# COMPARISON OF CONVENTIONAL LIGHT-FRAMED WOOD CONSTRUCTION AND STRUCTURAL INSULATED PANELS

by

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# Abstract

Conventional wood framing, also known as stick framing, has been around for hundreds of years. It is an easy, effective method for building new houses and small commercial projects. However, it may no longer the best option for new construction. The development of Structural Insulated Panels (SIPs) began over 70 years ago at the United States Forest Products Laboratory in Wisconsin. Scientists believed that plywood sheathing alone could provide adequate strength to support the loads a structure encounters. Over the years, SIPs have evolved to what they are today: a rigid insulation foam core sandwiched between two skins, often made of oriented strand boards (OSB). Compared to stick framing, SIPs are faster to erect in the field and also provide more strength to resist most loads; they are better with axial and transverse loads. Stick framing can be built more robust to resist in-plane shear loads. The quality of the material of SIPs also means better quality construction.

The insulating values SIPs provide are far superior to that of fiberglass insulation used in stick framing, saving money for the owner as well as energy from natural resources. Not only do they provide better thermal protection, but they are also better for the environment because of manufacturing processes and construction practices. When it comes to other issues such as fire, smoke, termites, and ventilation, SIPs are no worse than stick framing. SIPs follow the same steps for construction used in stick framing with, perhaps a little more care needed to insure proper ventilation.

SIPs have proven themselves in the laboratory and in the real world. SIPs should be considered more often as an option, replacing stick framing for the major structure elements and insulation for new buildings.

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I would also like to thank Mr. Ron Redmond, of SIP Panel Homes, for his help and insight, which was tremendously helpful.

# Dedication

This report is dedicated to my parents, Gary and Marlene Ledford, for their endless support and encouragement.  I would not be who I am today without them.

I also dedicate this to my fiancé, Jessica.  It has been a busy, hectic year.  Thank you for sticking by me when days got long and stressful.

# CHAPTER 1 - Introduction

Ever since humans moved out of caves and into constructed dwellings, timber has been a primary material used in creating shelter.  From thatched huts to modern homes, shelters have not really changed in basic design and function.  Larger timber pieces are the primary supports in a general framework for the rest of the structure and enclosure.  Medium sized pieces span the gaps and give the structure its overall shape.  Materials for enclosing a structural frame have historically ranged from palm fronds to plywood.

In modern wood framed buildings, medium sized pieces consist of studs and joists while sheets of oriented strand board (OSB) span these elements to enclose the building.  Insulation is typically installed between studs and joists to prevent dramatic heat exchanges between the interior and exterior of the structure, keeping spaces at a more constant and comfortable temperature.

This system works, but the purpose of this report is to investigate a newer product. Structural Insulated Panels, or SIPs, may be superior to traditional methods of framing wood buildings in many different aspects.

This report compares conventional wood framing (often referred to as stick framing) and SIPs.  A description of the two systems will be provided, and the history of SIPs will be briefly discussed.  The main body of this report consists of comparisons between stick framing and SIPs.  The first comparisons cover the construction aspects of both systems.  This is followed by a comparison of the structural aspects of the materials and structural systems.  Finally, other similarities and differences between the two systems are presented.

# CHAPTER 2 - Types of Light Frame Wood Construction

For residential and light-commercial buildings, the most common type of construction is conventional wood framing. This type of construction is also referred to as traditional framing or stick framing.  A relatively new type of construction compared to stick framing is SIPs.

## 2.1 Conventional Wood Framing

Conventional wood framing is the most common construction method for most residential and many small commercial projects.  It is commonly referred to as “stick framing” because “sticks” (studs, joists, and rafters) form the walls, roof, and floors of a structure.  This type of construction consists primarily of 2”x4” or 2”x6” studs for walls and larger 2x members for floor and roof framing for the skeleton framework.  All pieces are cut and nailed or screwed together on the building site.  Once the skeleton is complete, it is covered with a sheathing of oriented strand board (OSB), or similar material to from the enclosure.  For this type of construction, nearly all the assembly occurs at the building site as the laborers frame the walls, floors, and roof, sheath the structure, and insulate the walls and roof in different steps.  It is an inherently time consuming process on the job site.  Figure 2-1 shows the early skeleton in place for a stick framed structure.

**Figure 2-1 Walls in place of a stick framed structure**

## 2.2 Structural Insulated Panels (SIPs)

SIPs are a revolutionary way of framing, enclosing, and insulating a structure that takes the place of stick framed walls, roofs, and floors as described above. The panels are made in a factory, shipped to the job site, and pieced together like a large 3-dimensional puzzle. In a wall system, SIPs have strength in axial compression and in bending to resist out-of-plane forces. For typical roof or floor spans, SIPs have the bending strength to support the required live and dead loads as well as snow, wind, and seismic loads.

SIPs consist of two outer skins and a foam core sandwiched in between, as shown in Figure 2-2. The core material is expanded foam and varies slightly by producer, but all have very similar characteristics and properties. These cores come in standard thicknesses designed to match the dimensional lumber that it replaces. This means it is produced with a 3 ½”, 5 ½”, 7 ¼” etc. foam core, with a ½” thick skin attached to both sides. Most often, SIPs are available in four foot by eight foot panels, because most types of skin material come in standard 4’x8’ sheets. However, different manufacturers may produce different lengths and widths as SIP production technology improves. The actual production of SIPs may vary somewhat amongst producers; however, the basic process remains the same. The skin is attached to the core using a structural adhesive. This bond the glue creates between the oriented-strand board (OSB) and the foam core is stronger than the OSB itself (Redmond, 2010).

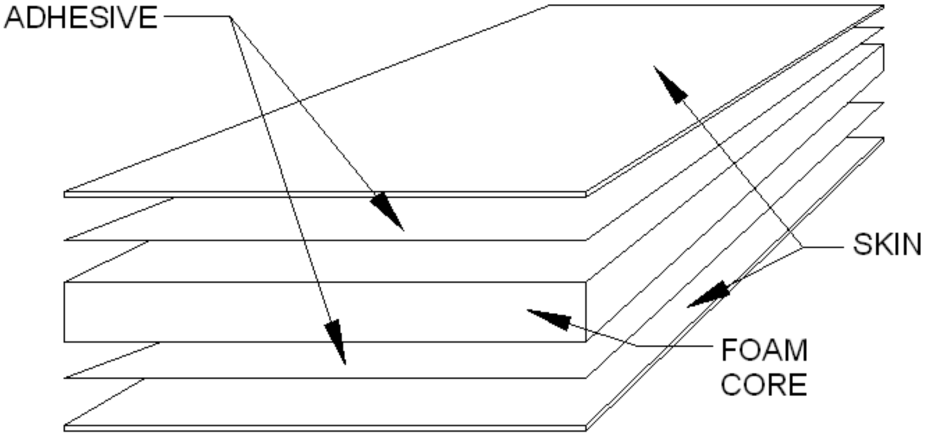


**Figure 2-2 Structural Insulated Panel**

SIPs can be made either structural or non-structural, based on the need. Structural panels carry some sort of load. They may be used in conjunction with another structural system or as the only structural system. Non-structural panels may be used as partition walls where the strength is not required, but panels are used for their insulation values or simply as a panelized system for quicker construction. For the structural panels, the skins are made of OSB or a cement board, though the latter is uncommon. Finishes, such as gypsum board or a decorative wood finish may be applied to the panel at the factory to speed up construction time.

Non-structural panels have many options for skins, depending on the manufacturer. Since strength is not required for these panels, OSB or cement board skins are not required and a decorative finish can be attached directly to the foam core.

SIPs can also be used in conjunction with other structural systems. For example, where the owner wants a steel frame, panels may still be used for speedier construction as well as thermal properties and sound prevention, such as shown in Figure 2-3. These panels provide the required support for snow loads to be carried to the steel structure.

**Figure 2-3 Building with a steel frame and SIP roofing and wall panels. Photo courtesy of SIPA.**

For flexural strength, SIPs behave in much the same way as structural steel wide flange beams do: the outer skins act like flanges, taking tension or compression, while the foam core represents the web by resisting out-of-plane shear. This can be seen in Figure 2-4. Individually, these parts would fail under minimal loading, but combined, they perform far better than their individual components (Morley, 2000).

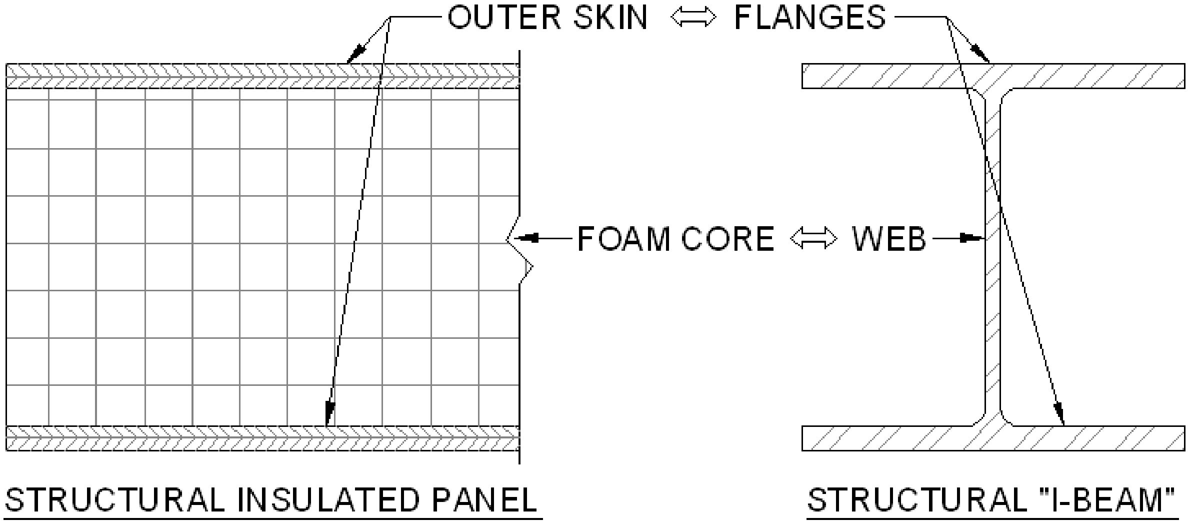
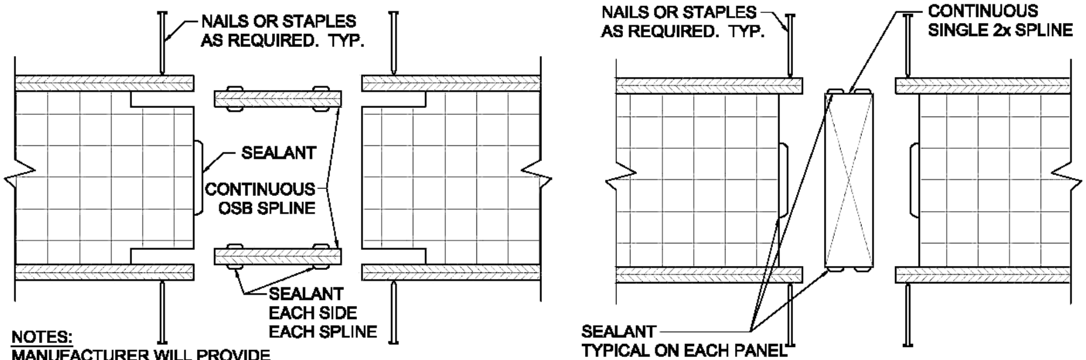


**Figure 2-4: Comparison of SIP and I-beam components to resist flexure and shear forces.**

The components of the SIP serve other purposes besides providing strength. The foam core provides strength, but it also acts as insulation. Rather than insulation batts which are interrupted by studs, the foam core provides insulation continuously across the entire width of the panel. The skins also serve a second purpose. Just like attaching OSB to stick framing to provide lateral, racking strength as shear walls, the OSB panels act the same way.

Installation of SIPs is very easy and requires generally the same tools as stick framing. Additional tools might be hot scoops and modified saws, which only required when production facilities do not fully fabricate the panel to final dimensions and final modifications to the panels must be made on site. If all information is known ahead of production, the manufacturer can provide all openings, angles, cutouts, and more in the factory. On site then, all that is left is to assemble the pieces. If regular, stock panels are delivered to the job site and final modification must be made, hot scoops are used to scoop out the foam core to depths in which top and bottom plates, splines, frames, or headers can be installed.  Special saws are available to cut the thick panels when that becomes necessary.

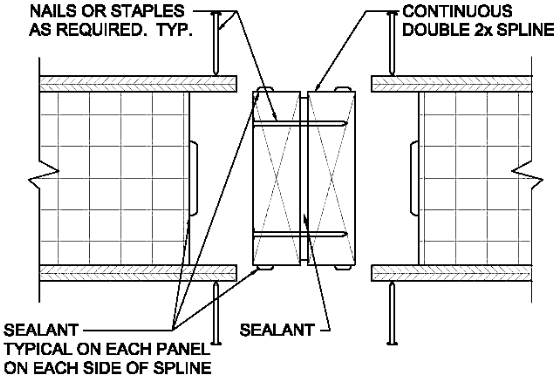
To connect SIPs to each other, sealant, splines, and nails or screws are used.  Nails, staples, and splines are used for the physical connection.  Sealant is used to maintain a thermal barrier by filling gaps between the spline or plates and the foam core.  Each manufacturer will have their own preference and provide direction on how to assemble and connect their SIPs at splines as well as other areas like roof-to-wall connections.  Some typical spline connections can be seen in Figure 2-5.  Strips of OSB may be used on each face of the panel, single or double 2x nominal boards, engineered wood I-beams, and insulated wood I-beams are just a few of the splines that could be used.  In each case, splines must be extensively tested to demonstrate their strength and loading capacity.



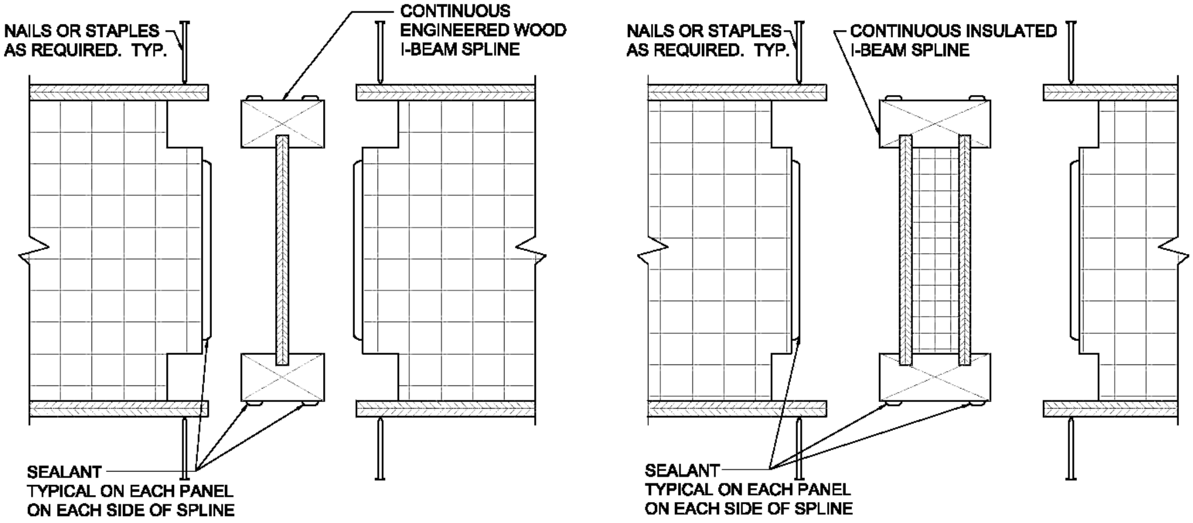
NOTES:
MANUFACTURER WILL PROVIDE
INFORMATION ON DIMENSIONS.

ORIENTED STRAND BOARD SPLINE
NOT TO SCALE

SINGLE 2x SPLINE
NOT TO SCALE



DOUBLE 2x SPLINE
NOT TO SCALE



I-BEAM SPLINE
NOT TO SCALE

INSULATED I-BEAM SPLINE
NOT TO SCALE

**Figure 2-5 Some typical SIP splines for panel to panel connections**

Panels are attached to sill plates along the bottom and to a top wall plate, much like stick framing. The sill and top plates are typically 2x dimensional lumber pieces with the same width as the thickness of the foam core. Bottom plates are attached first to the floor system or foundation wall. A layer of sealant is laid along the entire length of the plate. The panel is then situated over this plate, making sure the skins of the panel are resting directly on the flooring surface. The foam would be previously removed from the bottom edge of the panel so that the bottom of the OSB skins rest on the floor and the core is in contact with the sealant. A top plate is similarly installed along the top edge of the panel. The OSB skin is then nailed to the sill and top plates. Top and bottom plate details are shown in Figure 2-6.

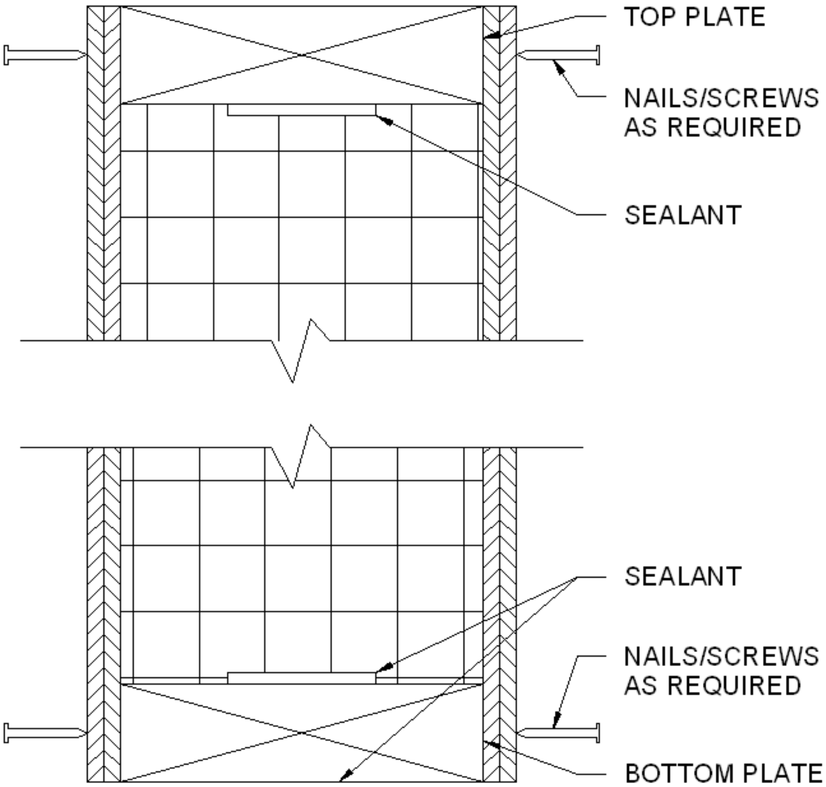


**Figure 2-6 Typical top & bottom plate connections**

The skins must not be in direct contact with concrete. As with stick framing, a treated sill plate must be laid down first when the panel is supported on concrete. A treated plate wider than the SIP is sufficient to separate the panels from the concrete. Sealant should be laid out on the top face of the wider sill plate before the bottom plate for the panel is attached, making sure to offset this plate from the edge of the lower plate to ensure the skins rest on the lower treated plate.  Figure 2-7 shows a treated plate on top of a concrete wall, with a panel bottom plate and SIP wall panel resting on it, all anchored to the concrete wall with an anchor bolt.

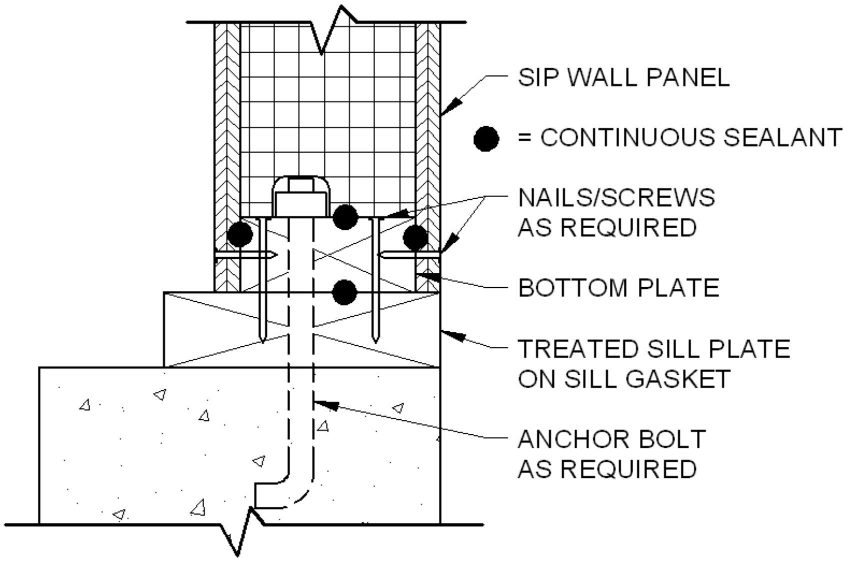


**Figure 2-7  SIP wall connected to a concrete wall.**

# CHAPTER 3 - History of SIPs

While stick framing has been used for hundreds of years, the SIP is a relative newcomer to residential and light commercial construction. Even though the idea of panelized construction is not new, SIPs have only been around for a few decades.

Panelized wood structures got their start over 70 years ago when research engineers at the U.S. Forest Products Laboratory (FPL) in Madison, Wisconsin in 1935 suspected that plywood alone could provide adequate structural support in walls, without the use of heavy stud walls. They took this idea and developed a panel with insulation sandwiched between two skins with some 2½” x ¾” studs, rather than the normal 2”x4” studs (Anatomy of a SIP: History of SIPs, 2008). Using the skin of the panel to take the load, the 2 ½” x ¾” studs framed the panel, permitting thinner walls and fewer materials. The FPL tested their idea by using it as a load bearing wall in a small house. This building still exists and is currently being used by the University of Wisconsin as a daycare center (LeRoy, Chaleff, Malko, & Lukachko, 2008).

Engineers at the FPL thought that if the skins could be made stable enough so that they could take all the loads applied without buckling, framing could be eliminated entirely (LeRoy, Chaleff, Malko, & Lukachko, 2008). An entire structure was built in 1947 with a corrugated paperboard system to determine if skins alone could take the structural loads. The building was periodically tested over the years for panel stiffness. The results showed minimal deflection over 31 years in Wisconsin weather (LeRoy, Chaleff, Malko, & Lukachko, 2008). Over 20 years after initial construction, foam cores were introduced for insulation, forming the modern Structural Insulated Panel (LeRoy, Chaleff, Malko, & Lukachko, 2008).

Around that same time, architect Frank Lloyd Wright was working on his own panelized structural system. Wright attempted to integrate simplicity and beauty into relatively low-cost houses. Rather than using insulation in his panels, Wright’s panels consisted of three layers of plywood with a layer of tar paper between each sheet. With no insulation incorporated in the panels, the systems had very low insulating properties and were therefore never commercially produced or used on a large scale (Morley, 2000).

In the 1950s, one of Wright’s architecture students, Alden B. Dow, took Wright’s ideas further, creating the first modern SIPs. Dow knew Wright’s panels were very inefficient as an insulator and was concerned about energy efficiency and dwindling natural resources (Anatomy of a SIP: History of SIPs, 2008). Dow's first panels consisted of 1 5/8 inch Styrofoam cores for insulation and 5/16 inch plywood facings for structural support and were used in houses in Midland, Michigan (Morley, 2000). The same panels were used on the roof over supporting structural framing spaced 42 inches on center. Some of these houses are still occupied today, over 50 years later (Morley, 2000).

Later that decade, Koppers Company first tried to produce SIPs on a large scale. Koppers Company had been an automobile production plant in Detroit, but converted to a SIP producing facility. Koppers produced SIPs by blowing pre-expanded Styrofoam beads between two sheets of plywood that had been glued to supporting framework. The Styrofoam and plywood were bonded using steam and glue (Morley, 2000).

Early acceptance of SIPs by owners and architects was slow, as is acceptance with most new building technologies, for a number of reasons. In the early '50s and '60s, energy efficiency was not a major concern as it is now because energy costs were considerably cheaper at that time. A second reason was that carpenters' unions in the northern states feared losing work because SIPs could be installed very rapidly (Morley, 2000). Because of this, they deliberately worked slower, at about half of the speed of similar construction in the South (Morley, 2000). For these reasons, SIPs were not competitive in the market place as an alternative to traditional stick framing.

While these two concerns are no longer relevant, a third reason that hinders acceptance even today is that architects are not widely familiar with the product and are therefore reluctant to use it. A growing number have heard of SIPs; they just do not know as much about SIPs as they do for stick framing. As with any new product, main-stream acceptance lags well behind invention. Delay does provide one positive aspect, however: it gives time for products to be perfected and production costs to be lowered.

SIPs have continued to evolve both in how they are made and their use. Not only has production improved to the point where panels can be made larger and faster, but improvements have been made to the panels themselves. Strength and insulation has improved as well as the technology to fabricate them. As an example, SIPs can now be curved, as in the building in Figure 3-1. Design possibilities are practically endless.

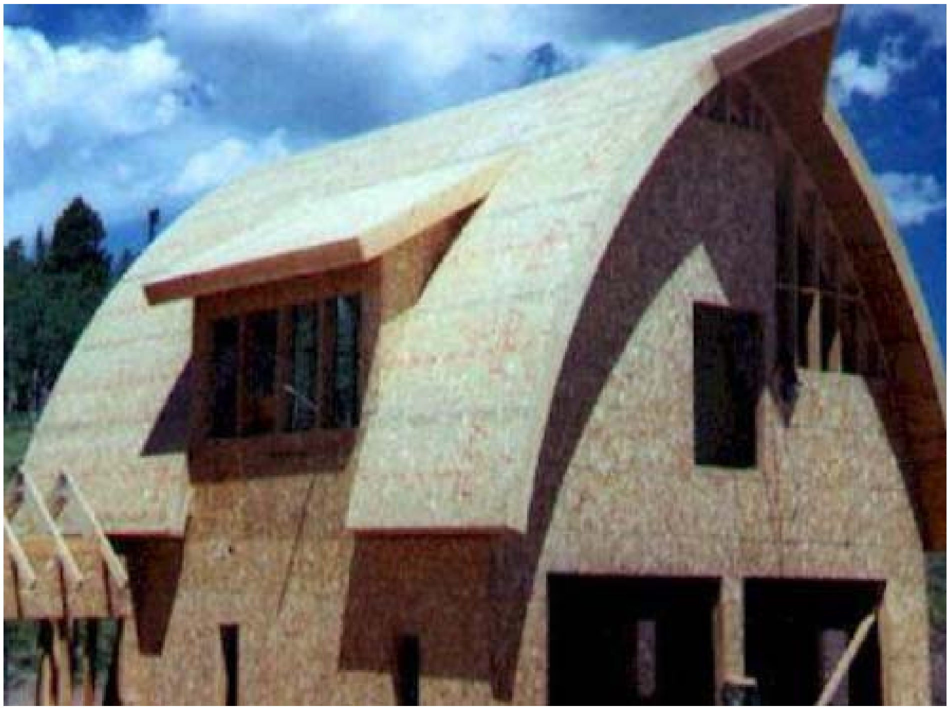


**Figure 3-1 Curved SIPs are now available.  Photo courtesy of SIPA.**

In addition to increased acceptance and better production methods, additional testing has established strengths and load capabilities.  Structures have been in place long enough that real world data is available.  With increasing concern about climate change, energy resource depletion, and sustainability, SIPs are beginning to gain the attention of both designers and builders.

# CHAPTER 4 - Construction Comparison of SIPs and Stick Framing

Stick Framing and SIPs use two different systems to create the same result. While the two processes work differently, they have similarities as well. This chapter will compare stick framing and SIPs in construction assembly, time, quality, and connections.

## 4.1 Construction

Construction on site of structures built with SIPs is considerably easier, faster, and can result in a finished product with fewer call backs than traditional wood framing. Rather than having three separate steps for framing, sheathing, and insulating for walls, roofs, and floors, the SIP manufacturer combines these steps for the contractor. Once at the job site, the panels just need to be assembled like a large three-dimensional puzzle. Figure 4-1 shows stacks of panels ready for installation. After the shell is in place, other trades can than begin to work inside, protected from the elements. Stick framing requires more time to construct on site.

**Figure 4-1 Panels stockpiled on site ready to be installed. Photo courtesy of SIPA.**

### *4.1.1 Stick Framing Assembly*

Stick framing is time consuming on site and often results in abundant material waste being hauled away to the landfill or burned. Walls are built by, first, measuring and cutting dimensional lumber plates and studs (if the design does not call for traditional 8 or 9 foot walls) to the proper lengths. Then, the wall studs are laid out flat on the floor between top and bottom plates. Once all the pieces are laid out, a carpenter must attach each stud to the plates, typically with two nails, totaling four nails per stud. After the wall is assembled on the ground, it is then tipped up, aligned, fastened to the floor, and braced. Depending on the size of the wall, it could take three or more persons to tilt the wall up, support it so it does not twist apart, and attach braces.

These unsheathed stud walls are not sturdy when left to stand on their own, they are quite flexible until sheathed. Studs are spaced out evenly and only fastened at the top and bottom by a couple of nails. If a wall starts to tip and twists, enough torque may be applied that a wall may come apart. Because of this, temporary braces must be installed to hold the walls in place until other framing and sheathing provide for adequate stability.

After several walls are constructed, a second top plate is installed. This plate is installed in such a way that it overlaps the joints of the first top plate. Generally, the structure is not stable on its own generally until roof or ceiling rafters are installed and sheathed, so the braces are left in place throughout most of the construction time.

As shown in Figure 4-2, stick framing often needs many braces in one room. These braces are made of dimensional lumber. They are nailed near the top of the walls and extend out into the floor space where they are attached to the floor. This creates tripping hazards as well as plenty of opportunities to bump your head when walking through these areas. It also creates problems when trying to move items or material through the building; the braces create a sort of a maze where it is not easy to walk straight through any room.

**Figure 4-2  Typical bracing for conventional wood framed walls.**

Once the walls are in place, sheathing must be applied.  Sheets of OSB measuring four feet by eight feet by one half inch thick typically sheath houses.  For one story structures, this is not too difficult.  Workers can place most of the sheets without a ladder, and the rest by climbing just a few rungs of a ladder.  The sheets are nailed directly to the studs.

When exterior walls get tall, attaching panels to the walls can become difficult and even dangerous to.  Generally, builders have two options.  The first is to apply the sheathing before the unsheathed stud wall is raised, while it is still on the ground.  This option has the disadvantage that the wall is then heavy and difficult to maneuver into place.  The carpenters must sometimes position the wall and the base plate without being able to see the edge they are lining up with.

The second option is to build the wall and apply the sheathing as normal.  This may require one or two men to climb ladders while carrying large pieces of OSB and nail guns, maneuver the piece into place, and attach it to the walls.

Moreover, for traditional framing, electrical work requires a dry structure for safety.  The building must be “dried-in” for the electrical contractor to begin.  Insulation is installed after the electrical work has been completed.

### *4.1.2 SIP Assembly*

Assembly of SIPs requires different methods than stick framing. Walls and roofs are assembled off site and are complete with sheathing and insulation. Panels are shipped to the jobsite.

Much like stick framing, base plates are attached to the floor, and the panels are attached to these plates. The depth of the base plate is removed from the core so that the outer skins rest directly on the floor. The core is also removed from the top and sides for installing top plates and splines.

Unlike stick framing, SIP construction requires very few braces because it has uniform strength and stability. Panels are less likely to torque and twist themselves apart. SIPs are installed by first placing a panel at a corner. This first panel will need a brace. The next panel goes on the perpendicular wall creating the corner. After the two are properly connected, the second panel needs no brace. From this point on, very few braces are required. As can be seen in Figure 4-3, several panels have already been installed, starting at the corner, and no braces can be seen. This creates a very clean and safe work site, reducing the amount of material used and obstacles to avoid.

**Figure 4-3 SIPs construction needs few braces. Photo courtesy of Fischer SIPs.**

Even though the panels are solid and take away handholds like attaching sheathing to studs before tipping the wall up does, SIPs are generally lighter than a stud wall, making them easier to handle than a fully sheathed stud wall. SIPs also have the advantage of attaching the base plate to the flooring system first. By doing so, workers are able to tilt the panel over the plate and know that the panel is in the correct location.

SIPs are also good for other trades. Once a final design is established, plumbing and electrical chase-ways can be installed during the manufacturing process. This helps keep the walls structurally sound because these tradesmen do not need to cut studs or joists to lay pipes and conduits. In a stick framed building, indiscriminant cutting could be disastrous.

A downside to construction with SIPs is that due to the size of the panels, larger equipment like a lift or crane is often needed to lift members to upper levels or roofs. However, the speed of construction means the equipment will not be required for very long.

### *4.1.3 Time*

Faster assembly time gives SIPs several advantages over stick framing and all are related to saving time and money.

Time savings is proven in a study done with Habitat for Humanity construction. While Habitat for Humanity projects do not necessarily directly represent construction as a whole, they do pose a very good correlation. A few differences between Habitat for Humanity and standard construction should be noted. First, on Habitat for Humanity projects, most workers are volunteers with little to no construction experience. Therefore, for safety reasons, it is a policy of Habitat for Humanity not to allow the volunteer workers to use nail guns.

For the study, two new houses were evaluated during Habitat for Humanity construction. One was stick framed, and the other was built with SIPs, both were of similar size. Interior walls in both buildings were stick built and, therefore, omitted from the study. After the results comparing construction time and effort were normalized to account for the design differences, SIPs had roughly 65% less on-site labor and time (Mullens & Arif, 2006).

Saving time on construction can be valuable. First of all, saving time on enclosing a structure can be significant during bad weather or if other factors limit the window of opportunity for construction (Morley, 2000). Second, saving time is important because labor costs can be reduced by saving one to four weeks of construction time, depending on the design (Morley, 2000).

Since the envelope of the building can be done faster, it will be “dried-in” in a matter of days rather than weeks. This allows other trades to start working earlier. Figure 4-4 shows that with the exterior walls up and just a few braces supporting them along with a beam running along the ridge, roof panels can be installed, completing the enclosure so that all trades can work. Once the structure is dried-in, crews can frame the interior partitions. If they start in one section and work their way out, other trades can follow in behind them while framers work elsewhere. Thus, the building is completed faster.

**Figure 4-4 Roof panels are installed with drying in the structure. Photo courtesy of SIPA.**

Finally, the quicker a building is completed, the quicker the owner can move in and occupy the space. For a residence, this may not have much financial impact, but if the SIP structure is for commercial purposes, quicker occupancy means more revenue faster than would be possible with stick framing.

Lumber yards can be found in nearly every town. SIP factories, however, are not so readily available. Because of this, material for stick framing may be obtained more quickly than SIPs. Since SIP producers are fewer in number, it is possible that they could become backlogged and production may be delayed, preventing construction from starting.

### *4.1.4 Quality Control*

Quality control has quite an impact on construction. Poor quality may lead to call-backs requiring small fixes or even complete repair. On the other hand, good quality control saves money by getting the job done right the first time. Quality materials are also advantageous during construction as it makes work easier and faster.

In stick frame construction, imperfections during and following construction are inevitable. This not always the fault of the contractor, it is due to the properties of the material itself. Dimension lumber is highly vulnerable to moisture. When a building is in the construction phase, wood is left unprotected. As a result, the timber is likely to absorb moisture. When wood absorbs moisture, it expands. This does not pose a significant structural problem. However, once in place and enclosed, it will start to dry. As the wood dries out, it shrinks. This could create a number of inconveniences.

To begin with, as more and more pieces shrink, the wood has more space to move. As structural members move as a result to loads such as wind or people walking, they rub against each other and make noise. Creeks and moans are a result of the dimensional instability of dimensional lumber used in stick framing.

Another nuisance with stick framing and its dimensional instability is the problem it creates with drywall, and therefore, painting, trimming, or other interior finishes. Two primary things happen: nail pops and cracks.

Nail pops form when the wood shrinks, but the tip of the nail remains at the same depth, resulting in a gap between the drywall and the stud. If pressure is applied to the drywall, the sheet will be pushed back against the wall. The nail, however, cannot move, resulting in an unsightly protrusion. Figure 4-5 illustrates how nail pops form. Cracks in the drywall or seams may also form. Both of these are easy to fix but can be unsightly as more and more occur.

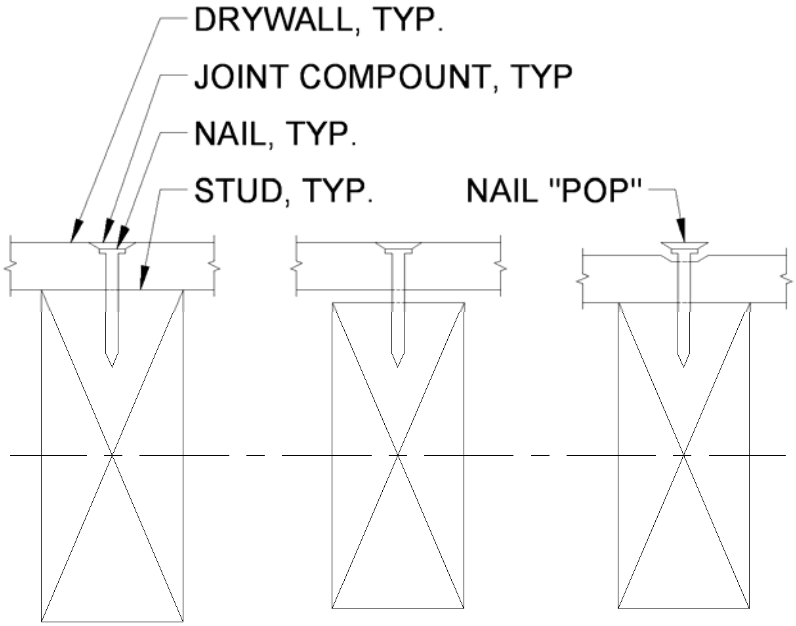


**Figure 4-5 How nail pops form**

Another advantage during the construction phase with SIPs is that it not only gives the framers more time, but it also benefits other trades as well. Because SIPs are manufactured in a factory and not pieced together with dimensional lumber, walls will be straighter and tops of walls will be flatter. They also do not absorb moisture; moisture in the lumber can lead to warping, and not all pieces warp the same, preventing straight, flat walls or floors. Additionally, walls designed other than at standard heights require either a pony wall above or cutting studs for a shorter wall. If measured or cut improperly, the height of the wall could vary at different locations. All of this can lead to problems with sheet rock, cabinets, or other issues. Shimming may be required to level the pieces. For long lengths of walls, this effect may intensify. By being built in a factory, SIPs may have better quality control during production which could result in straighter, flatter elements.

### *4.1.5 Connections*

Connections for SIPs are very similar to connections for conventional framing. Generally, the same fasteners and methods used in stick framing are also utilized to tie all SIP panels together. However, for SIPs, a few other pieces are necessary. Most often SIP screws, provided by the manufacturer, are used to penetrate the full depth of the panel and into the supporting member; in addition, foam sealant is required to fill any voids.

As with stick framing, starting at the foundation level, SIPs first require a treated plate to elevate the SIP off the concrete. This plate is bolted down, as in stick framing. For stud walls, a base plate rests on the treated plate. The same goes for SIP walls, with the untreated plate offset so that the SIP skin rests directly on the treated plate.

For buildings with a subflooring system, two options are available. Figure 4-6 shows an option where the wall extends all the way to the treated plate. In this system, the anchor bolt penetrates both the sill plate as well as the panel's base plate. The flooring panel then butts up against the wall panel. SIP screws penetrate the wall panel, securing both the wall panel and the floor panel. Producers will provide each method with the necessary spacing and the correct dimensions for all screws and nails, as well as the appropriate amount of sealant.

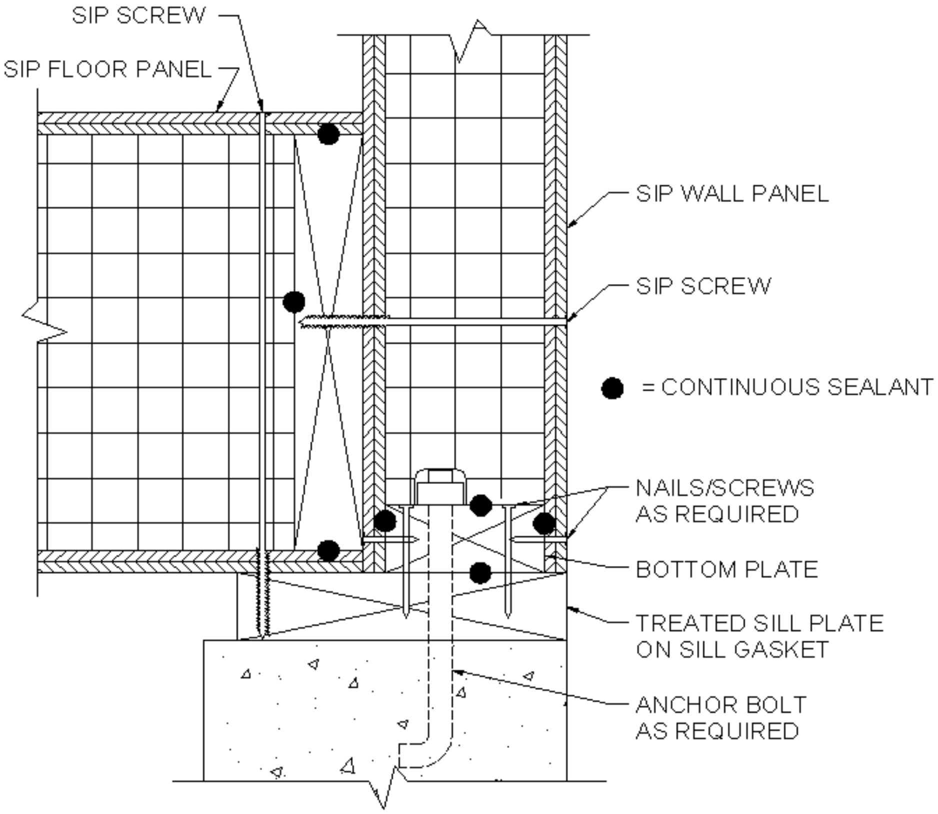


**Figure 4-6 Option one for a floor and wall connecting to concrete wall**

Figure 4-7 shows a system where the floor panel extends to the outside of the foundation wall, and the wall is placed on top of the floor panel. For this system, since the anchor bolt cannot penetrate the entire depth of the panel, a notch is taken out so the top of the bolt and the nut rest within the panel. SIP screws attach the panel to the treated plate. Normally, a rim board wraps around the perimeter of the building. With this system, the 2x placed at the edge of the panel serves this purpose. From here, the wall is built as normal, attaching a base plate to the floor and setting the wall panel on top of the plate.

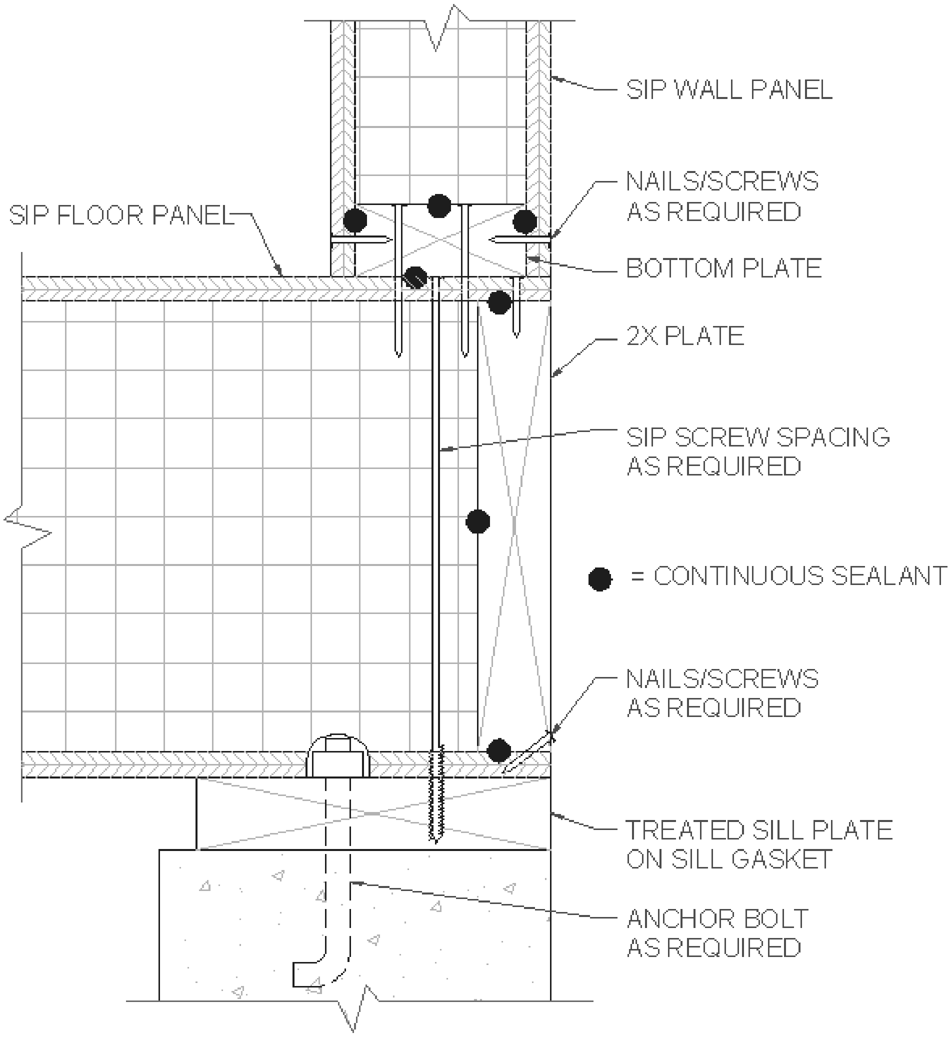


**Figure 4-7 Option two for a floor and wall connecting to concrete wall**

Sometimes, owners wish to use SIP walls with stick framed joists for floors and ceilings. In such cases, construction remains the same, and loads take the same paths they would in a conventionally built structure. Figure 4-8 shows a section with engineered lumber joists running parallel to a concrete wall with a SIP wall supported on the floor.

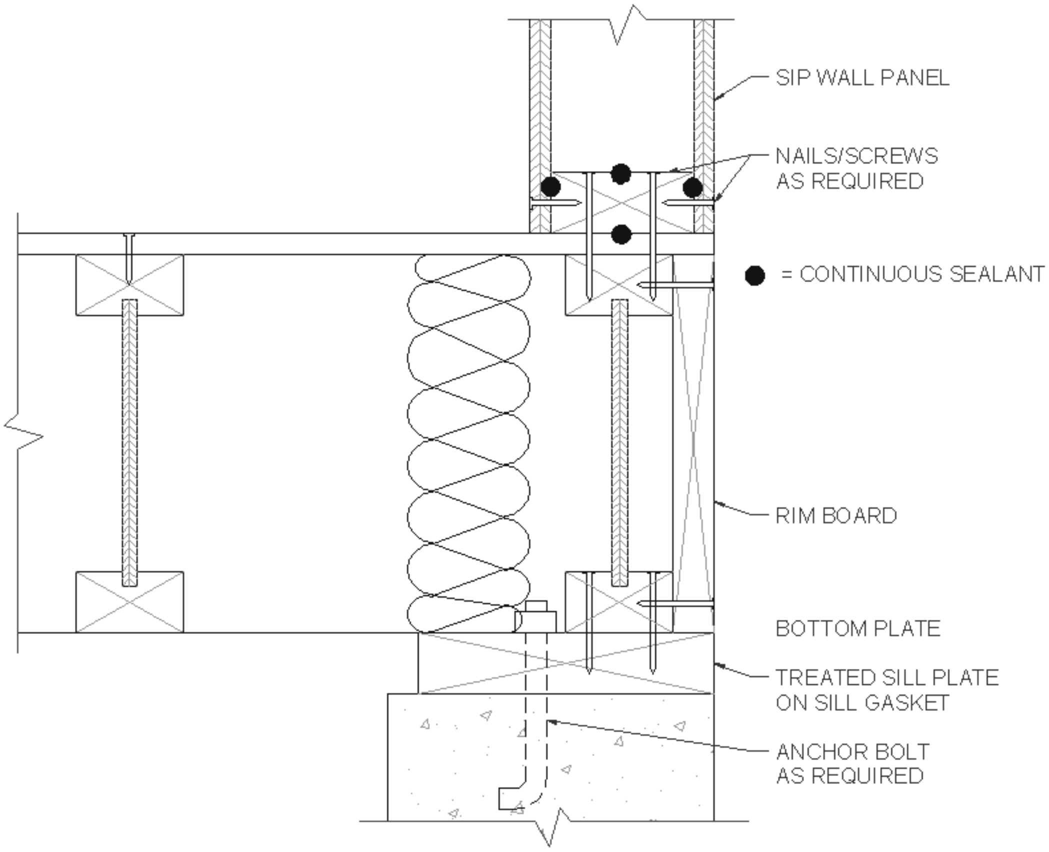


**Figure 4-8 Combination of SIP and stick framing**

In designs where hold-downs other than the regular anchor bolt are required, the same hold-downs used for stick framing can be used for SIP framing. In such cases, a section of the SIP skin and foam core is removed. Hold-downs are then attached to the end stud as in stick framing. Once in place, foam material will be installed to replace the missing foam and a piece of skin will be reinstalled, resulting in a normal hold-down being installed within a panel. Figure 4-9 shows a traditional hold-down used within a SIP wall.

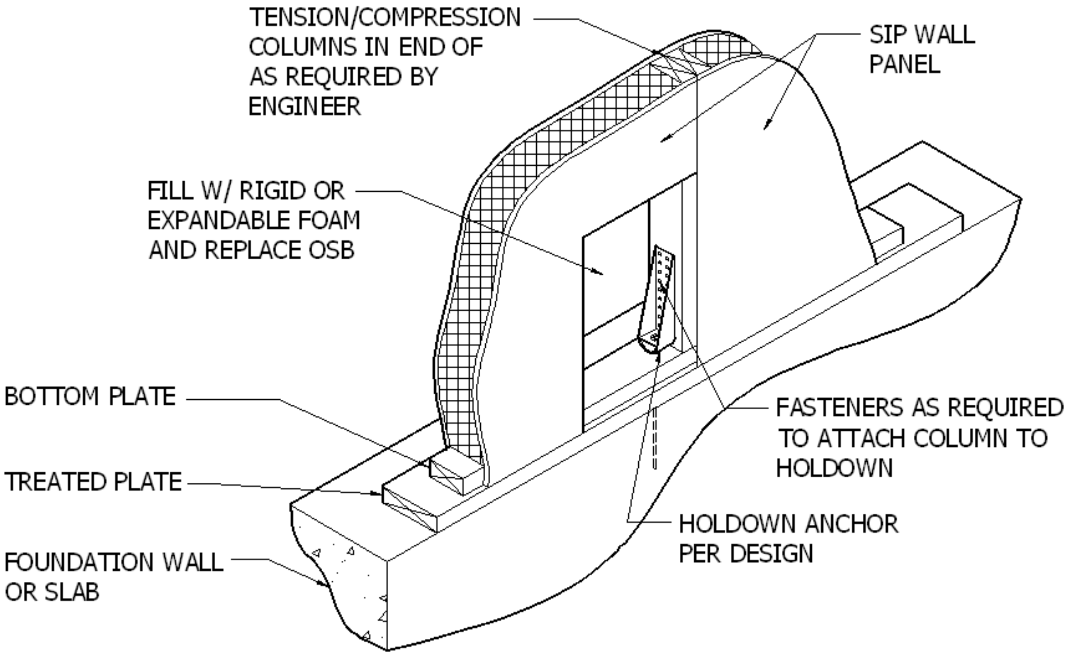


**Figure 4-9 Hold-down used within a SIP wall.**

Moving up from the foundation, connections other than panels connected in a line to form a wall are corners and interior partitions. For exterior corners, dimensional lumber is installed along the panel edge, protecting the foam core. These are attached with sealant and the nails prescribed by the producer. A typical, square corner is shown in Figure 4-10. SIP screws fasten the panels together. Producers can now produce varying degrees for corners. The only thing that would change is that the edges of the panels and the end studs are beveled to get flush edges.

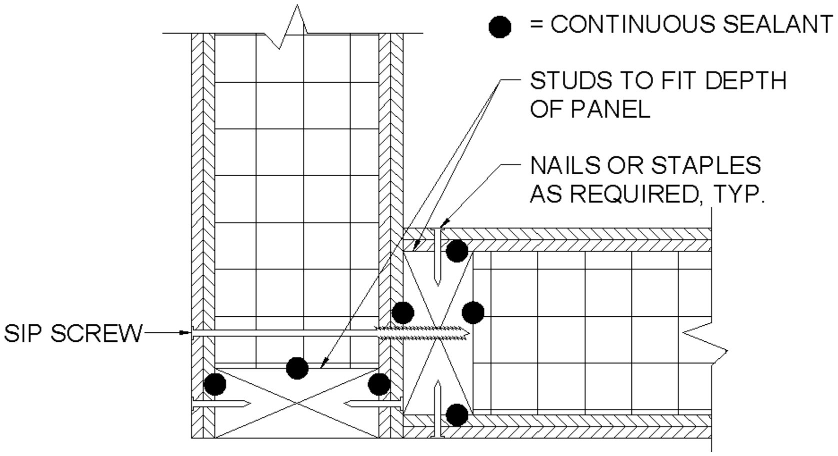


**Figure 4-10 SIP corner**

Interior partitions are joined similarly. Partitions are generally stick framed because they do not require the strength or insulating values that exterior walls require. If the owner wants, interior walls can be made of SIPs, and the construction remains the same. SIP screws attach the studs as in the corner construction above. Figure 4-11 shows the connection of an interior stick framed wall with an exterior SIP wall.

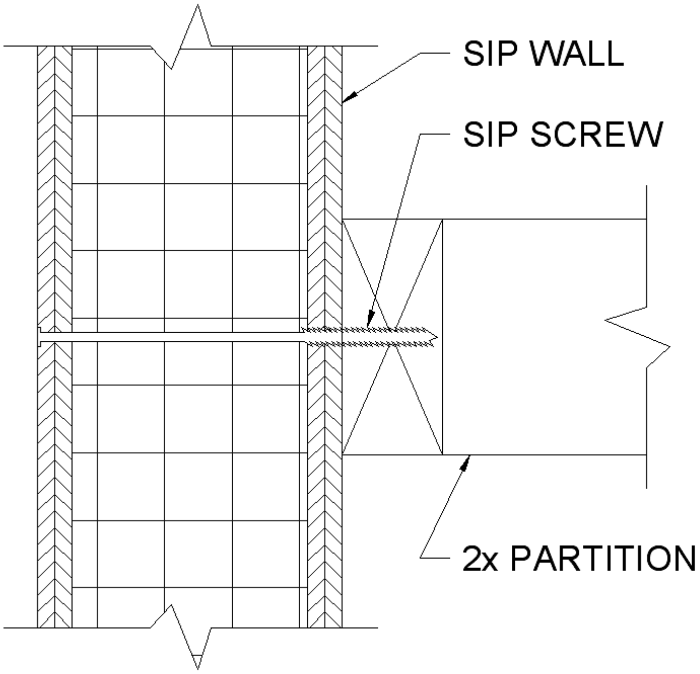


**Figure 4-11 Exterior and interior walls**

For a multi-story building, walls are interrupted by floors. There are several options for this, depending on the kind of structure and limits that may apply. For conventional framing, after a wall is built, joists either rest on top of the walls or are attached with hangers so that the top of the joist is level with the top of the wall.

In SIP construction, this is viable if the owner wants to combine the two construction techniques and use SIP walls with dimensional or engineered lumber joists. Like stud walls, joists can either be attached on top of or hung from SIP walls.

Another option is to use SIP flooring instead of joists. For this, the floor panel rests on top of the wall because hangers wide enough to support the load of a panel plus additional loading do not exist. In either type of flooring construction, SIP walls may continue above the floor as normal.

For openings, SIPs can provide headers up to a span prescribed by the manufacturer. Up to that span, a 2x dimensional board can be placed around the perimeter opening, recessed in so that the face of the 2x is flush with the opening of the OSB. Figure 4-12 shows an example door and window opening in a SIP wall and headers to be installed.

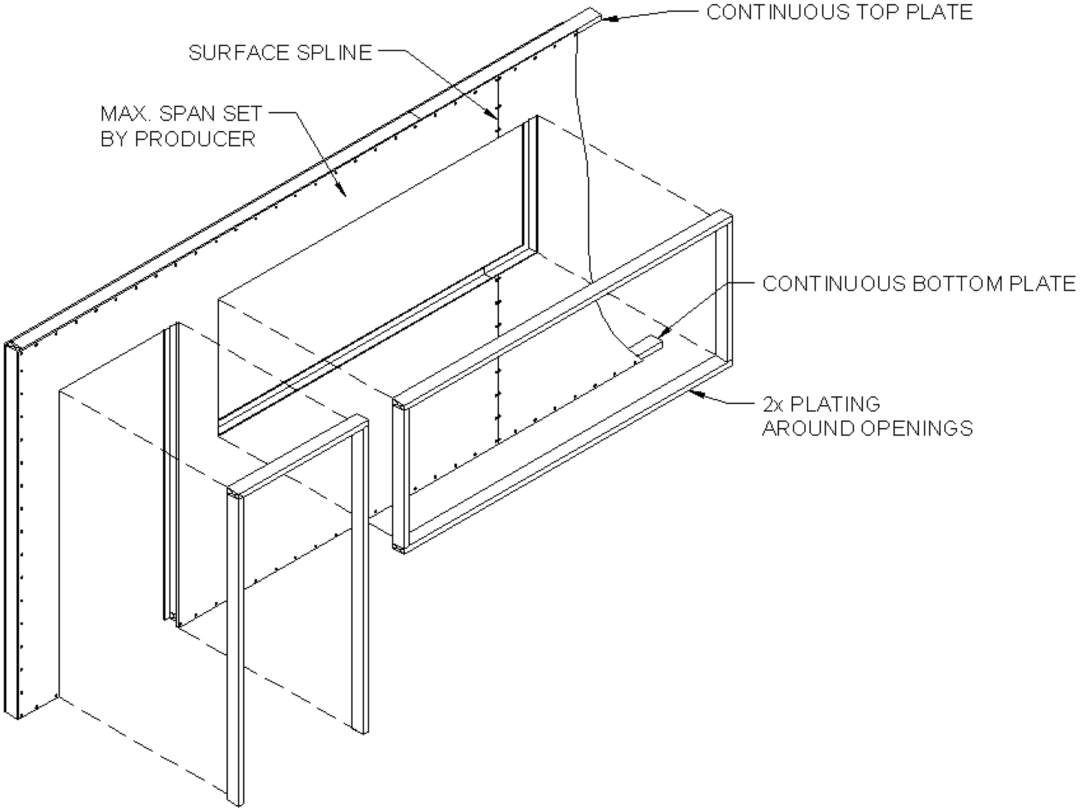


**Figure 4-12 SIP openings**

At the highest level, roof members are attached to SIP walls. The same restrictions apply here as for flooring, although any form is possible with SIPs now. Figure 4-13 shows an example of how an engineered truss could be attached to a SIP wall.

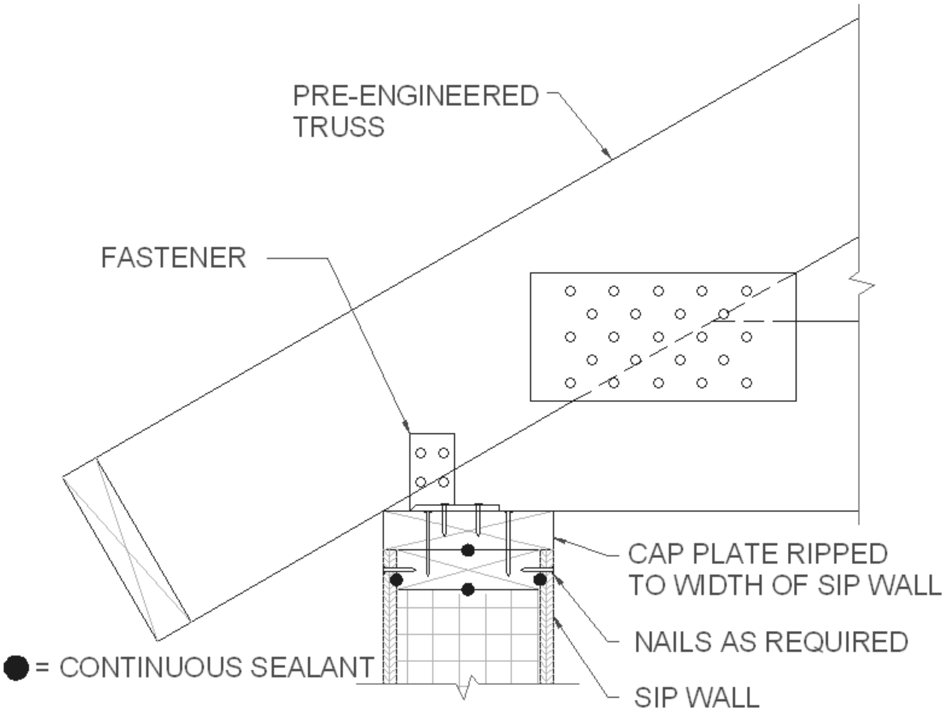


**Figure 4-13 Engineered truss connects to a SIP wall**

Many other options are available.  Producers have various connection options for SIP roof panels are to be attached to wall panels.  Where a sloped SIP roof is called for, foam pieces may be cut to fill in the angle after connections are made.  The tops of SIP walls can also be beveled to match the slope of the roof.

# CHAPTER 5 - Strength Comparison of SIPs and Stick Framing

A new building material is not a good alternative if it does not provide adequate strength to support required loads. SIPs provide a significant increase in axial and bending strength over stick framing, and have been exhaustively tested in the laboratory as well as surviving natural disasters worldwide to prove their strength.

As shown in Section 1.2, SIPs have many different options for connecting panels to one another. Note that different splines have different strengths, which affects flexural capacity. Each SIP producer tests to evaluate the strength of their particular panels to establish allowable load tables.

## *5.1 Strength of the Individual Panel*

Panel testing by independent laboratories has evaluated the strength of the foam core of SIPs as well as how well it adheres to the OSB. In all ten tests of one company's 3 ½" core panel, the core sheared before the skins delaminated from the core, and the average tension required to pull the panel apart was 87 pounds, demonstrating the strength of the adhesion and the panel (Morley, 2000). Each manufacturer uses different materials and has different methods of production, so checking with each producer is important.

## *5.2 Axial Strength*

Structural members such as columns and walls are often required to support loads in axial compression. In stick framing, studs spaced at intervals provide the strength for axial loads. Typical sizes and spaces for stick framing, depending on the design criteria, are 2"x4" studs at 16" on center, or 2"x6" studs at 24" on center. The National Design Specification for Wood Construction, NDS, provides a standard method for determining the required size and spacing of studs or allowable capacity.

This method depends on species of wood and grade of lumber to determine the axial capacity of timber. Different species of wood have different physical properties, resulting in different allowable strengths. Since the same forests are not readily available around the country, different regions usually use species native to the area for building materials.

Second, the grade of lumber affects the axial capacity. Higher grades result in a higher load capacity. However, availability of certain grades of lumber may be an issue. Higher grades of lumber are more expensive, and local lumber yards may even need to special order higher grades.

Moreover, builders may need to verify the lumber grade they use in construction is the same grade the design calls for. If a wall design calls for number one grade to meet the required capacity, but stud grade is used during construction, failure is a high possibility because stud grade lacks the strength of number one grade.

To compare SIPs and stick framing, a spreadsheet was developed to calculate the axial capacity of framing stud wall to compare to load tables provided by the International Code Council -Evaluation Service (ICC-ES) Report 2233 on R-Control brand SIPs.

For the comparison, 2”x4” wall studs were compared with the 3 ½” cores and 2”x6” studs compared with 5 ½” cores at all wall heights provided by the ICC-ES. For both stud sizes, 16” on center spacing was used. This spacing is typical for construction. For species type and grade, I arbitrarily chose to use Spruce-Pine-Fir with stud grade. The following procedure comes from the NDS for designing sawn-lumber members.

Certain factors depend directly upon the wood and size of the member. These factors are highlighted in the procedure. The values for $F_c$, compression parallel to grain, and modulus of elasticity, E, were obtained from the NDS Supplement table 4A. The size factor, $C_f$, can also be found in a table in the NDS.

While there are many variables and design values for every situation, certain assumptions had to be made for these calculations. A load duration factor of 1.0 for an occupancy live load scenario was used. The wet service factor, temperature factor, incising factor, and buckling stiffness factor were set equal to 1.0 as well, assuming a design under normal conditions. The variable “c” was set to 0.8 for sawn lumber. The buckling length coefficient, $K_e$, of 1.0 was used because it is difficult to obtain anything more than a pin connection in timber design.

| | | |
|---|---|---|
| Load Duration Factor, $C_D$ = | 1.00 | 2005 NDS table 2.3.2, pg 9 |
| Wet Service Factor, $C_M$ = | 1.0 | 2005 NDS sect. 4.3.3 |
| Temperature Factor, $C_t$ = | 1.0 | 2005 NDS sect. 2.3.3 |
| Size Factor, $C_F$ = | 1.05 | 2005 NDS sect. 4.3.6, table 4A, supplement pg 30 |
| Incising Factor, $C_i$ = | 1.0 | NDS sect. 4.3.5 |
| Buckling Stiffness Factor, $C_T$ = | 1.0 | NDS sect. 4.3.11 |
| Compression Parallel to grain, $F_c$ = | 725 | psi, NDS supplement table 4A |
| Modulus of Elasticity, $E_{min}$ = | 440,000 | psi, NDS supplement table 4A |
| $E'_{min} = E_{min} \times C_M \times C_t \times C_i \times C_T$ = | 440,000 | psi, NDS table 4.3.1, pg 27 |
| $F^*_c = F_c \times C_D \times C_M \times C_t \times C_F \times C_i$ = | 761.3 | psi, NDS table 4.3.1, pg 27 |
| c = | 0.8 | NDS sect 3.7.1 (c = 0.8 for sawn lumber, 0.85 for round timber poles and piles, 0.9 for structural glued laminated timber or structural composite lumber) |
| $K_e$ = | 1.0 | NDS appendix G, assume pinned-pinned |
| $K_e l_{e1}/d_1$ = | 27.4 | < 50, OK, 2005 NDS sect 3.7.1.4 |
| assume $l_{e2}$ = 2' because of bracing by sheetrock, $K_e l_{e2}/d_2$ = | 16.0 | < 50, OK, 2005 NDS sect 3.7.1.4 |
| $F_{cE} = 0.822E'_{min}/(l_e/d)^2$ = | 480.7 | psi, 2005 NDS sect 3.7.1 |
| $F_{cE}/F^*_c$ = | 0.632 | |
| $C_P = \frac{1+(F_{cE}/F_c^*)}{2c} - \sqrt{\left[\frac{1+F_{cE}/F_c^*}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}}$ | | NDS eqtn 3.7-1 |
| Column Stability Factor, $C_P$ = | 0.5193 | |
| $F'_c = F^*_c \times C_p$ = | 395.3 | psi |
| $P_{allowable}$/stud = $F'_c \times A$ = | 2075.5 | pounds |
| $w_{allowable} = P_{allowable}$/spacing = | 1,557 | plf |

The results were stunning. SIPs proved to be stronger at every height for both 2”x4” walls and even 2”x6” studs at 16” on center. At a minimum, SIP walls with a 5 ½” core could support an additional 300 pounds per lineal foot, even with 2”x6” studs spaced closely at 16” on center. SIP cores 3 ½” thick fared even better, almost doubling the strength of 2”x4” walls. Table 5-1 compares the axial loads of the studs to SIP walls of the same thickness and height.

**Table 5-1 Axial loads, plf**

| Wall Height | 2x4 studs @ 16" OC | 3.5" EPS Core* | 2x6 stud @ 16" OC | 5.5" EPS Core* |
|---|---|---|---|---|
| 8' - 0" | 1,557 | 2,750 | 3,722 | 4,000 |
| 10' - 0" | 1,088 | 2,500 | 3,171 | 3,500 |
| 12' - 0" | 786 | 2,000 | 2,573 | 3,000 |
| 14' - 0" | 589 | --- | 2,052 | 2,750 |
| 16' - 0" | 457 | --- | 1,646 | 2,500 |

* with 7/16" OSB on each side

### *5.3 Transverse Load Strength*

Walls, floors, and roofs all must have the strength to resist transverse loads. Transverse loads are any forces applied to the face of the structural member, forcing the member to bend. Forces that apply transverse loads to floors and roofs can include live loads and dead loads. Live loads include things like people and furniture. These items are not permanent; they can and do move from place to place, and they vary in intensity. Dead loads are permanent fixtures. An example in a commercial building could be an air-handling unit mounted on the roof. It is a constant force applied at a permanent position. For walls, the primary flexural force is wind out of plane on the panel.

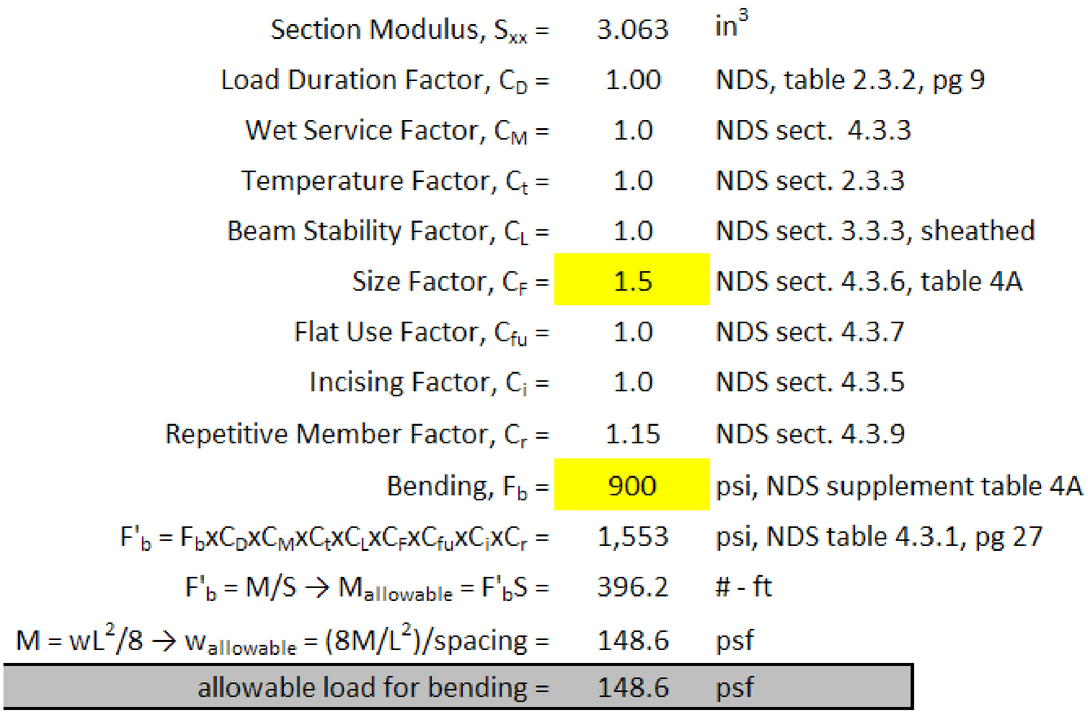
Surely no floor or roof in a residential or commercial building would be subjected to an elephant standing on it, but in case such heavy loads (such as an elephant) occur, one producer, Fischer SIPS, has proved in a demonstration just how strong SIPs are (see Figure 5-1).

**Figure 5-1 A SIP panel withstands the weight of two men and an elephant. Photo courtesy of Fischer SIPS.**

For designing stick framed transverse loading capacities, the NDS has prescribed methods for determining the overall bending strength of timber, just as for axial loading. Timber can fail three ways due to transverse loading and needs to be checked to establish capacity. The minimum bending strength, shear strength, and deflection will govern the available strength of the member. A spreadsheet was developed to calculate the transverse capacity of stick framing.

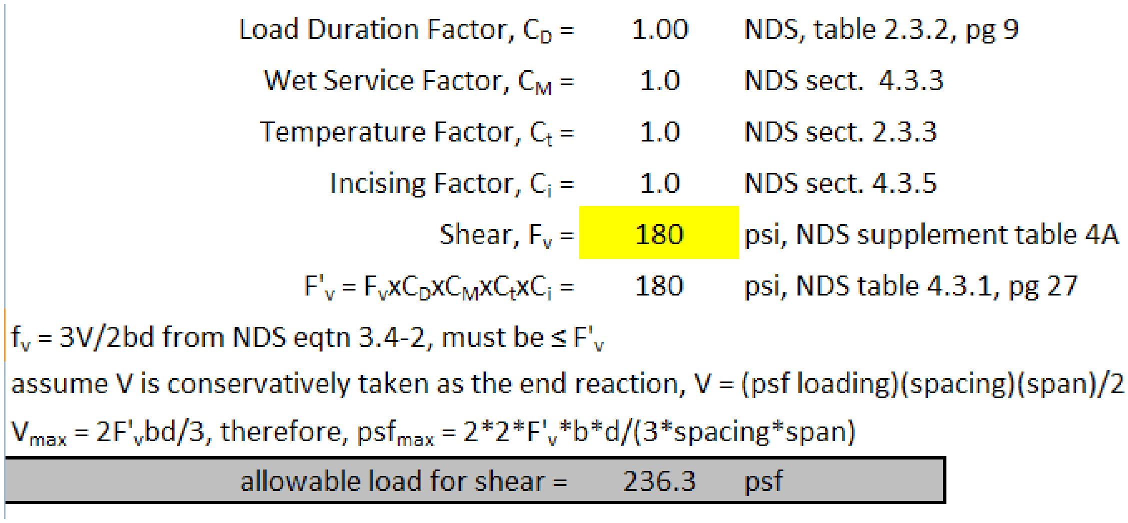
Initially, certain information must be known about the members and the design requirements. For the member material, I chose to use the species Douglas Fir-Larch with a number 2 grade. I used a typical 16” on center spacing for 2x nominal lumber ranging from 6” to 12” nominal depths. The spans ranged from 10 feet to 24 feet at 2 foot intervals.

The first calculation is for bending strength of the member. Several variables are needed for this step. I assumed normal conditions would apply so that the load duration, wet service, temperature, beam stability, flat use, and incising factors would all be taken as 1.0. The section modulus is calculated based on the size of the member. The size factor and reference design value for bending stress, $F_b$, also varied, depending on size and material of the member. These two items are highlighted, representing input values. Based on these variables, the allowable load due to allowable bending stress can be calculated following the NDS procedure. The following procedure shows an example calculation for a 2x4 under transverse loading. The final allowable load is set in the gray rectangle.



| | | |
|---|---|---|
| Section Modulus, $S_{xx}$ = | 3.063 | in$^3$ |
| Load Duration Factor, $C_D$ = | 1.00 | NDS, table 2.3.2, pg 9 |
| Wet Service Factor, $C_M$ = | 1.0 | NDS sect. 4.3.3 |
| Temperature Factor, $C_t$ = | 1.0 | NDS sect. 2.3.3 |
| Beam Stability Factor, $C_L$ = | 1.0 | NDS sect. 3.3.3, sheathed |
| Size Factor, $C_F$ = | 1.5 | NDS sect. 4.3.6, table 4A |
| Flat Use Factor, $C_{fu}$ = | 1.0 | NDS sect. 4.3.7 |
| Incising Factor, $C_i$ = | 1.0 | NDS sect. 4.3.5 |
| Repetitive Member Factor, $C_r$ = | 1.15 | NDS sect. 4.3.9 |
| Bending, $F_b$ = | 900 | psi, NDS supplement table 4A |
| $F'_b = F_b x C_D x C_M x C_t x C_L x C_F x C_{fu} x C_i x C_r$ = | 1,553 | psi, NDS table 4.3.1, pg 27 |
| $F'_b = M/S \rightarrow M_{allowable} = F'_b S$ = | 396.2 | # - ft |
| $M = wL^2/8 \rightarrow w_{allowable} = (8M/L^2)/spacing$ = | 148.6 | psf |
| allowable load for bending = | 148.6 | psf |

The next calculation is for allowable shear strength. Like bending, shear strength depends on certain variables, seen in the following spreadsheet. The only variable not in the previous calculation is the reference design shear stress, $F_v$, which depends on the species of the material and is highlighted in yellow to show that it is a variable. Again, the final allowable load based on shear stress is placed in the gray rectangle.



| | | |
|---|---|---|
| Load Duration Factor, $C_D$ = | 1.00 | NDS, table 2.3.2, pg 9 |
| Wet Service Factor, $C_M$ = | 1.0 | NDS sect. 4.3.3 |
| Temperature Factor, $C_t$ = | 1.0 | NDS sect. 2.3.3 |
| Incising Factor, $C_i$ = | 1.0 | NDS sect. 4.3.5 |
| Shear, $F_v$ = | 180 | psi, NDS supplement table 4A |
| $F'_v = F_v x C_D x C_M x C_t x C_i$ = | 180 | psi, NDS table 4.3.1, pg 27 |

$f_v$ = 3V/2bd from NDS eqtn 3.4-2, must be ≤ $F'_v$

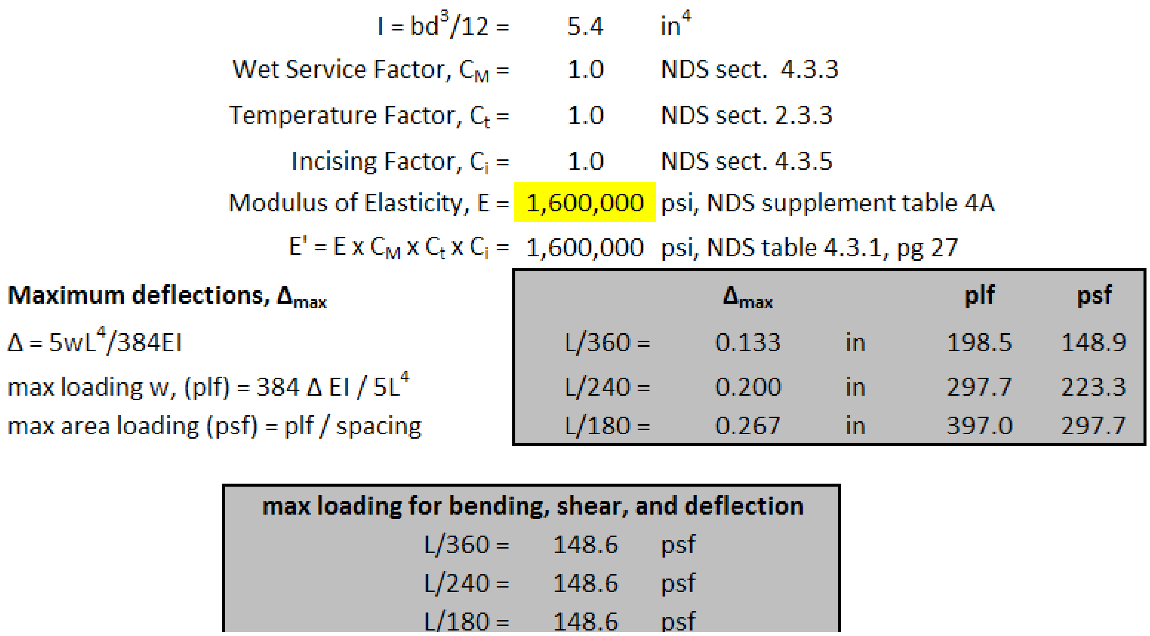
assume V is conservatively taken as the end reaction, V = (psf loading)(spacing)(span)/2

$V_{max}$ = 2F'$_v$bd/3, therefore, psf$_{max}$ = 2*2*F'$_v$*b*d/(3*spacing*span)

allowable load for shear = 236.3 psf

One last limit state is deflection. The amount that a floor, roof, or wall can deflect depends on the material and what that material supports. For example, roofs are generally permitted to deflect more than floors, while members that support large areas of glass are not permitted to deflect much because if they do, the glass could break. Different scenarios thus require three different deflection limits: L/360, L/240, and L/180, where “L” represents the span of the member in inches. L/360 represents a scenario where the members are not permitted to deflect much at all, and L/180 allows more deflection.

As with the other two checks, deflection is limited by several factors. The variable this time is the modulus of elasticity of the material. The following is the NDS calculation for determining allowable deflection of a 2x4 spanning four feet.



$I = bd^3/12 =$ 5.4 $in^4$

Wet Service Factor, $C_M =$ 1.0 NDS sect. 4.3.3

Temperature Factor, $C_t =$ 1.0 NDS sect. 2.3.3

Incising Factor, $C_i =$ 1.0 NDS sect. 4.3.5

Modulus of Elasticity, E = 1,600,000 psi, NDS supplement table 4A

$E' = E \times C_M \times C_t \times C_i =$ 1,600,000 psi, NDS table 4.3.1, pg 27

**Maximum deflections, $\Delta_{max}$**

$\Delta = 5wL^4/384EI$

max loading w, (plf) = $384\ \Delta\ EI / 5L^4$

max area loading (psf) = plf / spacing

| | $\Delta_{max}$ | | plf | psf |
|---|---|---|---|---|
| L/360 = | 0.133 | in | 198.5 | 148.9 |
| L/240 = | 0.200 | in | 297.7 | 223.3 |
| L/180 = | 0.267 | in | 397.0 | 297.7 |

**max loading for bending, shear, and deflection**

| | | |
|---|---|---|
| L/360 = | 148.6 | psf |
| L/240 = | 148.6 | psf |
| L/180 = | 148.6 | psf |

Once these three calculations have been completed, the governing load capacity is determined by the minimum of the three checks. Deflection never governs for given spans or depths, so the loading shown below in Table 5-2 is the allowable loading for all three deflection criteria. Table 5-2 shows the transverse load strength of stick framing compared to the allowable loads provided by the ICC-ES for R-Control SIPs. Only the loading capacity for the most stringent load case for SIPs is included in this table. All were higher than for the stick framed capacity. The other two deflection criteria for SIP panels and transverse loading allow greater loads.

**Table 5-2 Transverse loading for stick framing, psf**

| Span | 2x6 @ 16" OC | 5.5" EPS Core* | 2x8 @ 16" OC | 7.25" EPS Core* | 2x10 @ 16" OC | 9.25" EPS Core* | 2x12 @ 16" OC | 11.25" EPS Core* |
|---|---|---|---|---|---|---|---|---|
| deflection: | All | L/360 | All | L/360 | All | L/360 | All | L/360 |
| 10' - 0" | 51 | 53 | 82 | 89 | 122 | 150 | 164 | 177 |
| 12' - 0" | 35 | 40 | 57 | 65 | 85 | 111 | 114 | 148 |
| 14' - 0" | 26 | 30 | 42 | 48 | 62 | 84 | 84 | 115 |
| 16' - 0" | 20 | 24 | 32 | 37 | 48 | 65 | 64 | 89 |
| 18' - 0" | 16 | 19 | 25 | 28 | 38 | 51 | 51 | 70 |
| 20' - 0" | 13 | 15 | 20 | 22 | 30 | 41 | 41 | 56 |
| 22' - 0" | 11 | --- | 17 | --- | 25 | 33 | 34 | 45 |
| 24' - 0" | 9 | --- | 14 | --- | 21 | 27 | 28 | 37 |

* with 7/16" OSB on each side

The ICC-ES provides transverse load tables for R-Control SIPs. Unlike axial loading, where the load is carried by the panel and the splines do not contribute to the axial strength, the connectors are important in transverse design because they replace part of the foam core. Because each spline has different bending capacities, the overall transverse load that SIPs can take is limited, in part, by the spline. Some splines can better carry higher loads on shorter spans than others, while other splines may be better suited for longer spans. Therefore, directly comparing stick framing and SIPs is difficult with transverse loads.

Comparing the load tables provided by the ICC-ES, SIPs compare remarkably well with stick framing in transverse loading. Three out of the four spline designs provided allow spans up to 24 feet for the thicker panels. These three splines are double 2x, engineered wood I-beam, and an insulated engineered wood I-beam. The fourth spline, the OSB spline, design only allows spans up to 12 feet and has considerably lower load capacities. Stick framing compares relatively even with this spline type. The other three, however, have considerably higher strength capacity than stick framing for transverse loads. In many spans and thicknesses, SIPs have roughly twice as much transverse loading capacity as stick framing of the same depth.

### *5.4 In-Plane Shear Strength*

In-plane shear strength provides stability for a structure when wind or seismic lateral forces are applied as part of the lateral force resisting system. Shear strength takes lateral loads and distributes them to the ground, keeping the structure upright. Lateral loads for structures above the ground include wind loads or earthquake loads; they apply an overturning force to the structure.

In stick framing, these forces are dealt with by attaching sheathing, most often OSB, to the outer perimeter of the structure. The panels are attached with nails or staples with spacing generally around six inches around the panel edge and 12” within the field area of the board. The edge spacing depends on the specific loading criteria.

The 2006 edition of the IBC provides load tables for timber shear walls. Table 2306.4.1 gives the values for walls framed with Douglas-Fir-Larch or Southern Pine with varying panels and fasteners. For eight or nine foot walls, sheets are readily available so that all edges are fastened directly to studs or top or bottom plates. For taller walls, or a design where an edge of the panel may be unsupported, blocking should be placed behind the edge for fasteners.

For traditional 6” edge nailing and 12” field nailing using 7/16” sheathing and 8d common nails, the allowable shear from IBC 2006 Table 2306.4.1 is 240 plf of wall. This value can be increased to 350 plf by decreasing the edge spacing to 4”, 450 plf by decreasing the edge spacing to 3”, or even 585 plf by decreasing the edge spacing to 2”. To use the 2” spacing, the framing must be at least 3” nominal. For a design using studs spaced no more than 16” on center, these values may increase to 260 plf, 380 plf, 490 plf, and 640 plf.

In contrast, SIPs with a wall height to length ratio of 1:1 have an allowable shear loading of only 335 pounds per linear foot for both 3 ½” and 5 ½” cores (ICC-ES, 2009). Unlike conventional framing, SIPs are solid panels with a continuous connection between the core and skin, so the allowable shear of the panel can not be easily increased.

### *5.5 Real World Tested*

In a laboratory, everything is controlled. In the field, things are different; anything could happen: higher loads than expected, unique unpredicted loading, or other things not accounted for in tests or design. SIPs have been through it all though: hurricanes, tornadoes, earthquakes, and more.

One example of SIP homes surviving natural disasters took place in 1995 in Kobe, Japan. A 6.9 magnitude earthquake struck, leveling entire blocks. Homes built with SIPs were among the only structures still standing (Hodgson, 2009).

A different disaster struck Clermont, Georgia, in March, 1998. This time, it was a tornado. The home owner lost 25 mature trees and many shingles, while 27 homes nearby were destroyed. The SIP house suffered no structural damage (Morley, 2000).

In 2004, four high category hurricanes developed throughout the season. Category 4 Hurricane Charley struck Florida. Hurricane Charley left uprooted palm trees and destroyed homes and buildings. Three homes in its path of destruction remained nearly unaffected by this hurricane. These homes were constructed with SIPs made with fiber-cement skins, instead of the normal OSB skins, and used 4” thick cores. Two of the homes remained completely intact, while the third suffered only minor damage when a tree landed directly on it; it took only one day to repair the damage (Success Stories: PATH technology helps homes stand up to Hurricane Charley, 2006).

Figure 5-2 shows one of these homes and the surrounding trees before Hurricane Charley hit. After the hurricane, the trees had lost many of their branches, and some seem to have been broken off part way up. The structure of the home, however, remained strong and intact, as can be seen in Figure 5-3.

**Figure 5-2 Home and trees before Hurricane Charley.**

**Photo courtesy of Home Front Homes.**

**Figure 5-3 The home survived while the trees were destroyed.**

**Photo courtesy of Home Front Homes.**

# CHAPTER 6 - Other Comparisons of SIPs and Stick Framing

This section compares some of the non-structural areas of these two building systems: insulation, sustainability, fire resistance, insect resistance, moisture, and ventilation, concluding with some cost comparisons.

## 6.1 Insulation

Batt insulation is typically used in stick framing. It is made of fiberglass strands woven together. This traps air within itself, which creates a thermal blockade. This kind of insulation has many drawbacks that reduce its effectiveness.

The biggest disadvantage of batt insulation is its lack of consistency. After a wall is built and the exterior is sheathed, sheets of insulation, cut to the appropriate width and height to fit between studs or joists, are installed. The only thing supporting the sheets of insulation is friction between them and the studs surrounding them. In poor construction, insulation does not fully fill the voids between studs. Figure 6-1 shows improperly installed insulation. To perform correctly, batt insulation should not be compressed or folded. The result of compression or folding is lower insulating values. This image shows a strip of insulation that has been creased and compressed, forced into a narrow space.

**Figure 6-1 Improperly installed roof insulation. Photo courtesy of SIPA.**

These insulating practices also result in gaps around items installed within walls.  At the very least, electrical receptacles should be spaced around residential rooms.  Often, junction boxes for cables or other wiring is also installed in a room.  Improperly installed insulation around such receptacles loses much of its insulating properties.

The overall insulating value of SIPs is far superior to stick framing with batt insulation.  Figure 6-2 shows the whole-wall insulating values of various walls.  The table plots the insulating values over the entire wall; this accounts for insulation breaks such as at studs.  Amazingly, 4” SIP walls outperform even 6” stick walls, even when the wall is properly constructed and insulation properly installed.  However, poor installation means the 6” walls drop from equal to SIPs to three points lower.  Stick built walls that are 4” thick have an R-value 30% less than 4” SIP walls.  It should be noted however, that these values are produced by Structural Insulated Panel Association and are meant to show SIPs in the best possible light.  There are other options in stick framing with better insulation which will provide different results.  For example, insulation with higher R-values is available.  Common R-values for 2x4 framing are 13 and 2x6 framing is around 15.  For both sizes of stud walls, with studs spaced at 16”, the R-value drops approximately one point due to the interruption of studs.  Other methods of insulation are available as well, including spray-in and low-expanding foam insulations.  Both of these types provide better fitting insulation within walls and would compare better to SIPs than Figure 6-2 would suggest.

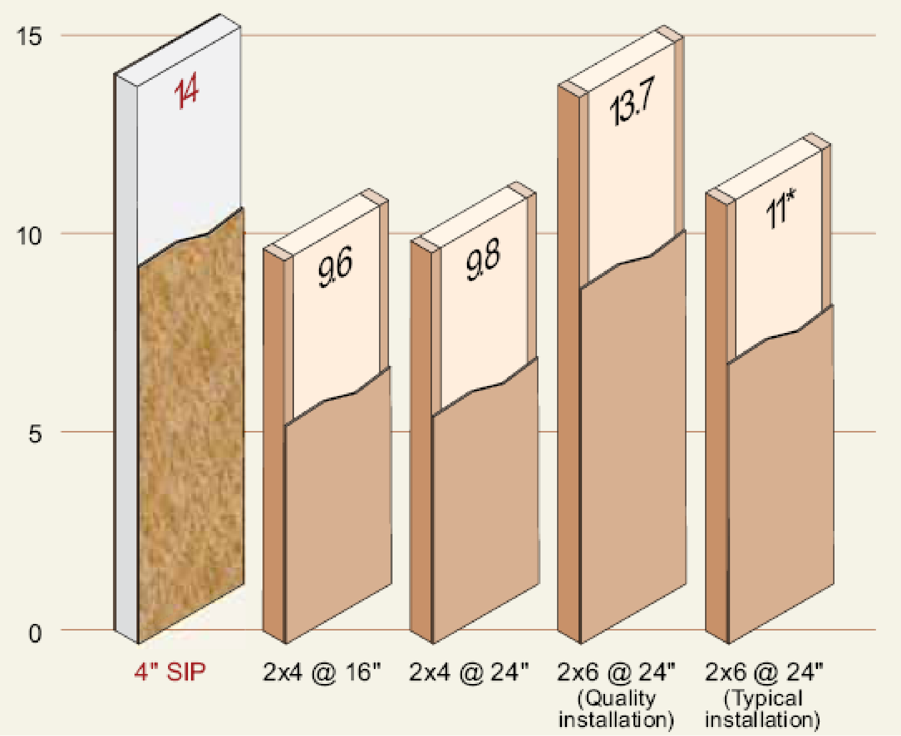


**Figure 6-2 Insulating values of different wall systems. Courtesy of SIPA.**

Infrared images can show how heat transfers through walls. Blue represents little heat transfer while yellow and red indicate more transfer. Figure 6-3 shows an infrared image of a stick built wall. The different colors show a large thermal gradient with the studs interrupting the insulation and causing the overall insulation value to drop.

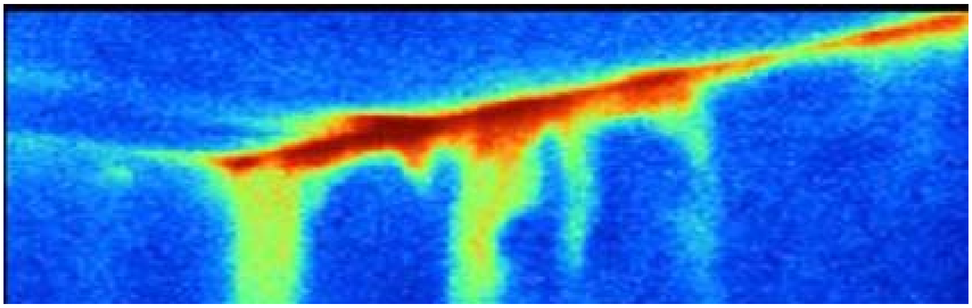


**Figure 6-3 Insulation breaks in stick framing. Photo courtesy of SIPA.**

Figure 6-4 shows an image of a SIP corner. The color in this image is constant. This shows that a SIP built structure can better maintain its thermal resistance uniformly across the entire wall.

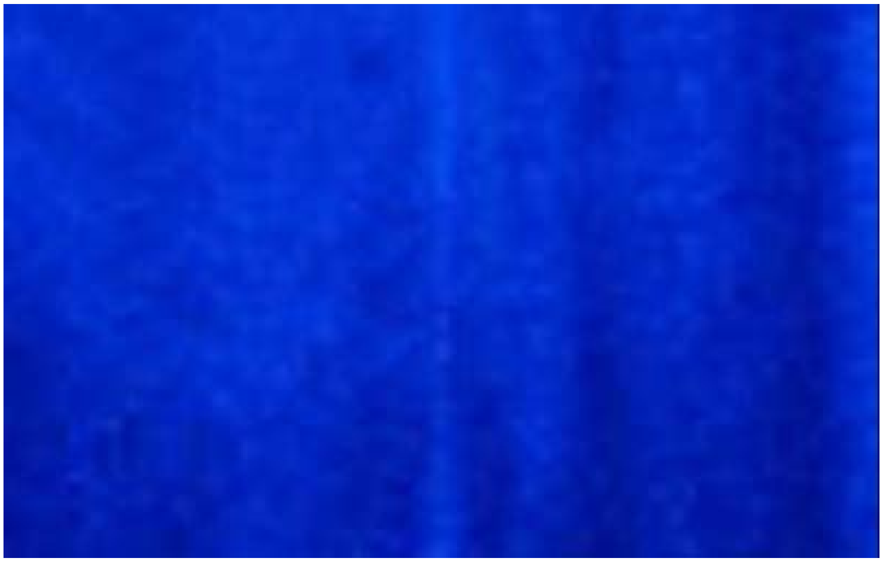


**Figure 6-4 SIP corner has uniform insulation. Photo courtesy of SIPA.**

With higher insulating values than stick framing, the interior is much better protected against thermal changes. In any season, the building will stay at a more constant temperature without requiring the air conditioning units to work harder. When SIPs are combined with other efficient systems like double-pane windows, energy costs could be reduced as much as 50-70% (Hodgson, 2009).

Up to 40% of heat loss within a building is due to air leakage (Association, 2007). A more tightly constructed building will have a lower heat exchange, preventing the air conditioning units from working too hard. SIPs are 15 times tighter than stick framing, preventing much heat loss (Association, 2007).

An SIP structure may, however, require a mechanical fresh air ventilator because of its tightness. Occupants and activities within a building produce moisture. This moisture can make the air very stagnant and get into the walls, destroying the structure from the inside, resulting in expensive moisture related repairs. This can occur in both SIP and stick framed structures. In stick framed buildings, however, the envelope is not as tight, which allows a certain amount of ventilation that prevents most of this problem. SIPs are much tighter, though, and may need a mechanical ventilation system, more to control air movement and circulation than heat or cool the structure. The SIP building with mechanical ventilation will have better indoor air quality and reduce expensive repairs (Morley, 2000).

Because SIPs insulate so uniformly, they have yet another advantage: no cold or hot spots along walls. In some buildings with poor insulation, temperature can change dramatically within a few feet based on where the insulation is. SIPs do not have this fault, resulting in a more comfortable space.

## 6.2 Sustainability

Much of manufacturing, agriculture, and even construction now focus on environmental sustainability. With the world population well over 6.5 billion people, and growing rapidly, and depleted fossil fuel sources, more sustainable energy and more efficient products are not only politically correct but economically necessary. Making a structure itself sustainable and "green," from production onwards, we have few options. In this section, we compare the sustainability of SIPs and stick framing.

### *6.2.1 Production*

Harvesting trees and utilizing wood building materials is a sustainable practice and can be shown in various ways. Forest owners and logging companies have become more environmentally friendly in how they harvest trees; trends have shifted in the logging industry to maximizing timber yield while at the same time protecting water ways, reducing erosion, protecting natural ecosystems, and enhancing wildlife habitats (DeStefano, 2009).

Moreover, mature forests remove less carbon dioxide from the atmosphere. Young forests extract much more carbon dioxide from the air as they grow than when they have matured. If forests are not thinned and harvested occasionally, they will eventually reach the point where carbon dioxide released by decaying trees and forest fires offsets what is absorbed by living trees. If these mature trees are used in the production of buildings that last for decades, the carbon dioxide is also removed from the atmosphere and environment for that time, rather than being released back into the air by decay or fire; this is referred to as "carbon sequestration" (DeStefano, 2009).

Producing SIPs is also environmentally friendly. Oriented strand board (OSB), the most common outer skin, is typically produced from forests that are sustainably managed (Jasmin, 2005). Up to 90% of logs can be used in the production of OSB sheets, and the rest can be used for energy in production (Association, 2007).

Even the foam core of the panels are "green." One foams that is typically used in manufacturing SIPs is expanded polystyrene (EPS). This kind of foam consists mostly of air; only 2% is plastic made from oil (Association, 2007). With the panels produced in a factory, the foam core is also 100% recyclable (Hodgson, 2009). Pieces that are cut out from one panel can often be reused in the production of another panel. One last advantage is that it takes 24% less energy to produce these foam cores than fiberglass insulation of equivalent insulating values (Association, 2007).

### *6.2.2 On Site*

A large portion of material savings can occur on the job site during construction. Because panels can often be manufactured according to plans developed in a factory, complete with openings, material saved during production and recycled can be used to make other panels. If panel modification occurs on site, the material will most likely be thrown in a dumpster and hauled to the landfill.

Another way SIPs can save material is by wasting less in building the wall. When building a stick framed structure, the builders have bundles of lumber delivered to the job site. These pieces are then cut, with the contractor trying to use as many left over pieces as possible. Unfortunately, many pieces are still left over as scrap and are often hauled to a landfill or burned. Over a five year period, new home construction produced 232.9 million linear feet of scrap, or about 44,110 miles of leftover lumber (Laquatra, 2004). SIPs can reduce waste from job sites by 60% (Hodgson, 2009). Since SIPs are produced in a factory, when openings, angles, and cutouts are made in the factory, leftover pieces are recycled and used to make another panel. Some manufacturers even specify an amount of recycled content to be used in their panels (Hodgson, 2009).

Figure 6-5 shows a new residence with stacks of 2x4s and much more in the front yard by the street as well as behind the house. Most of this will become part of the structure. However, some will be used only for braces or other temporary fixtures while other pieces will be leftover after cutting boards to the length required.

**Figure 6-5 Construction site of a new stick built house**

Figure 6-6 shows the construction site of a home being built with SIPs. Since fewer braces are required and panels are fabricated in a factory, much less material is required on site.

**Figure 6-6 Construction site of a new SIP house. Photo courtesy of Fischer SIPS.**

## 6.3 Fire Resistance

Wood is a combustible material and, as a result, fire and smoke is a concern. However, just like with stick framing, sheet rock can provide protection against fire. Single residence buildings typically require only a 15 minute fire rating. A single layer of standard ½” gypsum board attached to the SIP can provide this protection (Tracy, 2000). For light commercial or multi-family dwellings, more restrictive one hour ratings may be required. For this, there are two choices: two layers of 5/8” type X gypsum or one layer of 5/8” type C gypsum, both attached according to manufacturer’s code report (Tracy, 2000).

## 6.4 Termites and Other Insects

While termites could be an issue if they get to the OSB skins, SIPs are no more susceptible than stick framing. Both systems are wrapped and protected in the same manner after construction is completed. SIP producers also offer sprays and other treatments to block and protect against termites and other insects.

## 6.5 Formaldehyde

Formaldehyde off-gassing from the SIPs into living space is generally not a concern. While OSB does contain formaldehyde, it is only at 0.1 parts per million, well below the US Department of Housing and Urban Development’s standards (Structural Insulated Panel Association, 2007). To put this amount in perspective, formaldehyde is found in food, such as apples and onions, and is even present in a higher amount in the human body, at about 3 parts per million (Emery, 2008).

## 6.6 Repair

In any building, if damage occurs, a structural engineer familiar with the structural system needs to assess the damage. In a stick structure, individual members can be removed and replaced if damaged. For a SIP system, depending on the damage, panels can be repaired or replaced. For repair, the section can be cut out, the foam recessed 1 ½” and lined with 2x dimensional lumber. A piece of a SIP cut to the size of the opening can then be installed and fastened to the existing panel (Redmond, 2010). This is shown in Figure 6-7.

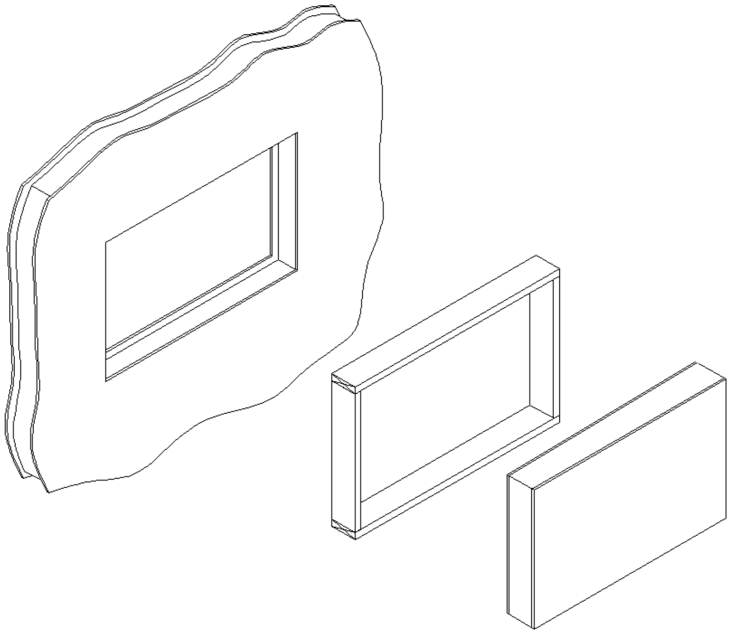


**Figure 6-7 SIP Repair**

## 6.7 Effects on Other Trades

SIPs can affect other trades. However, the producers of SIPs address the issue. The result is that, with a little care and planning, other trades have few issues working with SIP construction.

In general, unless the design requires it, plumbing and heating, ventilation, and air conditioning (HVAC) parts do not go in exterior walls, where SIPs are most likely to be used. This is primarily because the size of those pieces could replace a significant amount of insulation within the wall. Generally, plumbing and HVAC trades are unaffected by the use of SIP walls.

When plans do call for plumbing or HVAC designs within SIP walls, it is possible, if difficult, to design small chaseways within the wall with the assistance of the SIP provider. Another option is to build a small chaseway outside of the wall to conceal the pipe or ductwork.

For electricians, wires required in exterior walls, whether for switches, receptacles, cable, or other items are generally planned by SIP producers, who provide chaseways built into the panels. Typically two chaseways run horizontally, one lower for receptacles and one higher for switches. They also provide a vertical chaseway for running wires to other floors.

## 6.8 Cost

SIPs are so easy to erect that they require less skilled labor than stick framing (Morley, 2000). This is an advantage for two reasons. The first is that in a time where fewer people are entering the construction trade and there are fewer skilled stick framers (Morley, 2000), less experienced people can be hired to help build. The second advantage is with cost. Less experienced workers require less pay than experienced workers, thus saving on costs here as well.

It is difficult to compare the exact cost of a stick framed building with one built with SIPs. Prices vary across the nation for materials and labor and identical houses are rarely made using different materials. Material availability could be an issue in many places. SIPs are not widely used, so manufacturers are few, while lumber availability. This can drive the cost of materials up for SIP construction. Conservative estimates put material costs 10-25% higher for SIPs than stick framing (Barista, 2008). However, SIPs often cost closer to about 5% more (Premier Building Systems, 2009). Material costs make SIPs appear more expensive up front, but the entire cost of construction will reduce the overall cost.

Premier Building Systems (PBS) provides a case study comparing the construction costs of stick framing to SIP construction on their website. The study was based on a 2,500 square foot, single story house. SIPs saved 11 days of construction from the time the first layout chalk lines were snapped to the installation of drywall (Premier Building Systems, 2009). Four of these days were saved on framing, while the other seven days were shaved off because the electrician did not have to come in and drill holes through the studs because chaseways were preinstalled, walls were straight and required no furring to apply drywall (which may not be applicable in all cases), and the shear panels and insulation was already incorporated in the panel.

The study also broke down the labor cost savings. By cutting 4 days on labor at \$27/hour/day, one day with a 3 person crew instead of the regular 5, one day for not having to fur walls, and 2 days on panels at a rate of \$27/hour, \$1,944 was saved during framing. One day at \$12/hour, or \$96, was saved on electrical work. Insulation savings added up to \$1,400 (Premier Building Systems, 2009). SIPs thus saved \$3,440 on labor costs alone. Additional cost savings come from fewer drywall cracks and nail pops.

Estimated total costs for stick construction was approximately $110/square foot, and SIP construction was approximately $115.50/square foot, using a modest 5% increase of SIPs cost over stick cost (Premier Building Systems, 2009). For a 2,500 square foot house, the total cost of a stick built house was $275,000 and for a SIP built house was $288,750. Thus, a SIP built house is indeed more expensive. However, the study then subtracted the labor savings discussed above, $1,200 for downsizing from a 5-ton HVAC unit to a 3-ton unit, and $700 for having less waste to be hauled away. The total savings to the contractor alone by using SIPs over stick framing (even considering SIPs to have more expensive materials) was almost $2,000/house. The owner also saves considerably with lowered utility costs.

# CHAPTER 7 - Conclusion

SIPs have many advantages over stick framing.

- SIPs are faster to assemble on site.
- The finished product using SIPs is of better quality because they are dimensionally stable and will not shrink, creating cracks or pops.
- Compared to traditional designs of studs and joists at 16” or 24” on center, SIPs can carry a higher axial and transverse load.
- SIPs are far better insulated. By avoiding the need for studs, SIPs reduce the amount of thermal breaks that occur in stick framing. The rigid foam cores provide more insulation than batt insulation, resulting in a more comfortable space as well as lower utility bills.
- SIPs are more environmentally friendly than stick framing. In production, they require less energy to produce and can be recycled and reused within a factory. On site, they produce less waste and are less likely to be stolen. Stick framing is not customized to jobs at a factory, resulting in many linear feet of material being hauled away to a landfill.
- With total cost, for a 2,500 square foot house, SIPs reduce time of construction and require a smaller HVAC system, resulting in a lower overall cost.

In some areas, stick framing is better than SIPs.

- Stick framing can be made much more robust for resistance to lateral forces such as high wind and seismic forces.

In other areas, SIPs and stick framing compare evenly.

- Both systems contain wood and are thereby subject to fires. Sheet rocking can provide the necessary resistance.
- Termites can be prevented by using treated products.

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# Appendix A - Image Permission

The images contained within this document are property of the author unless otherwise noted. Images provided by others are used by permission of the entities cited in this section. Permissions are listed alphabetically by party.

## Fischer SIPS

Hi Brad,

Those pics are quite old and I couldn't find them again. I have attached a couple others similar to them. Hopefully these will work.

Damian
On Sun, Mar 7, 2010 at 1:25 PM, <btl@ksu.edu> wrote:

Hi Damian,

I decided I would like to try a couple other photos. On the websites products and services tab, could I get the last picture on that page along with the "Installation of a 12' x 8' wall panel in a residential project" picture on the under construction tab? Thank you very much for your assistance.

Brad Ledford
Kansas State University
Architectural Engineer
Graduate Student
btl@ksu.edu

**Original Message:**
From: "FischerSIPS Sales Box" sales@fischersips.com
To: btl@ksu.edu

Sent: Friday, March 5, 2010 9:43:10 AM GMT -06:00 US/Canada Central
Subject: Re: Fischer SIPs pictures

Sure. Let me know if you are needing any more. or if you're looking for something specific.

Damian

On Thu, Mar 4, 2010 at 10:15 AM, btl@ksu.edu wrote:

Hi Damian,

Thank you very much for the pictures. They will work great.

Brad Ledford
Kansas State University
Architectural Engineer
Graduate Student

**Original Message:**
From: "FischerSIPS Sales Box" sales@fischersips.com
To: btl@ksu.edu
Sent: Thursday, March 4, 2010 9:01:06 AM GMT -06:00 US/Canada Central
Subject: Re: Fischer SIPs pictures

Hi Brad,

I would be happy to allow the use of the elephant photo but you must use it without removing our logo. We've spent a lot of money to copyright these items. I've attached a copy. I would also be willing to send you additional photo's. I've also attached several 'construction photo's' for starters. Let me know if you're looking for something more specific.

Damian Pataluna
President
502-778-5577 x285

On Wed, Mar 3, 2010 at 12:12 PM, btl@ksu.edu wrote:

To Whom It May Concern:

My name is Brad Ledford. I am an architectural engineering student at Kansas State University. I am currently writing my Master's Report comparing SIPs and stick-framing. I would like to use the image of the elephant standing on the panel as well as possibly using some of your construction and finished product pictures. May I have your permission to use these images? Or is there a form you would like me to fill out or be more specific on which pictures? If you have any questions of me, please feel free to ask. Thank you for your time and assistance.

Brad Ledford
Kansas State University
Architectural Engineer
Graduate Student

## Home Front Homes

Brad,

Attached is some information that may help you with your study. You have our permission to use any of these images in your report as long as you footnote "Home Front Homes". In addition you may find the following video useful http://www.youtube.com/watch?v=M_-osDmJDxU

There are many other videos concerning SIPS on our YouTube Channel at http://www.youtube.com/user/HomeFrontSIPS?feature=mhw4.

Best of luck with your studies.

Jerry Gillman

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826 South Dixie Highway
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Email: jerry@homefronthomes.com
jerry@homefronthomes.com.ar
Web Site: www.homefronthomes.com

**Original Message:**
From: btl@k-state.edu
Sent: Monday, March 08, 2010 10:30 PM
To: info@homefronthomes.com
Subject: pictures of SIPs

To Whom It May Concern:

My name is Brad Ledford. I am an architectural engineering graduate student at Kansas State University. I am currently writing my Master's Report comparing SIPs and stick-framing. One section I have deals with the strength of SIPs compared to stick framing, and I am discussing real life examples of how SIPs have out performed other construction and survived natural disasters.

I have learned of your company through Partnership for Advancing Housing Technology's website and saw a house that survived Hurricane Charley. May I have your permission to use images of this house? If so, could you attach the pictures, or pictures of any other SIP structure you may have that has survived a natural disaster. Or is there a form you would like me to fill out or be more specific on which pictures? If you have any questions of me, please feel free to ask. Thank you for your time and assistance.

Brad Ledford

Kansas State University
Architectural Engineer
Graduate Student
btl@ksu.edu

## Structural Insulated Panel Association

Hi Brad.  Yes you may use any photo you choose from our website.  Attached are infrared photos as well.

Regards,

Bill Wachtler
Executive Director
Structural Insulated Panel Association
P.O. Box 1699
Gig Harbor, Washington 98335
Phone:  253 858 7472
Fax:  253 858 0272

**Original Message:**
From: btl@k-state.edu
Sent: Wednesday, March 24, 2010 6:46 AM
To: info
Subject: SIPs pictures

To Whom It May Concern:

My name is Brad Ledford.  I am a graduate student at Kansas State University in architectural engineering.  I am currently working on my Master's Report about Structural Insulated Panels.  Part of my report is about the history of SIPs and how they have advanced.  I have seen on SIPA's website a construction shot photo of of a tall building with curved SIPs.  May I have permission to use this photo in my report?

Also, I was wondering if you could supply me with a picture that shows the insulation properties of SIPs or stick framed structures. Charts or tables would work. Or if you have an infrared picture that shows how bad stick framed insulation can be, that would be appreciated.

Thank you very much for your time and assistance!

Brad Ledford
Kansas State University
Architectural Engineer
Graduate Student
btl@ksu.edu