (2) as appropriate.

FIGURE R610.5(4)
SIP WALL-TO-WALL PLATFORM FRAME CONNECTION

Design note: eliminate the duplicate title ("Figure R610...") at the bottom of Detail 3.1.

IRC Table R610.5(1), which is too large to be reproduced here, provides the minimum thickness of SIP walls required to support a SIP or light frame roof only (one story). IRC Table R610.5(2) provides the minimum thickness of SIP walls required to support a SIP or light frame story and roof (two stories). Both tables are for building widths of 24 feet to 40 feet with wall heights of 8, 9 and 10 feet. Wind loads are ultimate design wind speeds ranging from 110 mph to 140 mph for one-story construction and 110 mph to 130 mph for two-story construction with ground snow loads ranging from 20 psf to 70 psf for both single and two-story houses.

Tables are also provided by the IRC giving additional design information. Table R610.8 provides maximum spans for 11-7/8-inch or deeper SIP headers for two different load conditions (supporting roof only and supporting roof and one story), for ground snow loads ranging from 20 psf to 70 psf, and for building widths ranging from 24 feet to 40 feet.

Tables R610.5(1), R610.5(2) and R610.8 are also available in the *APA/SIPA Structural Insulated Panels Product Guide*, which provides the minimum thickness of SIP walls required to support SIP or light frame roofs and can be downloaded as an electronic pdf file from APA or SIPA.

***SIP D-BP 3.3:* Structural capacities are recognized for compliance with Model Building Codes in evaluation reports from ICC-ES, ICC NTA, Intertek or IAPMO.**

While SIPs are recognized in the IRC as discussed in SIP D-BP 3.2, they are not directly recognized in the IBC. But both the IBC and IRC allow for products and construction methods not specifically contained within these codes to be recognized as meeting their structural requirements, provided that these products and construction methods are subjected to testing and evaluation by third-party evaluation agencies. These agencies themselves must be recognized to conduct product and system evaluations by the Authority Having Jurisdiction (AHJ).

The evaluations by the Third-Party Testing and Listing Agencies result in published “Evaluation Reports.” This Evaluation Report process gives assurance to Building Officials that the construction method tested and evaluated is in compliance with the structural requirements of the evaluated Code. ICC Evaluation Services, ICC NTA, Intertek and IAPMO are examples of the Third-Party Testing and Listing Agencies providing evaluation services to the construction industry.

***SIP D-BP 3.4:* The structural capacity of SIPs changes with height/length, thickness and connection method, and *SIP D-BP 3.5:* SIP roofs offer great design flexibility to span long distances. SIPs can be combined with structural splines to**

span up to 24 feet. Exterior walls, beams, purlins, interior partitions, timber frame, or trusses constructed of either wood or steel are required to support a SIP roof.

SIPs can be manufactured in sizes up to 8 feet wide and 24 feet long and in varying nominal thicknesses ranging from 4-1/2 inches to 12-1/4 inches. This versatility in sizes offers the design professional a wide range of options to satisfy virtually any design situation. The 4-1/2-inch and 6-1/2-inch-thick SIPs are typically used for walls to resist both out-of-plane and in-plane forces induced by gravity loads and wind or seismic loads. The thicker SIPs are typically used for roofs and floors.

As an example, in accordance with the SIPA code listing report, a 6-1/2-inch-thick SIP can be used to span 8 feet carrying 56 psf for floors at a deflection limit of L/360 which is adequate for most residential floor applications. The same thickness SIPs can carry up to 80 psf for roofs at a deflection limit of L/180 which is adequate for most roof snow load situations in the U.S. The use of a 12-1/4-inch-thick SIP can carry up to 106 psf for an 8-foot span for either a floor or roof application.

Floors using traditional stick framing with a relatively thick 1-3/32-inch wood structural panel (WSP) sheathing would limit the span or spacing of support members to be a maximum of 4 feet on center to carry 55 psf as compared to the 6-1/2-inch SIP with a support spacing of 8 feet. Using a more common WSP thickness of 13/32-inch would require the support spacing members to be at a maximum of 2 feet on center for a floor to carry 100 psf as compared to the 8-foot spacing of supports for the 12-1/4-inch SIP to carry a 106 psf load. Similar comparisons can be made for roofs, demonstrating that the use of SIPs compared to stick framing requires far fewer support members to carry equivalent loads.

Load capacities vary from manufacturer to manufacturer for different SIP thicknesses, and spline types and manufacturer-specific code listing reports should be used to verify these capacities.

SIPs' longer span capabilities combined with the larger length and width combinations (jumbo panels) greatly reduce the construction time. Support members for SIPs can be exterior walls, beams, purlins, timber framing, trusses or other conventional framing members often associated with stick framing.

A common method for joining individual SIPs is the use of a surface or box/block spline. Both methods are easy to install in the field and do not introduce a thermal break as is typical for lumber studs used in stick framing.

However, dimensional lumber is used in conjunction with SIPs for some specific connection details. For example, solid chord members using 2x dimensional lumber are required at each end of each SIP shear wall segment. For SIPs used as horizontal diaphragms subjected to wind or seismic loading, a 2x dimensional lumber boundary member is used.

For longer span roof applications, up to 24 feet, lumber splines or I-joist splines are typically used. The width of these SIPs is typically limited to 4 feet. The design professional is advised to verify span/load capacities from manufacturer-specific design literature and code listing reports for these applications.

<u>SIP D-BP 3.6:</u> SIPs are compatible with interior conventional framing.

SIPs are generally used for all exterior framing of the structure but can also be used for interior walls. Typically, the interior walls are traditional stick framing. This method works well in conjunction with SIPs if the proper methods of connection are followed.

As an example, when there is an intersecting stick frame wall with a SIP wall, attachment can be made from the outside of the SIP using long panel screws through the panel into the stick frame wall. Stick framed walls can also be used to support spans of the SIP roof panels if the wall is designed properly for the gravity load and to the required height for the wall.

Electrical chases and wiring can easily be run inside the SIPs, but it is best to concentrate electrical needs in the interior stick framed wall as much as possible.

Plumbing is best to be pre-planned for interior stick frame walls. If there is a need for a vent in an exterior wall, consider using an island vent or mechanical vent system to redirect that to the interior stick frame wall. Always check with local code officials for acceptance of these methods.

As always, consult with your SIP manufacturer for specific details.

<u>SIP D-BP 3.7</u>: Point loads may dictate the need for additional structural components to be embedded internally. Avoid point loads over openings to allow SIPs to act as the header without the need for additional structural elements.

The SIP walls transfer the axial loads of a structure by fully bearing on the supporting element or structure. If the compressive resistance of the OSB facer is exceeded, additional compression elements must be used to adequately transfer the design loads. These additional compression elements are typically comprised of dimensional sawn lumber and engineered wood products. Steel may be used in extreme loading conditions.

If the designer can minimize point loading conditions over openings, the SIP wall may be able to act as the header without the addition of other structural elements in the SIP wall above the opening. This provides for a more economical SIP wall design.

<u>SIP D-BP 3.8:</u> SIP roofs can cantilever past walls to provide overhangs.

One of the key architectural design elements used to help protect exterior walls from exposure to rain is to provide roof overhangs on gable end walls or on eave applications. SIPs can easily be cantilevered past exterior walls to provide these overhangs. The use of SIPs to create the overhangs is advantageous because it speeds the construction of the project and saves labor costs associated with hand framing these overhangs such as with conventional stick framing.

The allowable overhang is controlled by the depth of the SIP, the orientation of the SIP with respect to the exterior wall, the type of spline used, and the load to be carried. Some SIP manufacturers provide recommended cantilever overhang spans for their products in their technical literature. Overhang spans can range from 1 foot to 4 feet when using a surface spline or box/block spline.

As a general guideline, SIPs can be used to create overhangs of up to 2 feet when the SIP is installed with the strong axis parallel to the support wall. If the SIP is installed with the strong axis perpendicular to the support wall, longer overhangs can be achieved with certain limitations. Designs are controlled by live load deflection and total load deflection and assume that the SIPs are installed with a back span equal to twice the overhang span.

Longer overhangs are typically achieved by using SIPs that utilize double 2x’s or wood I-joist as the spline mechanism. These longer overhang applications are created when the SIPs are perpendicular to the support wall and the SIPs extend back onto the roof to a support. Consult with SIP manufacturer for specific guidelines.

<u>SIP D-BP 3.9:</u> SIPs can act as their own header minimizing costs and maximizing thermal performance.

One of the inherent advantages of a SIP is that the wall can be used as a header to carry loads over openings in the wall. This not only minimizes construction costs but also minimizes thermal bridging that occurs when lumber structural support elements are required to act as a header to carry loads over an opening. The structural capability of the SIP wall to function as a header is a function of the opening size, the load to be carried, and the depth of the panel above the opening.

Some manufacturers provide header span tables in their code listing reports or in other technical literature. Table R610.8 of the 2018 IRC, excerpted in Table 3.1, provides recommendations for SIP header spans.

Table 3.1: Excerpt of IRC Table R610.8

MAXIMUM SPANS FOR 11-7/8-INCH OR DEEPER SIP HEADERS (feet)[a]

LOAD CONDITION	GROUND SNOW LOAD (psf)	Building width (feet)[b]				
		24	28	32	36	40
Supporting roof[c,d] only	20	4	4	4	2	2
	30	4	4	2	2	2
	50	2	2	2	2	2
	70	2	2	2	DR	DR
Supporting roof and one story	20	2	2	DR	DR	DR
	30	2	2	DR	DR	DR
	50	2	DR	DR	DR	DR
	70	DR	DR	DR	DR	DR

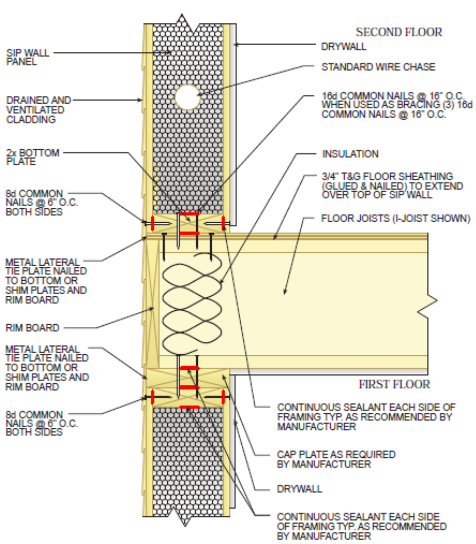
a. Design assumptions:
Maximum deflection criteria: L/240.
Maximum roof dead load: 10 psf.
Maximum ceiling dead load: 5 psf.
Maximum ceiling live load: 20 psf.
Maximum second floor dead load: 10 psf.
Maximum second floor live load: 30 psf.
Maximum second floor dead load from walls: 10 psf.
Maximum first floor dead load: 10 psf.
Wind loads based on Table R301.2(2).
Strength axis of facing material applied horizontally.
DR = Design Required.
b. Building width is in the direction of horizontal framing members supported by the header.
c. The table provides for roof slopes between 3:12 and 12:12.
d. The maximum roof overhang is 24 inches (610 mm).

In cases where a concentrated load is placed over an opening or the design loads exceed the capacity of the panel header, it is necessary to introduce built-up lumber or engineered wood framing to carry these loads. For typical situations, SIPs require the built-up headers to be placed directly beneath the top plate of the wall and the trimmer studs to extend up to the underside of the header. If required by the structural design, king studs can be added and attached to the trimmer studs. By using this methodology, the built-up header transfers the loads to the trimmer studs through bearing, and the SIP wall below the header transfers the wind loading to the king studs attached to the trimmer studs.

<u>SIP D-BP 3.10:</u> Wall SIPs may require a cap plate to meet high point load conditions.

SIP wall capacities are typically given in plf (pounds per lineal foot). This type of load description, plf, works well to determine the SIP wall capacity on a global scale. However, the designer is cautioned to review the load path from structural elements that are transferring load to the SIP wall. The localized loading that these structural elements transfer to the SIP wall may exceed the capacity of the wall and require the addition of a cap plate to provide additional localized capacity at the load transfer point. Refer to Detail 3.2 showing the cap plate on the lower level wall supporting the floor joist.

Detail 3.2



2ND FLOOR CONNECTION DETAILS

RIM BOARD

Glossary of Terms

ANSI: American National Standards Institute (www.ansi.org) is a private, not-for-profit organization dedicated to supporting the U.S. voluntary standards and conformity assessment system and strengthening its impact, both domestically and internationally.

APA: APA – the Engineered Wood Association (www.apawood.org) is a nonprofit trade association helping the industry create structural wood products of exceptional strength, versatility and reliability.

ASHRAE: the American Society of Heating, Refrigerating and Air-Conditioning Engineers (www.ashrae.org) is an American professional association seeking to advance heating, ventilation, air conditioning and refrigeration systems design and construction.

Cap plate: lumber ripped to the width of the panel that bears on the top of both facers of the SIP below. Not a top plate; it bears on the top plate. For illustration, refer to Figures 2.1 and 2.2 in Chapter 2.

CLT: cross-laminated timber, an engineered wood product.

Dimensional lumber: wood lumber that is cut to pre-defined, standard sizes (e.g., 1-inch x 4-inch, 2-inch x 4-inch, etc.).

Engineered lumber: wood products which are manufactured by binding or fixing the strands, particles, fibers, or veneers, or boards of wood, together with adhesives or other methods of fixation, to form composite material. Examples include glulam, Parallam, CLT, I-joist, LVL and rim board.

HERS: Home Energy Rating System. The HERS index measures energy consumption from heating, cooling, water heating, lights, and some appliances. The lower the index, the less energy a building is consuming. A HERS rating of zero signifies a net-zero energy building.

HVAC: heating, ventilation and air conditioning.

IAQ: indoor air quality.

IAPMO: International Association of Plumbing and Mechanical Officials (www.iapmo.org) works in concert with government and industry to implement comprehensive plumbing and mechanical systems around the world.

IBC: the International Building Code is a model building code developed by the International Code Council (ICC). The code provisions are intended to protect public health and safety while avoiding both unnecessary costs and preferential treatment of specific materials or methods of construction.

ICC-ES: International Code Council Evaluation Service (www.icc-es.org), a subsidiary of the International Code Council and a nonprofit, limited liability company that does technical evaluation reports of building products, components, methods and materials.

ICC NTA, LLC: a subsidiary of the International Code Council acquired in 2019 providing third-party testing, inspection, code evaluation, certification, and plan review (www.ica-nta.org).

I-joist: strong, lightweight, "I" shaped engineered wood structural members used extensively in residential and light commercial construction projects.

Intertek: a multinational assurance, inspection, product testing and certification company headquartered in London, United Kingdom.

IRC: International Residential Code. The IRC addresses the design and construction of one- and two-family dwellings and townhouses not more than three stories above grade, establishing model code regulations that safeguard the public health and safety in all communities, large and small.

ISO: International Organization for Standardization, a standard-setting body composed of representatives from various national standards organizations, promoting worldwide proprietary, industrial, and commercial standards.

LVL: laminated veneer lumber, an engineered wood product.

OSB: oriented strand board, a wood structural panel.

PLF: pounds per lineal foot.

SIPA: Structural Insulated Panel Association (www.sips.org), a non-profit trade association representing manufacturers, suppliers, dealer/distributors, design professionals and builders committed to providing quality structural insulated panels for all segments of the construction industry.

SIPs: Structural Insulated Panels, a high-performance building component for residential and light commercial construction.

Spline: connection system used to connect two panels together at vertical, in-plane joints. Many different spline systems are available including box/block, surface, I-joist, dimensional lumber and engineered lumber.

Thermal bridging: the movement of heat across an object that is more conductive than the materials around it. The conductive material creates a path of least resistance for heat. Thermal bridging can be a major source of energy loss in homes and buildings.

Top plate: a horizontal member positioned between the SIP facers above the foam. Sits under the cap plate. For illustration, refer to Details 3.1 and 3.2 in *SIP Design Best Practices 3: Structural Capabilities*.

WSP: wood structural panel; plywood or OSB facers used to laminate to foam, to form a composite SIP.