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Tools for Designing with and Evaluating the Benefits of Structural Insulated Panels

A Practicum Paper Presented

By

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ABSTRACT

Changing climate and increasing costs of energy are putting pressure on the building industry to adapt to higher performance building systems. One technology that can improve building performance is structural insulated panel (SIP) construction. The purpose of my practicum is to evaluate the possible benefits of SIPs and to identify obstacles to SIPs gaining a larger portion of the building industry. The benefits of SIPs are lower thermal bridging and air infiltration leading to lower operating costs and minimal material usage. Findings include the identification of obstacles to increased adoption of SIP technology. Recommendations are made to overcome these obstacles.

KEY WORDS

Structural Insulated Panels, High Performance Building, Revit, Take-off, Heat Loss Modeling, Air Infiltration, Thermal Bridging

INTRODUCTION

The scientific community has high confidence that the increased greenhouse gasses in our atmosphere are increasing the average global temperature (IPCC, 2007). Rising in tandem with the new climactic challenges, are worries about energy prices, availability, and sources. The building industry is feeling this pressure because the buildings we use consume significant quantities of materials and energy to build, and also during their operational life. According to the United States Energy Information Association, in 2013 buildings consumed about 40% of the energy used in the United States (US EIA, 2014). Therefore, buildings offer a significant opportunity for lowering our total energy usage. Because buildings have a very long lifetime, they must meet not only today's challenges, but the challenges of the next century, at least. This leaves the

building industry with a powerful need for effective and efficient use of materials and energy to meet the changing demands of our climate, now and in the future.

Structural Insulated Panels (SIPs) are a relatively new building technology, which appear to have the potential to significantly reduce energy usage of buildings.

Unfortunately, the building industry is very resistant to change. There are many good reasons for this tendency towards conservatism in the building industry. One of the considerations for builders which impedes change, is that structural failure can put human life at risk, and destroy the builders reputation. Another is that the many layers involved in the building process (manufacturers, architects, contractors, plumbers, electricians, laborers, clients, and regulatory boards) all must change at the same time to be successful. Each individual sector must be educated and motivated in order to change the system.

While SIPs appear to have significant potential, they have been slow to displace more established building technologies, and still account for only one to two percent of new construction (Builder, 2010). In order to understand the barriers to more widespread use of SIP construction, I engaged in a “Practicum” study, working for a manufacturer of SIPs for a year. This paper documents observations and data collected during the Practicum. In addition, this paper evaluates the merits of SIP construction and identifies possible actions to overcome the existing barriers to more widespread adoption of SIP technology.

PRACTICUM

Scope

My practicum began as an internship, working for Foard Panel Inc. in West Chesterfield, NH. Foard Panel was founded in 1985, and employs approximately 35 people, and is involved in 200 to 300 projects each year. It provides SIP manufacture,

design, technical support, and has several crews working to build SIP structures. Foard Panel's primary range is Northeastern United States. Consequently most of their experience is focused on the climate and regulations from southern New Jersey to northern Maine and as far west as western New York. These areas primarily fall in wet and cold dominated climates, with some high wind zones, but no significant seismic zones; these are the conditions in which I have judged SIPs.

There are many different types of SIPs with a variety of different compositions. This practicum focuses on the category of SIPs comprised of foam cores and wood based panel skins. At Foard Panel, SIPs were most commonly constructed with an expanded polystyrene (EPS) foam core, and two sheets of 7/16" Oriented Strand Board (OSB). However, Foard Panel also produces panels with Neopor (NEO), Extruded Polystyrene (XPS), and Polyisocyanurate (PIR) cores. Each of these foam core types has its benefits, but the best thermal performance per dollar value is EPS. EPS and NEO are also the only cores currently studied for structural properties. XPS has shown in Foard Panel's internal testing to be as much as twice as strong as EPS, while PIR has shown to be significantly weaker than EPS, but neither XPS nor PIR has third party data. Foard Panels' OSB and EPS SIPs are designed and tested for use in exterior walls and roof structures. These are the most commonly used SIP in residential construction, and therefore are the focus of this study.

SIPs have been extensively examined for structural safety and have proven to be safe for long unsupported spans, and are also highly resistant to racking (Yang et al. 2012). The NTA, which is a national construction product certification provider, has created a SIP design guide which provides the basic formulas for checking bending, shear,

deflection and bearing capacities of SIPs (NTA, 2009). While not all manufacturers have paid for the testing to produce the necessary property data to be used in full engineering calculation, many companies have this basic property data. The other companies have more simplistic information in the forms of span and loading charts, which can still be useful in many applications. The difference between these two types of data is the flexibility of use. Property data can be used by engineers to figure out if a SIP can work in many different situations, while span table data is limited in its application, but is easily accessible for designers. Regardless of the differences in these types of data, it is clear from both that SIPs are capable of being used safely in a large array of building applications.

Designers at Foard Panel are concerned about reported failures of SIPs due to poor installation. In one example, poor sealing of the joints allowed moisture to leak into the interior of the panels in a large development in Juneau Alaska causing severe creep and roof failure (Cooper, 2003). Unfortunately, the early failures of SIP buildings and the continued need for careful construction causes the perception that they are not as strong or durable as traditional stick frame buildings. SIP joinery details have evolved significantly since early failures, and more thorough testing has made the structural limits clear. The first step in evaluating any new technology for commercial use is structural and safety testing under many conditions. This initial step has been carried out, though it needs to be continued, as the uses to which SIPs are applied expand.

At Foard Panel I learned about the manufacturing and design of SIPs. I also developed material and cost estimation skills and an understanding of the attitudes of building professionals and their clients towards SIP types. I witnessed some of the most

common obstacles and delays in the building process and heard customer's perspectives about SIPs. These experiences helped me to develop some expertise in the process of design and "take-off". Take-off is the process used to generate a detailed list of materials from a plan. I also learned about the structural details used in adapting SIPs to various building applications, and in preventing repeats of early failures. Understanding of SIP structural details allowed me to do some thermal bridging analysis and calculation of thermal resistance, or "R-value". I also had access to information from many different projects for some case study information. All these experiences together allowed for practical evaluation of the obstacles to integration of SIPs.

Evaluation of the Benefits of SIPs

The only reason to use a new technology like SIPs, is if provides significant benefits. Therefore, it is necessary to evaluate the benefits of the technology. For this paper, beneficial is defined in three categories:

- 1) How well the technology performs against current energy and resource conservation goals.
- 2) How SIPs affect the design process, construction process, and renovation process of a building as a measure of its adaptability.
- 3) How SIPs compare economically for builders, and homeowners.

The environmental benefits of SIPs were formally evaluated as net positive in the Life Cycle Analysis (Kahhat et. al., 2009). This was due to the minimized material waste, use of easily renewable wood products, recyclable foam cores, and lifetime energy savings. Further evidence of the possible energy savings from SIPs comes from, the Oak

Ridge National Lab, which has used hot box testing to measure the effective whole-wall R-value of SIP construction. In their testing of SIPs with a calculated center of cavity R-value for one inch of 3.8 square feet hours degrees Fahrenheit per British Thermal Unit ($\text{ft}^2\text{hr}^\circ\text{F}/\text{btu}$) performed at $3.7 \text{ ft}^2\text{hr}^\circ\text{F}/\text{btu}$, or 96 percent of their nominal value (Oak Ridge National Lab, 1998). This data was obtained with a simple wall with no windows, so it is only comparable to a conventional light frame construction (LFC) wall with no windows. A LFC wall with studs at 16 inches on center, no openings, or floor decks; has a framing factor of 15 percent, so it is clear that SIPs have a much higher baseline thermal performance. In actual buildings with windows the typical framing factors are higher both for LFC and SIPs.

The new International Energy Conservation Code 2012 (IECC) provides requirements for high levels of insulation, and has options for continuous insulation, which due to the Oak Ridge hot box testing includes SIPs. For example: in the IECC 2012, the R-20 wall insulation code can be met by an R-14 continuous insulation (International Code Council, 2011). This gives SIPs an economic advantage for the lower end of the building industry. The code also suggests that a SIP building that is nominally R-20 is really performing equivalent to an R-28 LFC. Therefore, SIPs can provide a significant advantage for meeting new energy codes. SIPs are recognized by code and testing as having superior thermal performance potential.

The second important measure for energy performance is air infiltration. The IECC also defines requirements for air sealing (International Code Council, 2011). SIPs can help fulfill these new air sealing codes. SIPs cannot claim full credit or blame for blower door data because there are many other construction details that can affect the

final numbers. However, in all eight of the samples from Foard Panel the results are under 3.0 Air Changes per Hour at 50 Pascals (ACH₅₀), and four samples are below 0.68 ACH₅₀. The two buildings with numbers above 2.0 ACH₅₀ were both from the mid nineties, before Foard Panel started using mastic and interior joint taping in addition to the spray foam sealing between panels. Low air infiltration levels can significantly lower energy usage for heating and cooling, therefore SIPs can contribute to lowering energy usage both through lower conductive losses and lower air exchange losses.

The second criterion for the benefits of SIPs is their design, construction, and renovation processes adaptability. In this aspect, SIPs are currently at a disadvantage, because they are poorly understood by many design and construction professionals. SIPs have a different structural system than LFC. LFC is dependent on the many small pieces working together to provide structural support, consequently each individual piece is less important. In contrast SIPs are a composite material depending on the connections among all its parts to function. SIPs work similarly to I-joists, the facings act as the primary structure, equivalent to the flange of an I-joist, while the insulation core is acts like the web of an I-joist. In both an I-joist and a SIP, the components are not nearly as strong on their own.

SIP walls with their typical joinery have a specific engineered strength, just like a LFC wall with its typical stud layout and fastening pattern has a specific strength. The data from the Foard Panel's NTA Code Listing, gives a SIP strength values comparable to LFC values in the National Design Specifications (NTA, 2013). The difference is that current builders know how to increase the strength of the LFC wall by adding fasteners and studs. The same things can be done to a SIP wall: add a post or an insulated header

to deal with a point load, or use a double top and bottom plate and wider splines to increase shear capacity. The problem is that these details are not in prescriptive building codes and most carpenters do not know the ‘rules-of-thumb’ from years of experience. Therefore, it is hard for builders to just figure it out as they build, which is typical practice for most LFC.

Because the builders do not have the ability to adapt the panels on the spot, they must rely on the designers to figure it out ahead of time. Most architects do not have to specify such details. Consequently architects are even less familiar with how to adapt SIPs to various structural applications than the builders. SIPs currently require design help from the few qualified engineers and designers to achieve the adaptability which LFC takes for granted. The primary obstacle to the adaptability of SIPs is not the structural limits, only the lack of understanding of SIPs in the industry.

The third aspect of SIPs requiring evaluation is its economic competitiveness. Current estimating models account for initial construction costs with no consideration of long term operating costs. This is because the person paying the construction costs is not the person paying the long term maintenance costs. Another factor is that the current appraisal system does not give significant value to the long term energy savings. This means that builders and homeowners cannot get loans for or sell the buildings at a value that compensates them for the extra effort to build a high performance house. These two issues mean that most economic assessments do not come out strongly in favor of SIPs.

One study gives SIPs a competitive edge in construction costs. RSmeans, in conjunction with BASF, has a study of SIP construction in comparison with LFC, and finds that there is up to 55 percent savings when building with SIPs (Reed Construction

Data, 2006). This report includes significant information about the time it takes to build with SIPs compared to LFC and uses RSmeans national price and labor data. I could find no biases, but my experience at Foard Panel suggests it is not typical for SIPs to be cheaper than LFC. However, the RSmeans study is suggestive that in some cases SIPs can be cheaper even in initial construction costs.

Case Study: Island Residence Martha's Vineyard, MA

This project was a 'renovation' because the site was too close to the ocean for regulations to allow construction of an entirely new building. The foundation and first floor deck was retained as well as one small wing to meet the code requirements for renovations. I started with basic energy modeling and conversations with the client to determine what specifications he wanted to meet. Second, I helped with the take-off and cost estimating for the project. Third I watched the process of design, from 3D modeling, to engineering analysis, to layouts for manufacture. Finally I saw the install pictures and final blower door measurements of air tightness. The project was recently constructed, so there is not yet energy performance data available to compare with the initial energy model. Client satisfaction was the only available confirmation that SIPs performed as expected.

The first challenge was to understand what the client was looking for. The client wanted a high performance building, on par with Passive House or Net Zero standards, but he was not interested in applying for certification. He was primarily interested in the economic benefits of a these standards, not the sustainability benefits. He had originally come to Foard Panel with a heat loss model provided by someone else, and unrealistic expectations of LFC performance. He was looking for whole surface R-40 walls and R-

50 roof, but was comparing SIPs to double framed 2x4 walls (nine inches deep) and 2x12 framed roof, both with cellulose insulation, neither of which would be anywhere close to his desired performance, even if one didn't include the significant proportion of windows. Foard Panel explained thermal bridging and realistic insulation numbers for windows. Foard Panel also provided price estimates for various SIP combinations using hand take-offs from the architectural drawings. In the end the client chose 8.25 inch thick EPS walls and 10.25 inch thick EPS roof for the main portion of the house, and four inch Polyisocyanurate (PIR) nailbase walls and six inch PIR nailbase roof on the existing LFC wing. Nailbase panels are not structural elements, but provide a good surface to attach siding, while also providing good insulation. These panels consist of a layer of foam bonded to OSB, and they can be air-sealed to the same specifications as regular SIPs.

The cost incurred by the client was approximately \$144,000. That is about \$56 per square foot of living space for SIP walls and roof, as well as, the second floor deck materials and install. Of that about 41 dollars per square foot of living space was for the materials and 15 dollars per square foot was for installation. The customer told Foard Panel their price was within ten percent of the double stud LFC wall estimate. Foard Panel had done enough work to prove to the customer that the SIPs would perform at a much higher level than the LFC design. Combined with Foard Panel's much lower time on-site and integrated engineering package, the advantages outweighed the slightly higher price.

The design process started with a set of 2D drawings from the architect which Foard Panel's drafters turned into a 3D model of the SIP shell including ridge beams and window headers, posts, and other details. With that initial model the engineer carried out

the analysis needed to size the ridge beam, hip beams, window headers, and the floor system. The house was on the ocean therefore, wind loads were a significant issue. The house had a lot of windows, averaging 31 percent window, with one wall at 41 percent and another at 56 percent. This meant that there was not much structural wall, so Foard Panel had to resort to mechanical straps and hold downs to meet all the safety codes. The same design with LFC would require the same hardware to meet the codes. Once the engineer was finished sizing, the drafters updated the 3D model with all the correct sizes, and began making pre-cut drawings for the manufacturing team to use to cut each panel exactly right to fit into its particular place in the puzzle. Figure 1 is from the first page of the construction drawings, showing the panel layouts. The drawings were also used to figure out exact quantities of materials needed for the project.

The install team was on-site for two weeks to build the project from first floor up. The install included the second floor deck and all the posts, beams, and hardware necessary to hold the building up. Figure 2 shows the exterior strapping necessary for extreme wind conditions and the interior taping that helps achieve low air infiltration. After Foard Panel has done its part the rest of the building professionals came and did their parts. While the SIP part was substantially completed in November of 2013, the remainder of the project was not completed until the next spring. After completion, the house was blower door tested by the client. The house tested 340 cubic feet per minute at 50 pascals (CFM_{50}). It had a calculated area of 34,719 cubic feet, which results in an overall infiltration rating of 0.6 ACH_{50} . The home-owner was satisfied with the whole process and his air tightness numbers. The house is fairly unique because it used both

SIPs as a primary structure and nail base panels as purely insulation. The house also met difficult engineering parameters, while still meeting high performance standards.

From this project I learned several useful lessons. The first was that the client makes a huge difference. The client in this project was looking for high performance building and had enough money that, while cost mattered, it was not the dominant factor. I also learned that lenders do not have a good system in place to support people who want to make a greater initial investment for long term gains. It was fortunate that this client was not constrained by an outside lender. Second, I learned that good heat loss modeling can provide very useful incentives, but they can also be very easily manipulated. The client had been given some fairly outrageous R-value numbers for windows and insulation, which created confusion and uncertainty that require significant effort to overcome. Finally, I learned that no single part of the building can take full credit for the overall success of the project. SIPs definitely contributed to the low air infiltration number, but if the windows were poor quality or installed without care, then the numbers would be much worse. The project was a good example of a successful SIP project, but it was not an inexpensive house, and an important reason that the SIP construction price was as close as it was to the LFC price was likely because of the locally high price of labor on Martha's Vineyard.

FINDINGS

My practicum experience has allowed me to make findings in three areas. First, I am able to make some economic comparisons between SIP and LFC technologies. Second, it has given me an appreciation of how the limitations of the current CAD tools

create a barrier to greater adoption of SIPs. Finally, I have identified technical and perception based obstacles to full integration of SIPs into the building industry.

Economic Comparison of SIP and LFC Technologies

In order to directly compare the up-front costs and the life cycle costs of SIP and LFC technologies, I created an Excel spreadsheet based analysis for several types of buildings. Some of the calculations are simple to formulate, such as window perimeters and floor deck systems, but the designer's experience with specific construction details is still required in areas. Is it a building with structural loads requiring a double top plate? Which windows need headers? What is the roof structure? I did not find a good way to automate the estimating process; there are too many variables. Therefore, my spreadsheet is simplified, excluding those elements that are likely to be the same between the two structural systems. I do not think there is any way around getting an estimate from an expert in the field to get reasonable cost data.

Construction costs are highly variable from region to region and even from contractor to contractor, so any comparison will have unresolvable uncertainties. RSMeans is a nationwide database on construction data maintained and published by Reed Construction Data, and provides comprehensive prices for materials and labor which I have used in my Excel model. In general, the model calculates that SIPs are generally only slightly more expensive which matches my experience in the practicum.

Figure 3 summarizes the results from my combined energy model and take-off model. I used three variables, house type, percentage of window to wall, and air tightness. All of the paybacks are between three and fifteen years. Of the three variables the air tightness is the only one with consistent effect on the payback time. The

percentage of window was skewed because the price of windows was ignored by the take-off, more windows appear to make the payback shorter, which is unlikely because windows are much more expensive than walls and have much lower thermal performance. One interesting thing that the modeling showed was that small houses actually had a longer payback, because the savings was so small that even a modest increase in cost took a long time to payback.

I think there are two primary reasons that SIPs have higher up-front costs. One is increased overhead to pay for the design staff needed to turn typical architectural drawings into SIP shop drawings. The second is that the cost savings for shorter install time are really just moved into the cost of the materials and equipment. However, in regions where construction labor is very expensive, SIPs can have an advantage because the cost of the manufacturing labor for SIPs is constant, not dependent on location or time of year. SIPs may also be advantaged when the building is especially complex. In these situations the design costs for SIPs and LFC are similar due to the need for engineering on both types of construction. The simplified model does not account for either of these factors, thus SIPs always come out more expensive.

In order to make my conduction heat loss calculations more accurate, I analyzed the actual framing factors in SIP walls vs. LFC walls. In Figure 4, a sample wall is detailed showing all thermal bridges formed by wood in the walls. For this example, headers were excluded because the size of the header is highly variable and it would be substantially the same between the two wall types. The only difference is that SIP walls often use insulated headers to minimize thermal bridging, and it is a less common practice for LFC. As shown, this configuration adds an extra eight percent thermal

bridging for the LFC and only adds five percent for the SIP wall. This suggests that windows and floor decks add proportionally more thermal bridging to a LFC building than to a SIP building. Combined with the much lower proportion of thermal bridging in a blank wall, this suggests that SIPs will always have a significant advantage in thermal performance.

To get enough samples of the thermal bridging factors, I used four actual SIP plans and calculated the area of thermal bridging on several different walls in each house. Then I figured out what the thermal bridging would be for the same wall with typical LFC construction. I compared the framing factor with the percentage of windows in the wall as that seems to be the primary factor that affects the framing factors.

Figure 5 shows that there is about a 12-19 percent difference in the framing factor between SIPs and LFC. The greater scatter around the LFC trendline is a result of the thermal bridging of the floor decks. Depending on how large the floor deck was, the thermal bridging factor was quite different. In contrast, SIPs have the same amount of thermal bridging regardless of the thickness of the deck. The trendline equation provides an estimate of the framing factor in my heat loss calculations.

To summarize, my modeling indicates that SIPs are likely to be slightly higher in up-front costs, but have lower life-cycle costs due to their higher wall R-value and their reduced air infiltration losses. The payback for these lower lifecycle costs are likely to best on larger, more complex structures.

Design Tools

Revit is a commonly used CAD package from Autodesk, widely used by architects and other building designers. It has a structural analysis module that can allow

most designs to be completed without the expense of an in-depth structural engineering analysis. It also has a Building Information Modeling (BIM) capability which allows designers to quickly evaluate how changes to design parameters will impact cost. These Revit capabilities works with most LFC structures, however, they are far less effective for SIP construction. One of the core problems is that Revit does not recognize more than one structural element in an assembly. Since SIPs are inherently a composite structure with the two skins acting as their main structure and the depth of the foam determining the flexural strength. Therefore, Revit is incapable of doing proper structural analysis of a SIP structure. That means that an architect would need to transfer the design to another design platform for the engineer or manufacturer. Unfortunately, Revit is not set up to easily transfer 3D information to other design platforms, even the Autodesk's solid-modeling CAD program. While Revit is an excellent tool to layout the general form of a structure, it is not yet useful for integration of design with SIP detailing.

Revit has integrated take-off functions for use in economic and energy calculations. However the 3D details are very time consuming to construct and not useful for anything except visualizing how the SIPs are built, because they do not alter the take-offs. After learning how take-offs are used in the SIP building industry, I see that Revit by itself is not capable of providing the kind of take-offs that are accurate enough for material cost analysis. This is primarily because Revit calculates its totals exactly as used in the CAD model, but in the real world we do not use materials that efficiently. For example, sheet goods, whether SIPs or simply OSB and drywall, come in specific sizes. If the area is a little bigger than the sheet good size, one has to buy the next size up. Thus, the take-offs in Revit are a good starting point, but they need to be rounded up by a

considerable margin to provide accurate costing. The amount material quantities need to be rounded up is dependent on many details of the project, thus making simple assumptions risky. Revit take-offs have similar challenges when used for LFC, but there is much more predictability in rounding up for LFC estimating. Until there is more design and build history with SIPs, the tool will have limited use for costing material take-offs.

This project makes clear the strengths and weaknesses of the BIM software. Revit is an excellent design tool, and it can provide some useful material quantities, but it cannot yet replace the work of a trained estimator. Therefore it is a bad idea to encourage those who have limited experience with SIP construction to use Revit's take-off function, because it leads them to think buildings are much cheaper (and require less material) than the reality of the construction makes them. The difference between a Revit take-off and human take-off ranged between 20 percent and 40 percent. Given that the profit margin for construction companies can be as little as 20 percent, such a large uncertainty makes it very unattractive for builders. Given that 10 percent difference price might be the whole difference between SIPs and LFC, it provides limited information to homeowners.

Other Industry Obstacles

There are a couple of physical differences between SIPs and LFC that do create practical problems during the construction phase. One is that SIPs come in large pieces which are harder for small crews to move than individual 2x6 studs. SIPs do not always require a crane, but they are much safer and faster to assemble with access to a crane. The second difference is that one can put wiring in SIPs, but one cannot put plumbing in SIPs and it would be best if one kept the wiring to a minimum. In LFC it is a bad idea to

put plumbing in exterior walls for reasons of energy efficiency, freezing pipes, and condensation in your walls, but builders still do it on a regular basis. Therefore, SIPs not being able to give designers that flexibility could be considered a drawback. These are real obstacles, but they only affect a very small portion of the construction industry.

According to the manufacturers and engineers I worked with and my own energy modeling, the key to making SIP buildings more energy efficient than stick frame construction is in the air sealing details. Therefore, the more commoditized SIPs (4x8 sheets sold like other sheet goods) can lose much of the benefit of SIP construction through poor joint sealing and many joints. Looking at photos from many investigations of SIP failures done by the company, confirmed that a high level of expertise is required to get the best results from SIP technology. The widespread lack of this expertise may be a significant obstacle for more widespread adoption of SIPs.

A good example of this is roof underlayment. Foard Panel does not recommend using anything except tar paper directly against SIPs and they also always design for vented roofs and walls. The newer building weather barriers are all hydrophobic, meaning water vapor can pass through but liquid water cannot. This means that any water that gets behind the underlayment is trapped, because there is not enough heat loss through the assembly to evaporate the water and allow it to escape. These underlayments work very well in lower performance buildings because the minute amounts of water that get through nail holes from outside and air leakage from within are able to be evaporated by the significant heat loss from the building. Because SIP buildings are built at much higher performance levels, small amounts of liquid water can remain trapped behind the underlayment in the OSB skin for years. These same effects can be seen with many other

high performance assemblies. Unvented roofs and hydrophobic underlayments work fine if there is not much insulation or for attics where the ceiling below is insulated and air sealed.

SIP Manufacturers have some incentive to ask builders to change their typical finishing details because they may bear responsibility for the structural performance of the SIP, whereas a retailer bears no responsibility for the performance of a 2x10 rafter. This contributes to a perception of SIPs as a less flexible material. This perception of SIPs as more difficult to build with is the primary obstacle to common acceptance by general contractors, electricians, plumbers, and other members of the construction industry.

SIP technology may also be perceived as a threat by some construction trades. Most of the labor takes place at the factory. This means that it is not necessarily attractive for general contractors who make money on labor while buying materials as cheap as possible. However, the faster build time makes them very attractive for owners wanting projects built as fast as possible. All these obstacles come down to the fact that SIPs create a different relationship between the people involved in a construction project. The designer has to think more about the construction details, the engineer needs to do more by hand instead of relying on software, the general contractors and sub-contractors have to change the normal methods of pricing jobs, and adjust their timelines accordingly.

RECOMMENDATIONS AND CONCLUSIONS

Based on my practicum experience, adoption of SIP technology is likely to increase as obstacles are overcome in a variety of areas. Some key actions to accelerate the adoption of SIPs might include:

Span Tables:

The development of software and span tables to do SIP sizing, equivalent to the widely available tools for roof trusses, floor decks, and beam sizing would make SIPs more attractive to designers and builders. The math is no more complicated than the math for wood I-joists, but the lack of easy to use tools is hindering the use of SIPs by general contractors and architects who do not have the engineering background to work out the sizing themselves. Most designers rely on span tables and simple beam sizing software, some SIP span tables are available, but they are not widespread and there is not yet any sizing software for SIPs. While Foard Panel has a simple Excel tool, and many other manufacturers have simple span tables, it would be best if more extensive tools could be developed and the funding for the insurance required to distribute such sizing tools could be shared.

CAD Software

This project showed that Revit has three significant weaknesses that create obstacles for SIP technology. One is that the BIM takeoff functions provide only rough estimates of SIP material usage. The second is that the Revit model is insufficient to produce the actual construction details. The third is that Revit and the 3D CAD model needed to do the structural and joint details have incompatible file types.

Hopefully, these are problems that can and will be solved by Autodesk in the near future. If not, it would be helpful if a competitive software product is created which does not have these drawbacks.

Thermal Analysis Tools

It is clear that easy-to-understand heat loss calculations and pay-back calculations are key for convincing customers, architects, and builders that SIPs are worth the extra effort to build with them. Heat loss calculations might also be useful tools for the appraisers and lenders to help all higher performance buildings to be valued for their long term benefits. For this practicum I developed an Excel based analysis tool which was helpful, but had many limitations. It would be beneficial to the SIP industry if a better model was developed that could produce clear and convincing projections that allowed SIP technology to be directly compared with conventional building technologies.

To be most useful, a tool like this should be produced by an organization that does not have a vested interest in any specific technology, such as a governmental agency, or a University.

Conclusion

SIPs are a materially efficient, time efficient, and energy efficient building system that can provide beautiful and livable buildings. As the technology continues to improve, and the design and analysis tools improve, a higher and higher percentage of people will have the opportunity to live in SIP homes.

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FIGURES

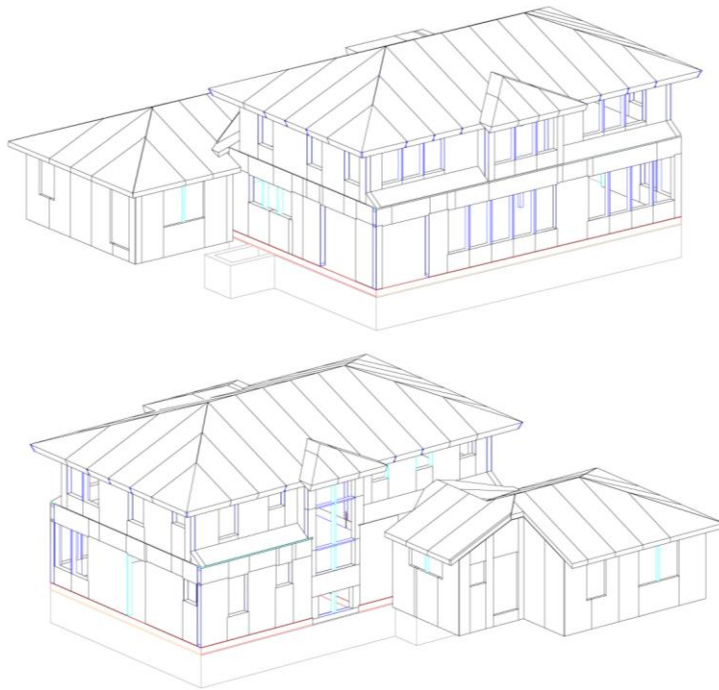


Figure 1. Hobart Panel Layouts. This is the first page of the shop drawings used to construct the house. Subsequent pages detailed all walls and floor decks including exact dimensions and edge finishing of every panel, as well as floor deck and roof structural elements.



Figure 2. SIP Construction Finished. These two photos show completed panel: the exterior picture shows strapping made necessary by high winds and lots of glass. The interior picture shows the ridge beam and hips used to support the hip roof and the green Siga tape used to supplement the mastic sealing panel to wood joints.

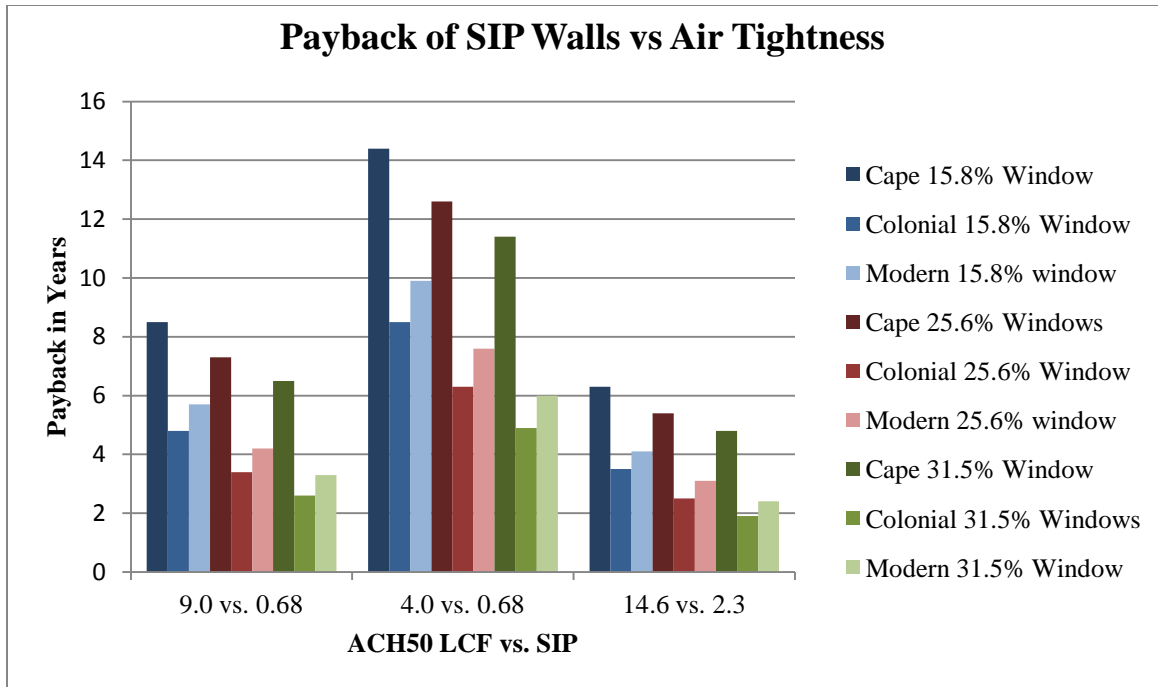


Figure 3. Payback of SIP walls vs, Air Tightness. I used my limited cost take-off model combined with a heat loss model to compare three houses. The cape was the smallest house and consequently the differences in cost were not paid off for a long time because the energy used by the house was not all that much even with the LFC construction. The window percentage shows that higher percentages of window paid off quicker, however this is because windows themselves were not included in the price data because they were assumed to be equal between the LFC and SIP houses. Windows are likely much more expensive per square foot of area than walls so the payback for the whole house would likely be much longer with more windows. The only thing that this made clear is that air sealing is the biggest influence on the overall payback.

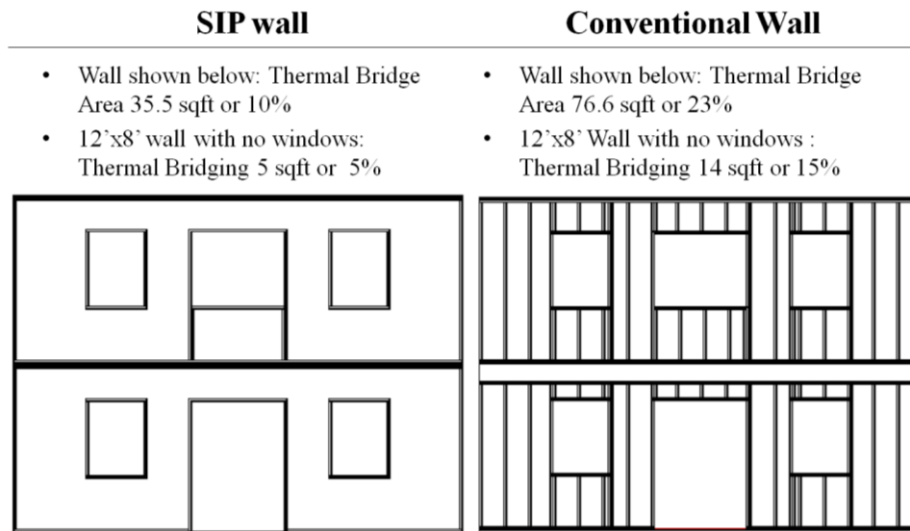


Figure 4. Thermal Bridging Comparison Between SIPs and LCF. The biggest factors in the difference between the areas of thermal bridging are the portion of windows and floor decks in any given wall. The only other difference is the ten to fifteen percent difference caused by Studs. The more clear wall the less thermal bridging, but SIPs can get down to two percent while a LFC wall can't get much below thirteen percent even in a clear wall with no floor decks.

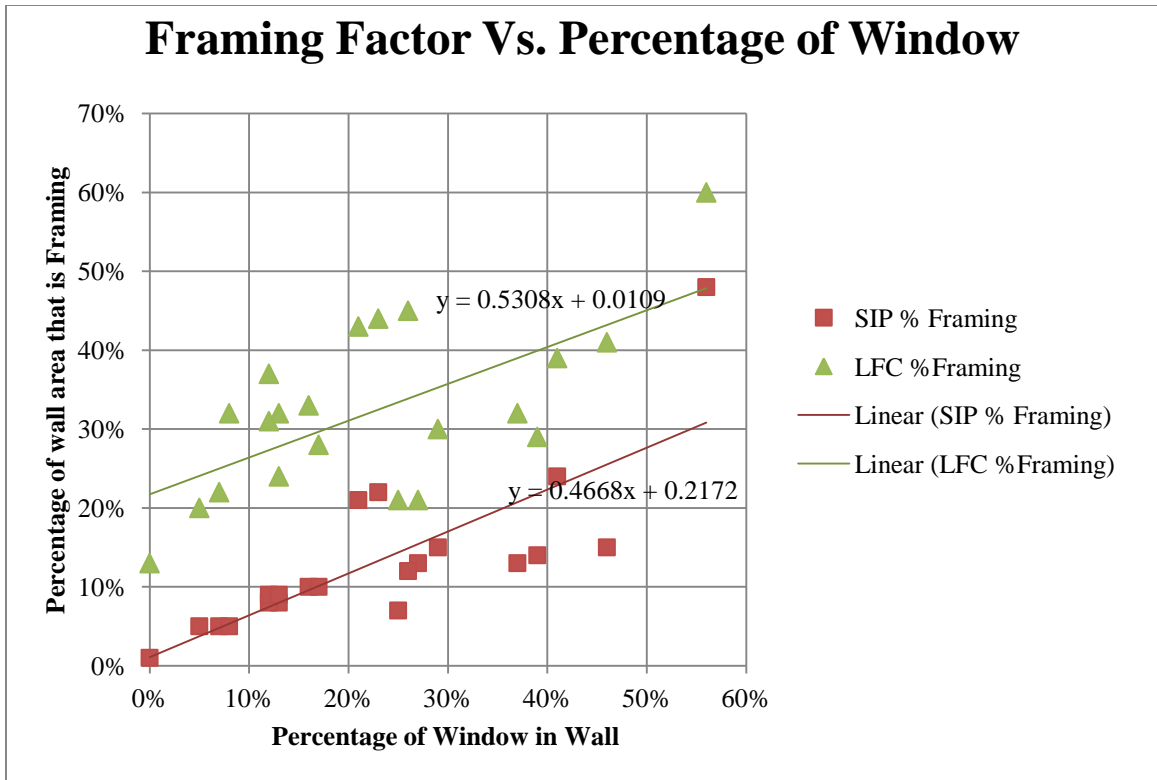


Figure 5. Framing Factor Vs. Percentage of Window for SIPs and LFC. Four different SIP houses were analyzed to find the portion of wall that was window and the portion of clear wall that was solid lumber both in the SIPs as built and in a hypothetical LFC version of the same walls. SIPs can have very low portions of thermal bridging the more windows there are the closer the SIPs are to the LFC proportionally.