STRESSED SKIN INSULATING CORE PANEL HOUSE – DESIGN, CONSTRUCTION AND EVALUATION

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ABSTRACT
This paper describes three projects related to stressed skin insulating core (SSIC) panel construction: the energy and cost estimating software – *SIP Scheming,* the Stressed Skin Insulating Core Panel Demonstration House design and construction, and the Experimental University Housing testing.

1. INTRODUCTION

The housing projects involve the design, construction, and evaluation of stressed skin insulating core (SSIC) panels. *SIP Scheming* is software that can be used to evaluate the energy performance of SSIC panels and estimate their cost.

Stressed skin insulating core panels employ a "sandwich" of lightweight insulating core material faced with two layers of structural sheathing; the result is a highly energy efficient structure.

2. *SIP SCHEMING*

SIP Scheming is an energy design and cost estimating tool for the Macintosh computer. Used during the schematic design phase, it features an intuitive graphic (non-numerical input and output) interface so that it can be used and understood by those with relatively little technical knowledge. The calculations include the effects of conduction, solar radiation, internal gains, ventilation, daylighting, and mass for all building types. The output is a loads analysis for 24 hours for each of four days. The software can export cost estimates for SSIC panels, 3D building geometry information to ArchiCAD, and Loads Description Language input files for DOE-2.

SIP Scheming is designed for users who are visually oriented. This visual aspect combined with cost estimating makes it ideal for marketing and sales of SSIC panels. We anticipate *SIP Scheming* will be used by panel sales personnel, architects, engineers, building designers, developers and builders.

The stressed skin panel tool is potentially important to panel producers because 80% of their quotes do *not* result in sales. The software shortens the quote process from as much as one day to as little as one hour and helps the sales person sell the energy qualities of the panels at the same time.

3. SSIC PANEL DEMONSTRATION HOUSE

3.1 Design

The goal of the project was to show that SSIC panel construction can deliver good quality with high energy performance at lower first cost than conventional construction. The demonstration house was designed to match the annual energy performance of an "architecturally equivalent" conventionally framed house built to the Bonneville Power Administration's (BPA) stringent long term Super Good Cents energy standards but for $2,000 less.

The SSIC demonstration house has a number of features and innovations that make the demonstration house cost competitive with conventional construction and mark an improvement over standard SSIC panel construction.

Features that distinguish the stressed skin insulating core panel demonstration house from conventional construction are:

- Site labor is reduced by 40+%.
- Project length is reduced by one week.
- The panel system replaces sawn lumber with a variety of plentiful wood resources.
- Because only three consecutive days are required for shell construction, this system extends the building season.
- The structurally integrated roof and 2nd floor system eliminates the ridge beam and the need for internal supports.

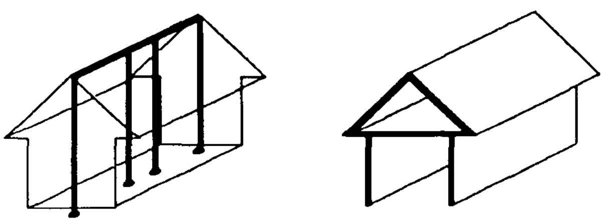

Fig. 1. Structurally integrated roof and floor system compared to ridge beam

- The integrated floor and foundation system, using the 2-way spanning capability of the SSIC panels, distributes the floor loads evenly and reduces the size of the horizontal members, reducing cost.

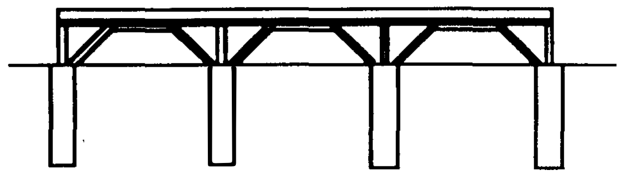

Fig. 2. Integrated floor and foundation

- Offsetting the wall-to-wall and floor-to-wall connections provides an increase of 28 square feet (2% of floor area).

Features that distinguish the demonstration house from standard SSIC panel construction are:

- The design optimizes the skin area for structural, thermal, and cost performance.
- Structural siding laminated directly to the insulation core eliminates a layer of OSB.

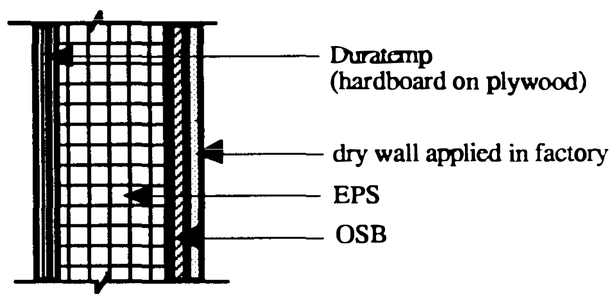

Fig. 3. Panel section

- Internal plumbing vents minimize envelope penetrations, reducing energy transfer through the shell.
- Panel cutoffs at the gable ends are reused at the opposite end of the building to reduce waste.

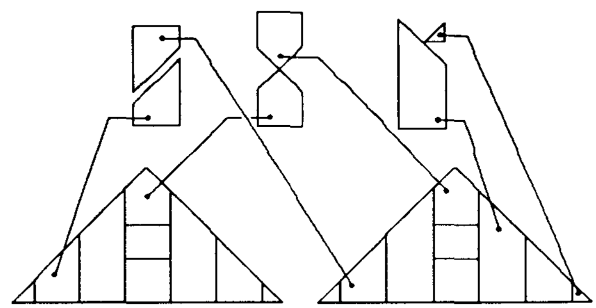

Fig. 4. Gable ends reused at building ends

- Offsetting building corners reduces the impact of dimensional variations in long walls and floor panels.
- The house plan is based on the panel module to

reduce waste.

- Locating panel joints at the exterior openings reduces panel waste.
- Minimizing dimensional lumber in the floor and roof reduces thermal bridges.

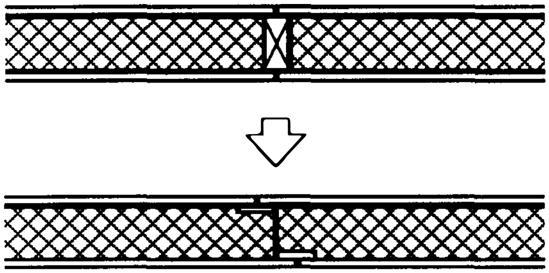

Fig. 5. Reduced dimensional lumber in panel joints

- Shiplap joints reduce installation by 20%, improve air tightness and reduce fasteners by one half.

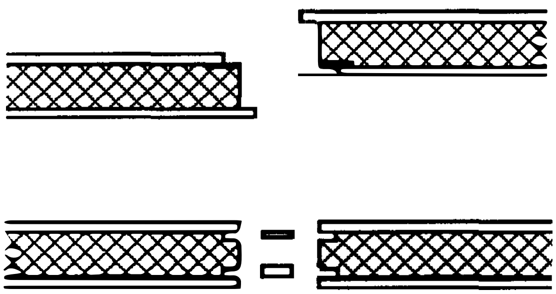

Fig. 6. Shiplap Joints

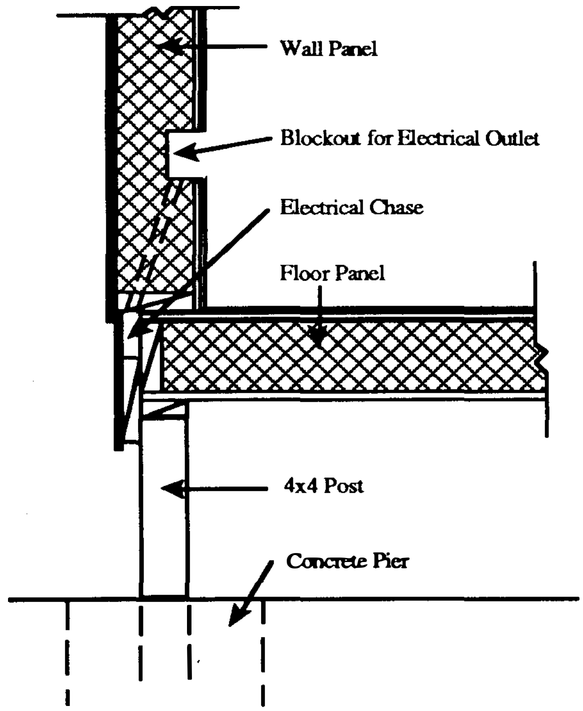

Fig. 7. Exterior electrical chases

- Exterior electrical chases minimize wiring in the panels and increase R-value, reducing installation cost by 5%.

- The overlapping ridge joint improves R-values, reduces infiltration and improves thermal performance.

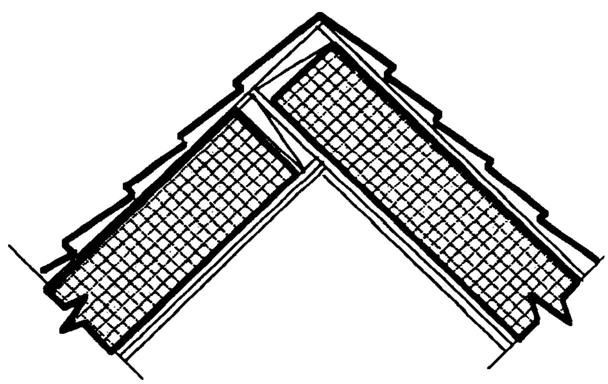

Fig. 8. Overlapping ridge joint

As of March 1993 the projected cost of the complete house including the land, in Eugene, is $91,487 for the demonstration house and $92,354 for the reference house, a difference of $867 in favor of the demonstration house. As would be expected, materials are a larger percentage of the demonstration house cost, whereas the labor percentage is larger for the reference house.

In terms of reaching our goal of $2,000 reduction in first cost, we fall $1,100 short in markets where labor costs are low and panel costs are high, such as Eugene, but surpass our goal by as much as $2,000 in metropolitan markets where labor costs are high and panel costs are low, such as Cleveland. Since most housing in the U.S. is built in high labor cost metropolitan markets, we feel we have reached our objective for a large percentage of the market.

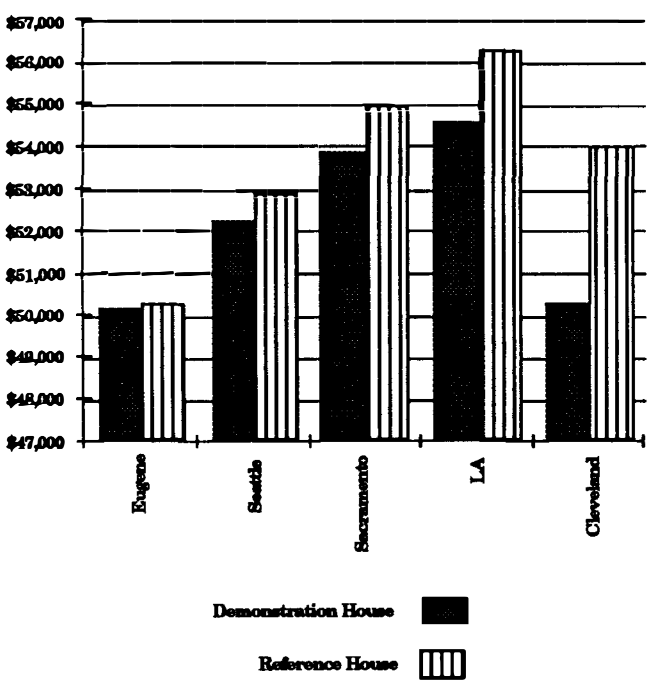

Fig. 9. Demonstration and Reference House Costs for Portion of the House Affected by the Panels

3.2 Construction

The process of building the SSIC demonstration house has shown some clear successes among the ideas tested; it has also revealed others which are less successful. In either case we have gained insights into underlying factors that contribute to success and failure of these and other approaches, and have developed refined ideas to be addressed in future projects.

Most successful: The shiplap joint worked well, permitting the two-man crew to join large panels with relative ease. The builder clearly preferred the shiplap joints over the spline joints on equal sized panels. Early estimates that this approach would save 20% in installation time seem realistic. Blower door tests have not yet revealed how tightness of these joints compares with spline joints.

The perimeter electrical chase also worked well, providing the electrician with a roomy, accessible chase around the building at a comfortable working height. While it impacted only a fraction of the total wiring, this feature seemed to offer a speed, hence cost, advantage over both conventional SSIC panel and frame construction. Again, our estimate that this approach might save 5% in installation costs still seems plausible.

Somewhat successful: Offsetting the wall panels to provide this chase added to the usable building floor area, and our structural tests found no notable adverse effect on the racking strength of the wall/floor connection. Offsets at the building corners proved useful for accommodating dimensional variations but could have been more fully exploited.

The 2-way span, integrated floor/foundation system seems from our tests to provide a satisfactorily stiff floor, and was relatively (given its novelty compared to a conventional floor) straightforward to build. At this point it is unclear whether this first iteration cost less to build than a frame floor on a perimeter foundation, but we believe that a second such project would realize some clear time and cost savings.

The integrated roof and second floor remains conceptually attractive, but the difficulty of manually placing large panels (4' x 18', based on limits in the panel fabricator's press size) suggests that using larger panels (8' x 18') hoisted by a crane or boom truck might work better.

Least successful: The incorporation of siding into the wall panels in this instance may have cost more than it saved, because of two factors. First, the siding materials (and their joints) are made to tighter tolerances than either the other panel components or the completed panel assemblies, so that consistently tight siding joints are inherently problematic. Second, the use of small (4' x 10' maximum) sheets of siding to produce SSIC panels as large as 8' x 12' creates significant fabrication, quality control and weather sealing problems. Changing the siding joinery, and matching the siding to SSIC panel size might ease these problems. The siding used in our project proved relatively tolerant of handling and transportation abuse.

4. UNIVERSITY EXPERIMENTAL HOUSING

The University of Oregon constructed six units of experimental housing designed by the Center for Housing Innovation. Each of the duplexes used one or more panelized construction strategies, enabling side-by-side comparisons. These units are to meet the Bonneville Power Administration's Super Good Cents energy performance levels.

4.1 1-Story Unit Pair (1488 sq. ft. total)

- Stressed Skin Insulating Core (SSIC) and Closed Panel Construction, (R-23 SSIC; R-29 framed; insulated headers)
- Insulated slab on grade foundation (R-5 Under Slab, R-15 Perimeter)
- Mass wall (filled CMUs)
- South dominant glazing (U=0.35)
- Vinyl Window Frames
- Cross and stack ventilation (Temp. sensitive bi-metallic controls)
- Raised heel trusses (R-49 vaulted ceilings, R-38 flat ceilings.)

4.2 1-1/2 Story Unit Pair (2093 sq. ft. total)

- Open Panel Construction (R-26 Walls; R-49 flat ceilings; R-38 vaulted ceilings; insulated headers; raised heel rafter trusses)
- Insulated slab on grade foundation (R-5 Under, R-15 Perimeter)
- Stack ventilation (Temp. sensitive bi-metallic controls)
- South dominant glazing (U=0.35)
- Vinyl window frames
- Cross ventilation

4.3 2-Story Unit Pair (1600 sq. ft. total)

- Closed Panel Wood Construction (R-26 walls; R-38 flat ceilings; R-49 vaulted ceilings; insulated headers; raised heel trusses)
- Insulated slab on grade foundation (R-5 under, R-15 perimeter)
- Mass wall (filled CMUs)
- South dominant glazing (U=0.35)
- Vinyl window frames
- Stack ventilation (Temp. sensitive bi-metallic controls)
- Cross ventilation

4.4 Testing

Blower door tests and tracer gas tests were performed to examine the air-tightness of the units. Co-heating tests were conducted to assess the as-built conductive building load coefficient (UA) for each unit. Thermal insulation quality was examined by using an infrared scanning technique. Energy use was monitored for a ten-day unoccupied period. In addition to the energy use data, the dry bulb temperature, mean radiant temperature, relative humidity and south wall surface temperature inside the units were continuously monitored. A weather measurement station was installed on the roof of the east unit of the 2-story building to continuously record the local weather data, which included the outdoor dry bulb temperature, mean radiant temperature, relative humidity, solar irradiance, wind direction and wind speed.

Preliminary results from the blower door tests showed that the closed panel units were more air-tight than the open panel units. In order to compare air-tightness among units that have different geometries, a crack-length normalization approach was employed. This approach first assumed that the primary leakages of the six units were through cracks of panel joints, doors and windows. Secondly, it was assumed that the cracks of doors and windows dominated the leakage areas for the closed SSIC panel units, since the panel joints of both types of closed panel buildings were typically tightly sealed. By normalizing the equivalent leakage area at the house pressure of 10 Pa for each closed panel unit with the total crack length of doors and windows, it was found that the equivalent leakage area per unit and the total crack length for each closed panel unit was very close to one another.

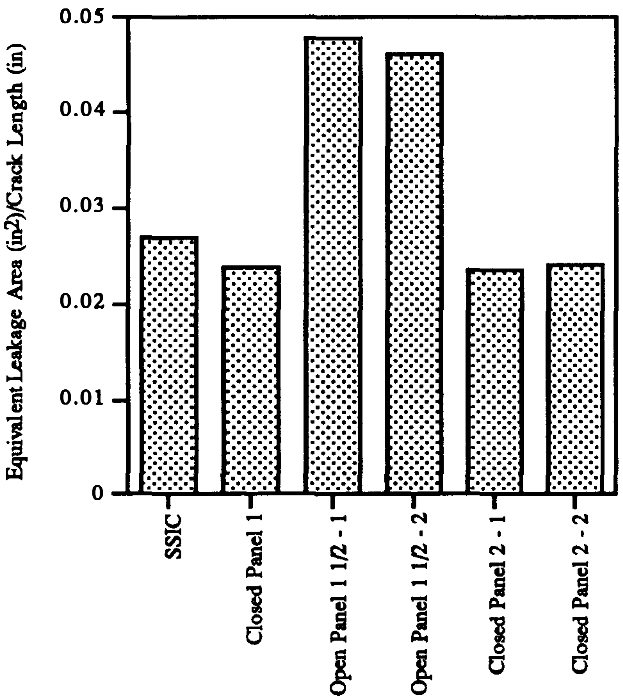

Fig. 10. Crack length normalization

This finding supported our second assumption that the leakages for the four closed panel units were primarily a function of the total crack length of the doors and windows. This normalized leakage area was then used to predict the equivalent leakage area for doors and windows for the open panel units. Since the equivalent leakage area for doors and windows was found to be less than 60% of the total equivalent area for each open panel unit, this suggested that significant leakages were through the cracks in the open panel joints. This suggests that the open panel joints are less air-tight than the closed panel joints.

6. ACKNOWLEDGEMENTS

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