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Structural Insulated Panels (SIPs) - The Home Building Industry's "Hybrid"

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A ToolBase TechNote

Building on their approximate one percent share[1] of the U.S. residential building products market, structural insulated panels (SIPs) could be the residential home builder's sleeper equivalent to the automotive industry's hybrid car. Properly detailed designs for SIP construction can create economies of scale that may make SIPs cost-neutral in comparison to conventional light frame practices and real dollar savers over the life of a home.

SIPs are more uniform in composition than conventionally-framed walls, so houses built with this technology can be made more air tight, energy efficient, and comfortable with fewer labor hours and trades involved in system integration. Like hybrid car owners, SIP homeowners will spend less money at the meter, stretching their energy dollars, because SIPs can provide a tighter building envelope with a nearly-continuous thermal barrier.

The Latest Model off the Assembly Line

SIPs are engineered, factory-produced, load-bearing components that consist of foam bonded to oriented strand board (OSB) panels[2] with structural adhesives similar to those used for other engineered wood products. SIPs can be used as walls, roof, and floor assemblies that provide strength and stiffness to a structure and facilitate longer clear spans than can be achieved with conventional framing.

SIPs are designed with foam cores that vary from 3 ½ to 11 ¼ inches dependent on structural application and climate of construction. The thicker the panel, the greater its thermal resistance and ability to span longer distances between load transfer points. In addition, the foam interior of a SIP has a low permeability rate and high resistance to air and water penetration. This means that controlling air infiltration and restricting the natural tendency of warm air to move toward cold air, as well as shedding liquid water, can all be managed by a building envelope that is put together using SIPs.

Three for the Load

The OSB sheets on the outside of the panels are rated for structural adequacy, dimensional stability, and bond durability[3]. Racking strength, bending stiffness and strength, uniform load capacity, and fastener holding capabilities have all been performance tested for each thickness of a rated panel. The foam sandwiched between the OSB sheets is usually expanded polystyrene (EPS) that has a stated density, thickness, R-value, and compressive strength. The materials, adhered and set under pressure, form a strong, homogeneous, structural panel. Polystyrene foam is dimensionally stable and inert - there is no off gassing. In addition, EPS material emits no ozone-depleting chemicals during the manufacturing process.

The two OSB skins, stiffened by the adhered foam between them, can outperform a conventionally built wall of similar dimension in carrying typical light-frame loads - axial loads

transferred by floors, walls, and roof above and wind, or transverse loads generated during storm conditions.

Designers may be able to provide solidly engineered structures for wind hazard areas with SIPs without increasing the wall thickness. Roofs and floors constructed with SIPs can be engineered similarly. High wind and seismic connections call for an exacting combination of properly attached dimensional lumber splines and hardware.

Fuel Savings

SIPs are homogenous with continuous foam from panel edge to edge. The EPS foam typically used in these insulated panels has an R-value range of 3.6 to 3.8 per inch, or a minimum of R-12.6 in a 4 ½-inch SIP. On its face, this may seem comparable to an R-13 fiberglass batt in a conventionally framed wall, however, unlike in SIPs construction, a lot of a wood wall is wood, not insulation. As an example, an 8-foot by 24-foot conventionally framed wall section, without openings, has 19 studs and 72 lineal feet of plates, or 27.33 square feet of wood surface that precludes insulation placement. Therefore, 14 percent of the wall, in this example, contains an R-4.38 solid wood stud instead of an R-13 batt. A comparable SIPs panel, with wood on the edges only, reduces by 71 percent the area where wood displaces insulation in a conventional wall. This means that whole wall thermal resistance is higher in a wall built of SIPs[4].

Schedule a Test Drive

Panel manufacturers have the capability to develop a SIPs-based plan from a conventional blueprint. The process of SIPs assembly will become familiar by reading the manufacturer's Installation or Design Guide[5]. During that Assessment of the process of framing a house with closed panels, the systems that require thoughtful integration, and design or layout efficiencies that might enhance the end product will surface while performing this background check and provide discussion points when handing off plans for a quotation.

Panels can be made in sizes up to 9-foot by 24-foot and are as versatile as conventional frame construction in accommodating custom designs. Each weighs between 3 and 4 pounds per square foot. A builder wanting to maximize the thermal efficiency of a SIPs structure will incorporate the longest panels that can be used in the design. A 24-foot a panel weighs around 600 lbs., so a crane would facilitate panel installation.

Structural insulated panel to panel and SIP to deck connections usually require the recessing of a dimensional member, like a 2-inch by 4-inch stud, into the edge of the SIP. These edge studs are adhered to the foam and then the overlapping OSB of the panel surface is face nailed to the inset stud. This solid wood edge band then becomes the nail surface for attachment to other panels, decks, and floor assemblies. Alternatively, connections at vertical panel edges can incorporate an OSB spline rather than a wood stud as the connector. Gutter spikes and long screws provide the connections at corner intersections.

Door and window openings can be cut with laser layout precision in the factory or customized in the field. The cleanest opening cuts can be made by routing the OSB and hot wire cutting the foam, but reciprocating saws have also gotten this job done, just as they have for conventional framing. Openings for doors and windows that exceed 3.5 feet (dependent on the depth of material that remains above the opening in the SIP panel) and excessive point loads require additional structural framing that is most efficiently accomplished by butting the SIPs to either side of a wood-framed opening. Structural insulated panel sections can be fit around the structural framing of large openings, like a curtain wall.

Customization that speeds field assembly, like routing foam for the connector (stud or spline) recesses at panel edges and installing the studs (and wire holes) at panel edges and window and door openings, can often be added by the manufacturer. Panel foam can be expanded with a termiticide for use in areas of heavy termite infestation. Ask about the additional costs and weigh the value to your team. Interior walls are more cost effective if conventionally framed with either wood or steel.

Manufacturers that file an ICC-ES legacy report have presented test results on the characteristics of their product(s) and are required to have a third party certified quality assurance program in place in their facility. Secure a copy of the ICC-ES report to be assured of the panel's capability to perform.

Notify the building inspection department at the time of building permit application, or sooner, that structural insulated panels will make up the building's framework. Reviewers may request panel specifications, engineer's seal, load tables, assembly and connection details, an ICC-ES Legacy Report on the SIP, or other information. The manufacturer or distributor should be able to furnish these. Keep copies on the job for installer's and inspector's use.

Will Your Trade Contractors Enjoy the Ride?

SIPs are most cost effective as exterior bearing walls in most climates and roofs in cold climates. Regardless of wall system employed, it is best to keep pipes and ducts out of outside walls. Like wood, these conduits displace insulation in the cavity and compromise the efficiency of the thermal envelope. Knowing this, assume that your HVAC and plumbing trades are unaffected by a SIPs change to the exterior envelope, and then follow through accordingly.

For instance, if the design uses SIPs for the roof, divert all plumbing and combustion equipment stacks through sidewalls which are simpler to detail against leaks. Use complimentary technologies like air admittance valves to minimize vent stack lengths, as well as envelope penetrations. Work with your mechanical contractor to devise an economical ventilation and air exhaust strategy that uses an inline fan and one exhaust port serving multiple bathroom fans on timers. Remember that all state-of-the-art airtight structures require a method to introduce fresh air and to vent water vapor that is sourced within the home. Ventilation and combustion duct penetrations through the exterior wall should be through floor system rim boards and not the SIPs panel, whenever possible.

The electrician is the primary trade affected by a change to SIPs. For convenience wire chases are formed in the panel during the manufacturing process. Verify their location with your manufacturer prior to production. Usually there are one vertical and two horizontal chases in every 4 feet of panel. Horizontal chases are located at receptacle and switch height in the middle of the panel thickness, and 1 - 1 ½ inches in size. The location of the chase in a 4 ½-inch SIP is consistent with the "...1.25-inch free space for the full length of the groove in which the cable or raceway is installed..."[6] requirement for unshielded wire clearance in the International Residential Code (IRC®). Wiring that is directed through these pre-manufactured chases should not require additional protection, but review details with your code official beforehand.

Limit exterior wall wiring to feeding receptacles, switches/lighting located there. Plan receptacles for the minimum required - one every 12 feet ("...so that no point along the floor line in any wall space is more than 6 feet, measured horizontally, from an outlet...")[7]. Feeds to other levels of the home should be planned through conventional floor or interior wall assemblies. It may be more practical to conventionally frame the exterior wall where the electrical service panel is mounted to allow for the numerous wires that will be installed in that wall.

Receptacle and switch boxes are installed above the chase that is molded into the SIP. Electric boxes should be cut out before wire is pulled. A panel router and a hot wire cutter are used to cut the OSB and foam for receptacle boxes. Surface-mounted fasteners are the simplest method of mounting the boxes and narrow-depth or "remodeler" boxes are suggested. SIPs installers should locate and drill the chases through panel edge studs and plates, so the chase remains accessible. Fish tape or other semi-rigid snaking rods and a crew proficient in running wire in remodeling applications will make easy work of rough wiring the SIP walls.

Drywall can be glued and fastened (with nails or screws) directly to the interior OSB surface of the SIP. Vertical drywall seams should be offset from structural insulated panel seams.

Exterior siding or masonry veneer can be applied to a SIP similarly to stud-constructed walls. Because fasteners will be embedded in the 7/16-inch OSB sheathing only, review of the cladding manufacturer's attachment requirements and the OSB fastener withdrawal strengths is advised. In some high wind areas, horizontal lapped siding may require both blind and face nailing on prescribed spacing for proper attachment to SIPs[8].

Wall cabinets require similar planning for total load when attaching these to SIPs. The cabinet will need a structural rail that is continuous along the back. The cabinet rail will provide adequate locations for screw attachment. Fastener spacing will depend on cabinet size and maximum planned capacity of the unit.

Window and door jambs will fit in SIPs openings similarly to the fit in a conventional wall of like dimension - i.e., 4 ½" structural insulated panel nets the same overall wall thickness as a 2-inch by 4-inch wall sheathed with 7/16-inch material.

What's Down the Road?

Unlike some of the new wall technologies like insulating concrete forms (ICFs) and light gauge steel (LGS) framing, the International Codes and older model building codes do not contain specific language about building with SIPs. That means that the more than 14,000 buildings [9] that are constructed with SIPs annually are individually engineered and reviewed at permit application in a case-by-case approval process.

HUD's Partnership for Advancing Technology in Housing, (PATH) is sponsoring initiatives that will serve to advance SIPs use by facilitating model building code recognition of standard methods for SIP construction. Known as Prescriptive Methods, these works provide guidance

that enable designers, builders, and code officials to easily determine how panels should be used and connection requirements in residential structures, easing the tediousness of design and inspection. A draft prescriptive method for building with SIPs should be completed by the end of 2005. It will take several years after completion to vet the document for model building code inclusion.

More Money Maximizing Strategies

SIP floors can work well over unconditioned crawlspaces and garages. Or, traditional floor system rim joists can be engineered as flush headers to maintain thermal continuity in the wall; a practice that generally saves labor. As with Advanced Framing techniques, a design that capitalizes on the spanning capabilities of SIPs will provide the most cost effective approach. Some roof panels can clear span up to 15 feet.

Electrical raceways will speed wire installation, maintain the thermal integrity of the wall, and facilitate remodeling efforts. Raceways currently used in commercial applications can be surface mounted as baseboards or flush-mounted to the finished floor surface. Switch wiring at exterior entrances can be designed into a raceway built behind the jamb and the door trim.

Adhesives are best for wood to wood seals. Foam sealants provide the best bond between foam and wood. Siliconized caulk or manufacturer's tape should be used to seal panel butt edges, as per manufacturer's recommendations.

Caveat Erector

Structural insulated panels are factory built to exacting standards - irregularities in the foundation/sub assembly will make panel installation difficult. The panel's strength is derived from the three layers of the wall working as a system, so full bearing across the wall and including both OSB layers is required.

All mechanicals that penetrate exterior SIPs walls should be minimized or eliminated entirely. Wire chases must be continued (drilled) through the plate and stud edges by the panel erector as they will be difficult to locate after installation. Recessed fixtures should not penetrate SIP panels. Continuous horizontal slits or large openings in either of the OSB skins will compromise the structural capacity of the SIP.

The characteristics that make SIPs a good choice as a thermal and air barrier will also work to trap water and water vapor in the wall. Best practices in detailing the structure-foamed and taped panel edges, mechanical flashings, building wrap, etc. - are required to ensure that water doesn't enter the wall[10]. Manufacturers recommend that moisture-reduction steps be taken during drywall installation. Two such steps are; install the drywall block coat with a quick drying compound rather than pre-mixed joint compound and provide adequate ventilation during the drywall finish phase.

Foam insulation is slow to ignite but when lit, it burns readily and emits a dense smoke that contains toxic gases. Foams used for construction require a ½" gypsum wallboard covering as a fire thermal barrier in addition to the OSB skin of the SIP. The drywall has a 15 minute fire-rating that also provides the fire protection for conventionally built structures. Fifteen minutes is recognized as the time needed for the occupants to exit at the outbreak of a fire.

Some fire departments have voiced concern about assessing the structural integrity of a partially-burned SIP floor or roof panel; recommending that emergency response and forensic personnel not enter a SIP structure. SIP products covered by ICC-ES reports have passed all of the fire tests[11] required of conventional construction. Many manufacturers have conducted tests of 20-minute and 1-hour rated wall assemblies with SIP cores.

Navigating Owner's Expectations

Being an engineered wall panel doesn't handicap SIPs' adaptability over the long run. All of those conventionally-built homes out there rely on design-specific details for their structural integrity, too. When frame homes are remodeled it is common practice to remove, re-support, and engineer new load-bearing components for the added space and features. A home constructed of structural insulated panels has the same possibility.

And for the owners who want to customize - wall hangings, closet shelving, chair rail, and other items attach to a SIP wall very simply. The 7/16-inch OSB beneath the ½" drywall will provide a firm fastener base for either a screw or a nail - just size the fastener length to penetrate to the OSB (1 inch or more, dependent upon load). One SIPs manufacturer, Premier Industries, has done a good job of matching nail sizes with pullout strength that facilitates both interior and exterior fastener detailing[12]. Molley bolts and plastic anchors will not be effective with SIPs.