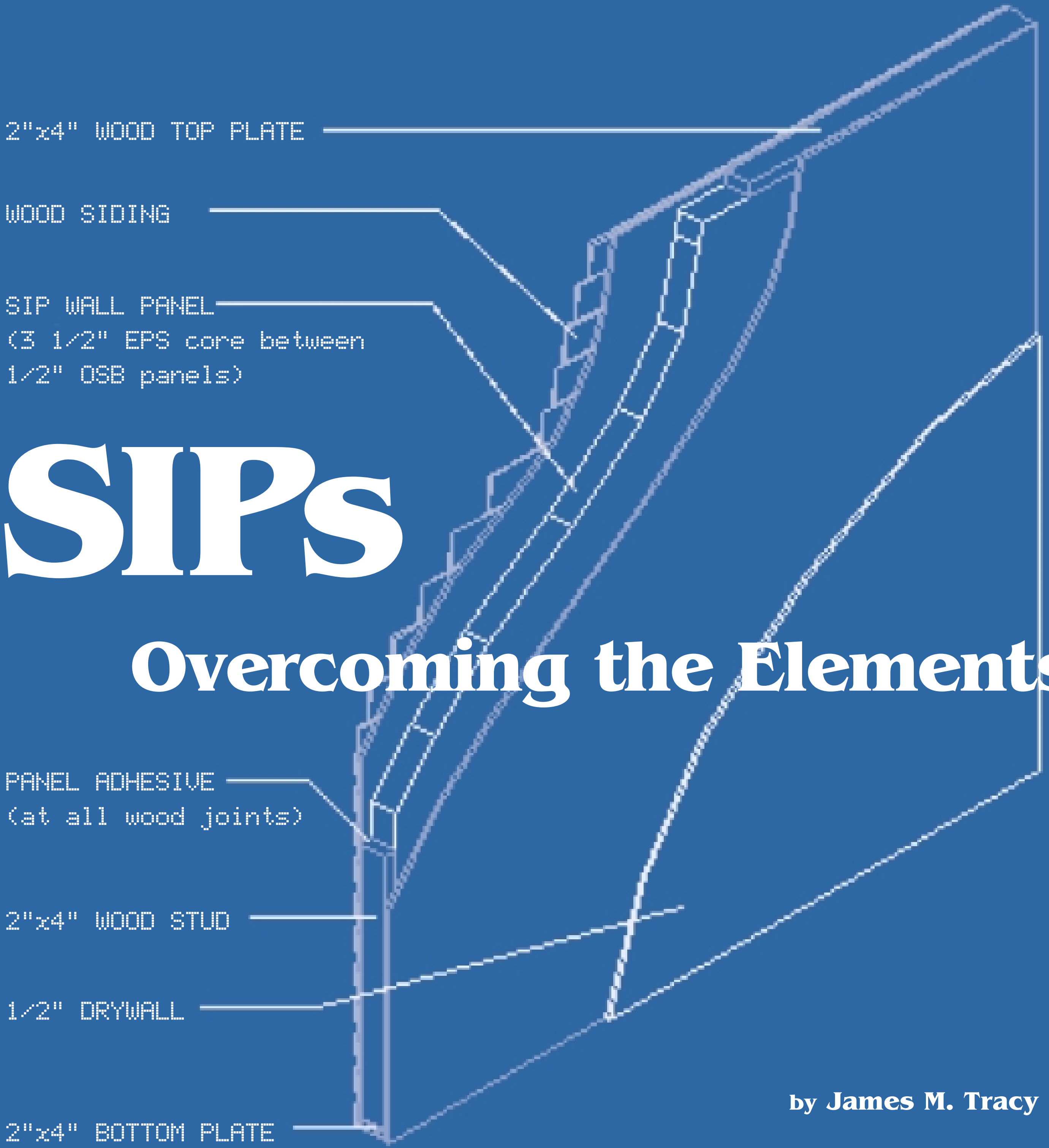
SIPs

Overcoming the Elements



by **James M. Tracy**

Structural insulated panels, commonly referred to as SIPs, have fought the elements of extreme climates and every kind of natural disaster and come out on top. Now they are fighting the elements of the human kind: resistance to change and complacency within the construction industry. It would appear from their growth pattern over the last few years that these products are now gaining the upper hand there too. SIPs are a composite assembly of an unlikely combination: wood and plastics. One would have to search hard to find more unlikely partners, but the unique attributes of the components yield a remarkably strong and stable final building product. SIPs are found where one would expect to see 2 by 4's, rafters, or joists, but there are significant differences between this engineered wood framing system and traditional systems.

SIPs are not new; they have been used in many limited applications since the 1940s. Their popularity has increased dramatically over the last decade primarily due to the remarkable savings in labor costs and the shorter construction time. Prior to that, they filled niches, like curtain walls and short-span roofs over timber-frame construction. They also found limited success in subdivisions that were developed jointly by SIP product manufacturers and pioneering builders. Some manufacturers, now in their third decade of producing SIPs for residential and light commercial construction, have created regional markets where houses that utilize SIPs are the norm. The industry has also pulled together to form its own trade association and is promoting the positive aspects of this system referred to as "the Pentium chip of the construction industry" by a lumber material retailer magazine.

What are SIPs?

SIPs are engineered wood products resulting from a controlled environment lamination of high performance rigid insulation and oriented strandboard (OSB) skins. They can either be viewed as a component of construction or an entire building system. The most common use of these products is exterior wall panels (Fig. 1). They are also frequently used as roof panels to create a vaulted or cathedral ceiling. SIP floor panels are usually only found in places where floors separate the occupants from unconditioned spaces, like crawl spaces and tuck-under garages. SIP ceiling panels can be found in the desert southwest where flat or low-slope roofs are more common. When SIP components are combined into a system, they create an unusually strong and energy-efficient building envelope. Panel sizes are limited by the size of the skins. The most common single-piece panels are 8 feet by 24 feet; mills that are currently constructing continuous mat lines or larger presses will soon be producing larger SIPs.

The panels are cut in the factory and shipped out as fabricated construction walls or houses to be assembled rather than pieced together like traditional framing. SIPs use the same tools as traditional framing and subcontractors have had an easy time learning to utilize SIPs; the learning curve is very short.

Where are SIPs Used?

While the northern tier of the United States was the first region to really embrace SIPs, they have found their way into virtually every North American market. Most manufacturers report significant exports. The Pacific Rim, Canada, and Mexico are the highest export destinations, but SIPs from North America have found their way to the Eastern Block countries, many parts of Western Europe, and both Central and South America as well.

Light-frame commercial and residential structures are the most prevalent users of SIPs. In the residential market, the most frequent user is the custom homebuilder who seeks higher quality and has a need to control escalating labor costs. More builders who are production-oriented have now taken note and several have begun to use SIPs in subdivision work. During the mid-1990s, the second fastest selling subdivision in California was built entirely with SIP walls.

Figure 1. Fabricated SIP wall panels. (Photo courtesy of SIPA.)

Senior housing has also become a growth market for SIPs. The climate-control and draft-free environments have become selling points in both short- and long-term health care facilities. SIPs are attractive to investors in senior housing because they have a positive impact on energy cost, which is the third highest cost of ownership, after debt service and labor.

Nonresidential uses are on the rise. The short time it takes framers to complete a weather-tight shell using SIPs allows the other trades to start and finish their work more quickly. SIPs have been used to construct restaurants, schools, churches,

Figure 2. Pine Crest Elementary School, Bremerton, Wash., is an example of a nonresidential building constructed with SIPs. (Photo courtesy of SIPA.)

motels, office buildings, and many other mixed-use buildings (Fig. 2).

Other industries that require close environmental control and temperature consistency are beginning to be big users of SIPs. Fermentation buildings in wineries are a good example because close control over temperature is vital to the vintner's success. Panelized produce storage buildings require smaller HVAC systems and spoilage is reduced when optimal temperatures are maintained.

Why are People Choosing SIPs?

There are many diverse reasons for using SIPs and the reason depends upon who the decision-maker is. Design professionals appreciate the predictable performance of SIPs. Destructive product testing coupled with the engineering assistance that most manufacturers provide create the security that comes from an engineered systems approach and a well-documented manufacturing process. The designer also benefits from clients that are happy with the performance of their home or building. Lower energy costs might not be a significant thing on the front side of construction, but it is a constant reminder of the designer's good decision. That creates word of mouth business for the architect or engineer involved in the project.

The single largest issue in construction today is labor. The current low unemployment rate has created a crisis in the construction trades. That low labor supply has escalated costs and lead times for quality framing. With the average age of today's carpenter increasing, it becomes obvious that less young people are entering the trade. Further, those who are in the trades at the beginning portion of their careers have fewer journeyman level carpenters to learn from. With the decrease of experienced framers and housing demand at record levels, something has to give. Therefore, SIPs are a natural asset to the contractor because framing decisions are made by computer-aided drafting and executed in a plant environment. Assembly, rather than interpretation of plans, means that fewer framing errors are made on the site. Lower-skilled personnel can handle SIP assembly, with only a good lead person required to keep the job on track.

The flat surfaces provided by a solid OSB backing also yield benefits to the builder. Flat walls mean no shimming of drywall and easier installation of the drywall because there are no studs to hit, or miss. Because SIPs do not require studs, nail pops from missed studs and stud shrinkage are eliminated, which means fewer homeowner call-backs for repairs. Cabinets and countertops also fit against a SIP wall without the required scribing to the irregular wall surface that studs create due to twisting, warping, and cupping. Siding also benefits from not following the convoluted surface created by traditional framing.

Similar to the designer, the contractor also benefits from increased home or building owner satisfaction. The construction business becomes a better world when you have happy clients. Word of mouth is still at work when a builder puts a superior finished product out in the marketplace.

Consumer interest has been extremely high in terms of the attraction to SIP methodology. The grass roots interest has swelled, making "pull through" marketing through dealers, designers, and builders a reality for the producer. SIP manufacturers are bringing consumers to their regional stable of specifiers and builder customers. This is due in large part to the large custom home visibility that was one of the initial big niches for the panel maker. The benefits of energy efficiency were another draw for consumers who are, according to recent demographic studies, staying in their houses longer. Many SIP homeowners also report that their houses are much quieter than similar homes that do not incorporate SIPs. This is not borne out by the sound transmission class testing, but may be the result of a more airtight structure and other energy efficiency options selected by the builder or architect, like a better grade of window. Federal programs like "Energy Star Homes," through the U.S. Department of Energy, have also fostered a renewed interest in energy-efficient construction. The PATH (Partnership for Advancing Technology in Housing) program has also featured SIPs as one of its advanced technologies. These programs have helped validate the burgeoning consumer desire for a better home or building.

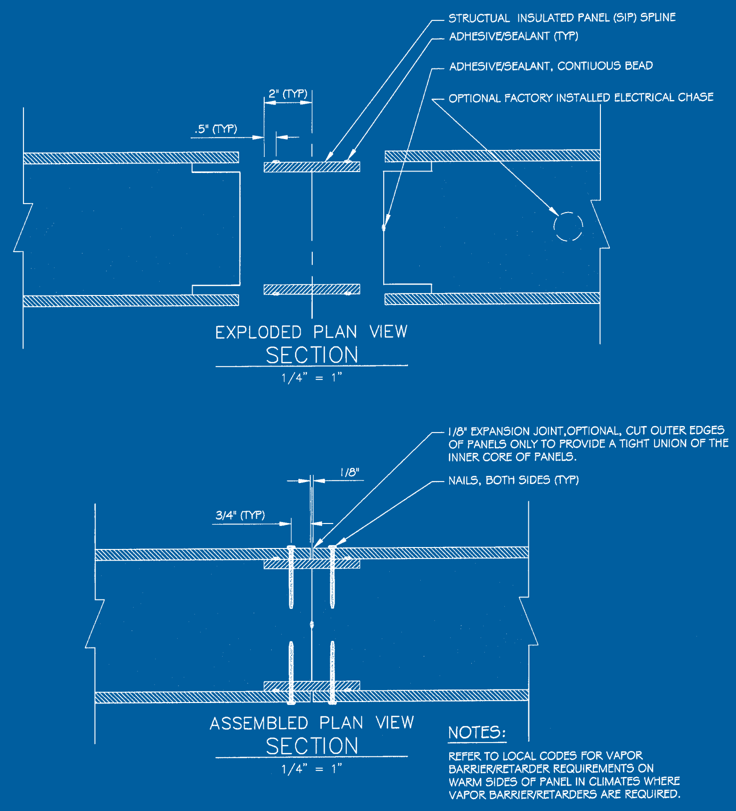
How Do SIPs Work Structurally?

SIP structures have endured through natural disasters and exceeded engineering expectations. The SIP structures that were subjected to the earthquakes in Northridge, Calif., and Kobe, Japan, showed superior resistance to seismic damage. Structures in areas hit by Hurricanes Andrew and Iniki displayed high wind resistance. Recent world record snowfalls in both the Cascade and Rocky Mountains showed that SIP structures could withstand three times the design load without drywall cracking. There are many anecdotal stories that are a testament to SIP design and engineering, but the values derived from structural testing were what allowed these dramatic successes to occur.

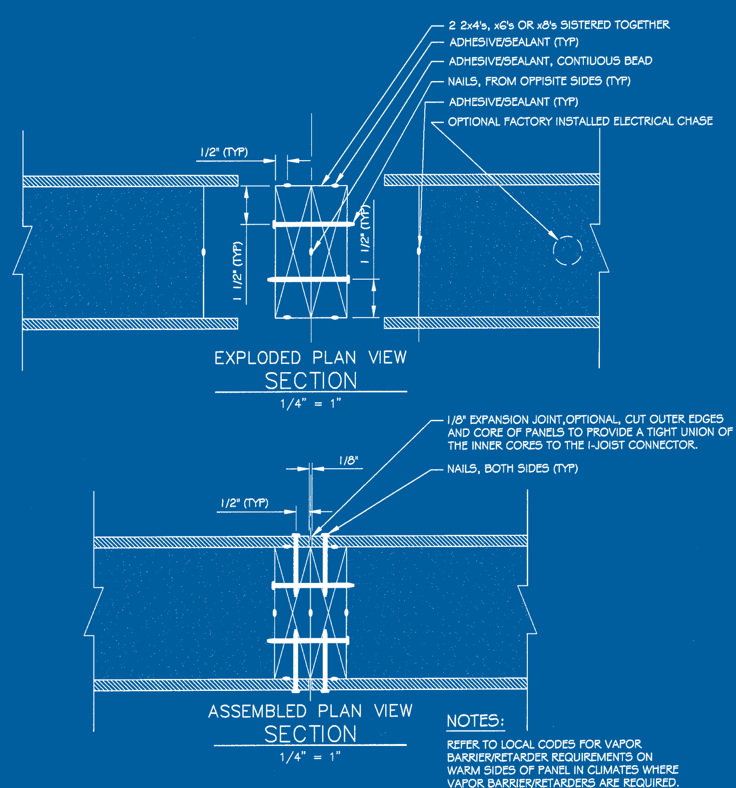
SIPs must complete a significant battery of structural testing that is destructive in nature to achieve any level of major model code listing. Most of the testing is done according to *ASTM D-1803, Test Methods for Determining the Structural Capacities of Insulated Panels*. Among the basics are transverse load tests under ASTM E-72, which uniformly load the panel in a flat plane and measure deflection. The top skin is in compression while the bottom skin is in tension. The predominant mode of failure is deflection, so lumber or wood I-joists are used as connecting splines when spans exceed the deflective capacity of the SIPs. The stiffness of the spline allows spans far greater than the SIP could produce without the onset of cold creep, or compression set (Fig. 3).

Axial loads generally exceed 2,000 plf with a single 2-by top plate that sits in a cavity between the skins. The load capacity almost doubles, however, when a cap plate that puts the skin edges in a load-bearing condition is installed. The cap plate is wider than the lumber plate by the thickness of the two skins (Fig. 4).

Some manufacturers have combined axial and bending (transverse) testing while others have



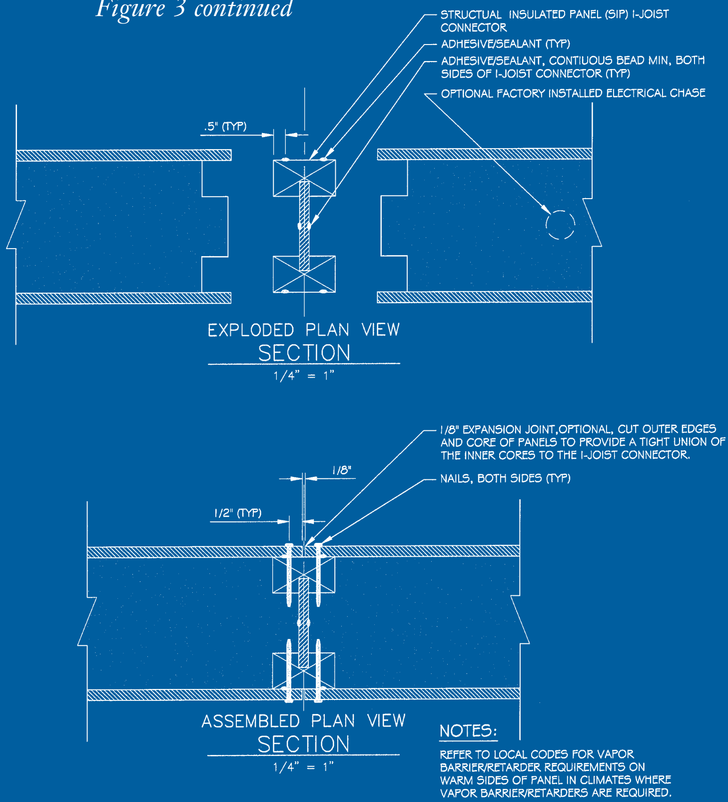
a plan view of double spline connection;



b plan view of sistered union connection

Figure 3. Spline connecting options.

Figure 3 continued



C plan views of I-joist spline connections.

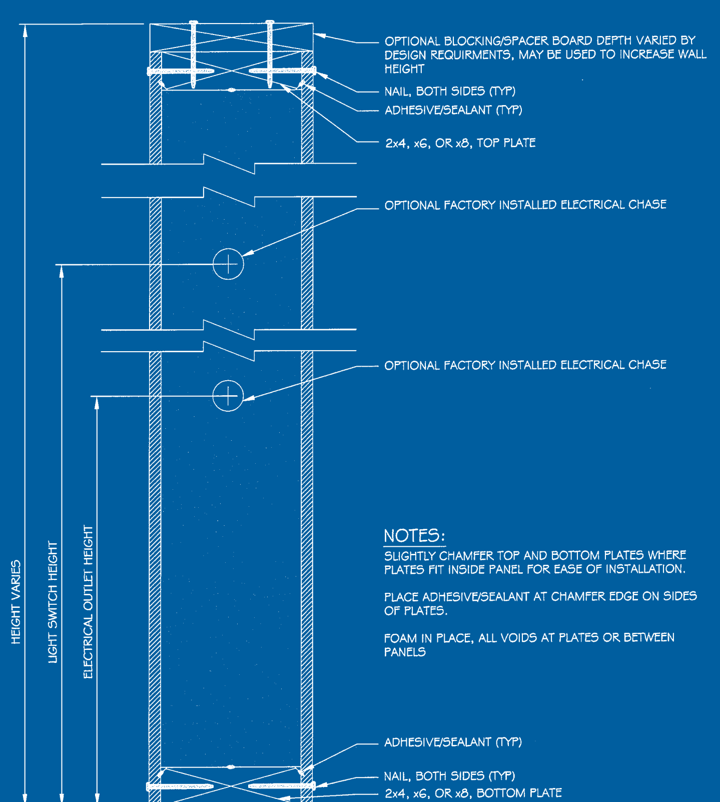


Figure 4. Panel-to-bottom and top plate connections.

employed the unity equation for specific system design. Manufacturers will supply code reports and/or load design charts for individual designs and projects.

Racking shear testing typically shows that SIPs can withstand more than 300 plf shear load, but this level can be increased with the addition of more fasteners at the panel's perimeter. Diaphragmatic test results show 750 plf by virtue of long screw fasteners that are installed all the way through the SIP into the underlying structure. In the case of a roof, this might be a ridge beam or purlin system. Tightening up the fastener frequency can also increase the diaphragmatic resistance.

How Do SIPs Respond in a Fire?

My personal experience has convinced me that SIPs are very durable in fire situations. I witnessed a blaze near Omaha, Neb., and the aftermath of a propane explosion and subsequent fire in Portland, Oreg., and the SIP structures performed very well. Manufacturers across North America have proven the fire performance of SIP systems through some of the most extensive fire assembly testing in the construction industry. The results of this destructive testing allow documentation of SIP performance under rigorous test standards. National standards like ASTM-E119 and ASTM-E84 have been met by protecting SIPs in a similar fashion as other wood-based structures.

Residential structures are typically required to meet a 15-minute standard and they can meet that standard by installing 1/2-inch common gypsum over SIPs (Fig. 5).

Light commercial and multi-family structures can be required to meet the more restrictive 1-hour fire resistive standards. Some of these prescriptive assemblies are listed in the *UL® Fire Resistive Assembly Manual,* and they can be summarized as follows:

1. Two layers of 5/8-inch "type X" gypsum, attached per the manufacturer's code report, on SIPs with various connections.
2. One layer of 5/8-inch "type C" gypsum, attached per the manufacturer's code report, on SIPs joined with dimension lumber or solid engineered wood products 48 inches on center or closer.

As with any fire resistive issue, the local jurisdiction requirements will vary by region, building classification, and structure occupancy. The design professional involved should contact the local building and fire departments to determine

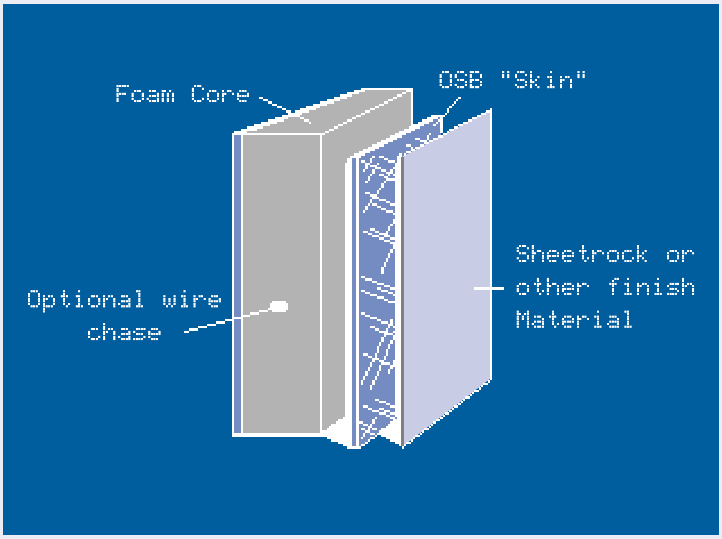


Figure 5. Gypsum over SIP.

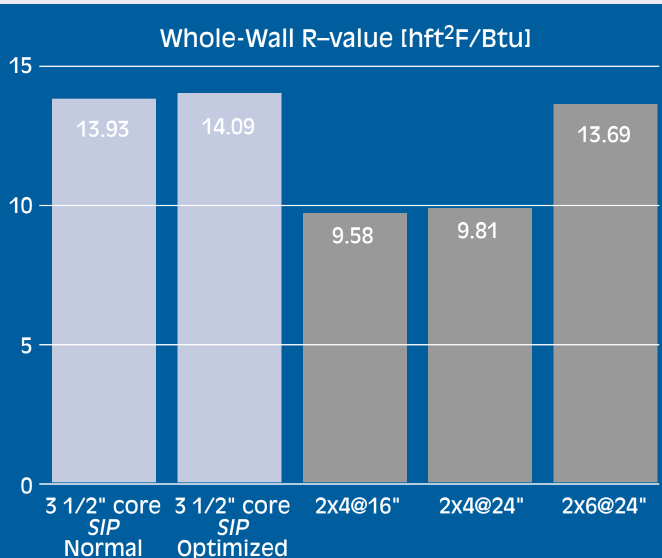
those local requirements and to ensure compliance with local and national codes.

How Energy Efficient are SIPs?

An impressive example of the energy efficiency of SIPs is the "Energy Diet Home" built by the municipal utility in Brigham City, Utah, in 1988. This house used 8-inch SIP walls and 4-inch SIP ceiling panels with mineral insulation blown on top of them in a truss cavity. The 1200-ft.[2] home was designed with the goal of being under $100 per year to heat, all electrically. The first year total heating cost was $54.80.

Oak Ridge National Laboratories (ORNL) recently completed testing for the Structural Insulated Panel Association (SIPA) that proved a 4-inch SIP wall had a higher whole-wall and clear-wall R-value than its more traditional 6-inch counterpart: stick framing (Fig. 6). Because SIPs are the structural elements, there are no studs or braces to cause interruptions in the insulation value. The final result is a more comfortable, energy-efficient structure that performs up to specifications in real-world conditions. Unlike stick-and-batt construction, where insulation can be poorly installed or completely missing, SIPs insulation is integral to the product. It cannot be forgotten or removed by another subcontractor.

By contrast, state-of-the-art technical analysis of whole-wall performance indicates that the losses in a stud wall are much greater than you might anticipate: on average, the other standard components in stick-and-batt construction can reduce R-values in as much as 30 percent of the wall surface area. Fortunately, that's not the case with SIPs. The ORNL study found that SIPs perform at approximately 97 percent of their stated R-value overall, losing only 3 percent to nail holes, seams, splines, and the like. Wiring chases are precut or preformed into the foam core, which allows an unbroken layer of insulation. SIP walls also outperformed stick-and-batt walls when it came to maintaining consistent interior temperatures, and that translates to improved occupant comfort. As shown in Figure 7, the interior surface temperature of frame construction drops precipitously at every stud, while the SIP wall remains consistent across its entire surface. No temperature dips means improved occupant comfort, regardless of where you are in the room. That's a big part of what people are talking about when



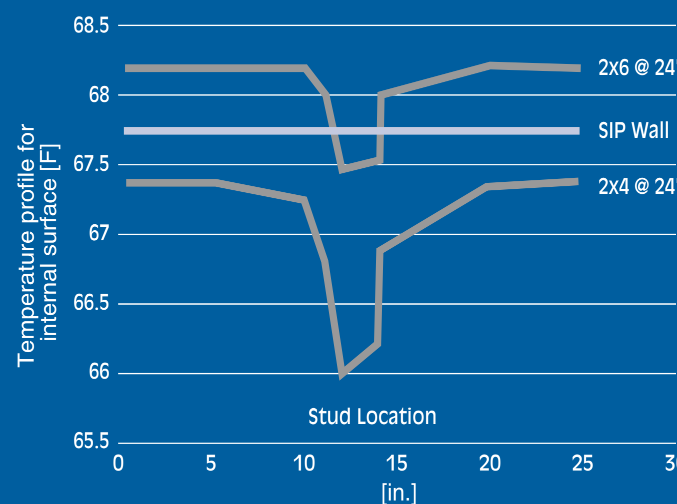


Figure 6. Comparison of whole-wall R-ratings.

Figure 7. Comparison of interior wall surface temperatures.

they say they can immediately "feel the difference" in a SIP-built residential or commercial space.

How Much Do SIPs Cost?

This is a tough question to clearly answer. Some builders charge the home buyer the same for SIP construction as they do for traditional framing; other builders charge more. It is difficult if not impossible to compare the cost of SIPs and traditional framing because of the volatility of the commodity lumber market. Some builders feel that the long-term inventories maintained by SIP manufacturers allow them to purchase directly from the mill and hedge pricing slightly while cost-averaging instead of price-shifting to the customer.

The series 2000 McDonald's restaurants are a classic example of how SIP construction can be advantageous. If the project can be finished only 1 week faster because of SIP construction, the McDonald's franchisee has an extra week to let the cash register ring. One extra week of revenue could offset the entire cost of the SIPs.

How are SIPs Made?

SIPs typically have three components: OSB is sandwiched over rigid foam insulation that has been coated with structural grade adhesive. The most prevalent method is a permanent cold press bonding done under pressure that drives the adhesive into the small spaces between the cells of the expanded polystyrene (EPS) foam. The adhesive that is driven into the foam then creates a permanently bonded mechanical link between the EPS foam and the OSB. SIPs then stay in the press about 1 hour so the water-based adhesive can cure. The two-part adhesive, an emulsion polymer isocyanate, becomes an inert plastic that displays remarkable resistance to moisture, temperature, and environmental degradation. Another adhesive that is common is the moisture-cured urethane that uses a nip roller or cold press while the adhesive cures.

Another method is to foam in place between the OSB skins with urethane (either polyurethane or polyisocyanurate) liquid foam that expands to fill the void between the skins. The urethane then cures quickly as it exits the production line between fixed platens that control its expansion. The adhesive properties of the foam itself create a permanent bond between itself and the OSB.

By far, the most common method is cold pressing utilizing both EPS and OSB as substrates, but plywood is sometimes used and urethane's slightly higher R-value has created a loyal following.

What Are the Challenges?

The SIP industry is somewhat fragmented with regional manufacturers fighting regional battles. Because they are generally smaller companies, they operate much the same as regional truss or I-joist manufacturers. The industry needs to develop a set of cohesive national product standards that would reduce the burden of individual testing of proprietary products for individual code listing.

Acceptance by the construction community can be a problem, but as savvy builders start to examine total project costs instead of simply material prices, acceptance will increase. This should accelerate further as the labor crisis intensifies. Perhaps the best advocate for SIPs is the competitive builder who is making money while using SIPs. Success is the greatest motivator to change builders' minds and now many builders are reporting fiscal improvement based on the use of SIPs in their business.

Just as with any high-performance construction system, mechanical ventilation of the structure is required. Heat recovery ventilators or air-to-air heat exchangers are a great idea in any home, and are rapidly becoming included in building codes as indoor air quality attracts more attention from the public and the consumer alike. To prevent problems related to wood-boring insects like termites and carpenter ants, the foam core can be treated with a deterrent, like borate, and a metal insect clip should be installed at the top of the foundation. Another approach is to use borate-treated OSB in the panel skins. Like the treated EPS, the skins can be incorporated easily into any lamination process and should be considered if the building site is a likely source of infestation. Because the borate is encapsulated in the manufacturing process for both the skins and the core, it will be an effective deterrent for many years.

While the true cost of SIP construction has been very difficult to track, even by builders who build both ways, the general consensus is that SIPs are still slightly more expensive than traditional framing. SIP manufacturers must put forth a marketing effort in order to generate more volume, which will allow them to benefit from economies of scale and be more cost competitive with traditional systems.

The SIP industry is a growth industry that has prospered and endured throughout several building cycles. It has encountered and conquered the difficult embryonic product life cycle that has killed many building products. SIPs can very effectively withstand nature's elements and they are also conquering the human element: resistance to change. SIPs are here to stay!

For more information on SIPs, visit the SIPA website: www.sips.org

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