COST ANALYSIS FOR A STRESSED SKIN INSULATING CORE PANEL DEMONSTRATION HOUSE, SPRINGFIELD, OREGON

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ABSTRACT
This paper summarizes a detailed cost study performed to evaluate the first cost of the building system innovations in a stressed skin insulating core (SSIC) panel demonstration house built in Springfield, Oregon. The objective was to compare this building envelope system to a conventionally built, architecturally equivalent Reference House designed with the same energy performance that the Demonstration House provides.

The Demonstration House proved to have a lower first cost and to be more profitable to the builder than the Reference House. The primary cost benefit of the Demonstration House is the reduced amount of on-site labor required through the use of SSIC panels. In addition to providing high insulation values and a very tight building envelope, using these panels reduced the use of framing lumber by almost 50%.

1. INTRODUCTION

The purpose of the Demonstration House was to show that SSIC construction can provide a high quality building envelope with excellent energy performance at a lower first cost than conventional construction. Documentation of the construction process was used to prepare a cost study comparing it to a standard wood frame construction house with the same design and energy specifications. This analysis included a series of sensitivity studies that demonstrate the effect of variations in material, labor and panel prices and learning curves in cost of construction.

The Demonstration House was designed using SSIC panels for the walls, roof and first floor and was constructed in 1994 by a crew of two workers who had not built with SSIC panels before this project. The basic construction system is illustrated in figure 1.

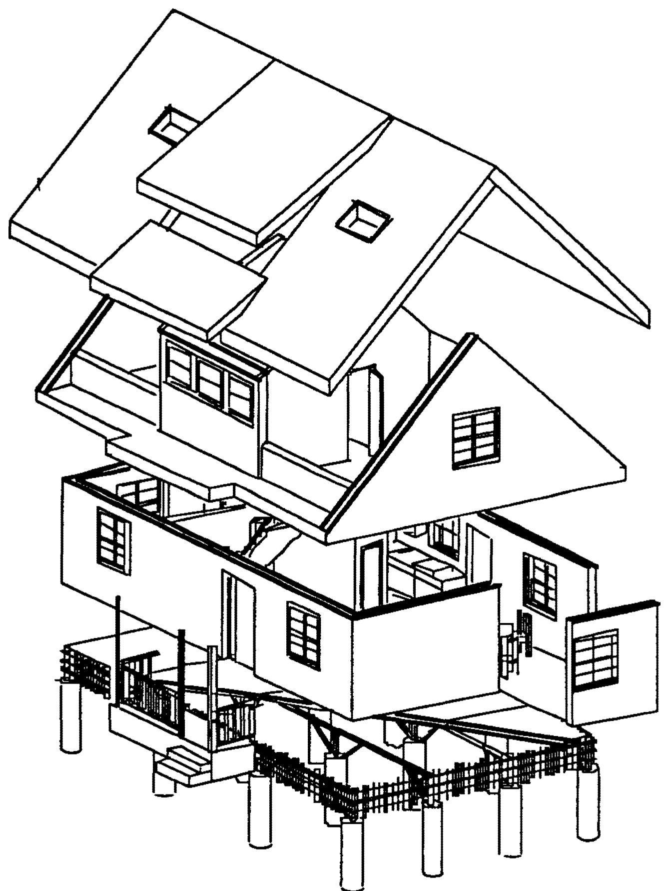


Fig. 1 Exploded axonometric of Demonstration House

design.

Panel thicknesses for each element of the envelope were selected to meet BPA's long term Super Good Cents energy standards which were 40% better than the Oregon code.

The Demonstration House has several innovations that distinguish it from typical SSIC panel construction as well as from conventional framing. Two of those features relating to the building envelope include an integrated floor and foundation system using wood trestles, and a structurally integrated roof and second floor system. Special shiplap panel joints in the floor and roof panels eliminate thermal bridging in those elements as well as reduce construction time. The wall panels were made with structural finish siding laminated directly to the insulating core, as illustrated in figure 2, which eliminated the cost of one layer of oriented strand board (OSB) as compared to standard SSIC panels. This innovation along with the use of exterior electrical chases also reduced site labor cost.

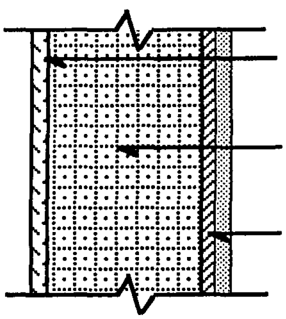


Fig. 2 Wall panel section.

For comparison purposes, it is easiest and most valid to look at whole construction assemblies such as floors, walls and roofs. Nevertheless, the systems studied in the cost report were also disaggregated into discrete elements of labor and materials to help determine where there is the greatest potential for savings and improvement in the Demonstration House construction.

Market forces have an ever-changing effect on how much builders will charge for various items. Therefore, attempts were made to separate cost from price by determining actual amounts of material and labor necessary for each construction system. The inherent differences in SSIC panel versus stick frame construction systems made the comparison of labor hours generally more meaningful than raw materials. Although this study is based on the houses as built in Springfield, OR, construction prices are also compared across a range of city cost indices to provide a more general comparison based on price.

2. METHODOLOGY

The primary goal of the cost study report was to provide a cost analysis of the Demonstration House envelope system as built and compare it to a baseline Reference House as if built on the same site. The baseline cost analyses for both houses were prepared using standard estimating practices with *Means* data. The labor amounts used in the Demonstration House study were derived from builder time sheets and detailed review of video footage of the construction processes.

The approach taken in the report was to disaggregate the building assemblies and examine those that represent the greatest innovation. Materials, labor hours and cost for each assembly process were estimated and compared.

The Reference House cost analyses are based on plans and specifications that provide a conventionally framed house with a design identical to the Demonstration House. Construction systems are consistent with the prescriptive recommendations of the BPA's long term Super Good Cents program so as to make it comparable to the Demonstration House with regard to energy standards. The labor hours required to complete tasks within each of the systems for the Reference House come from the Unit Price Section of the *Means Cost Data.*

Most material, equipment and labor costs for both houses come directly from *Means* as well. Since most of the materials for the Demonstration House were donated, it was not possible to use actual prices for its components, so it was decided, where possible, to use Means data for consistency. SSIC panel price per square foot was determined through a phone interview of suppliers across the country.

Computer spreadsheets were developed to disaggregate each system into sub-assemblies and work processes and then further categorize them into basic building components and/or tasks. For each item, material quantities, labor hours and costs for material, labor and equipment are given along with the rates used to determine these values. All cost numbers are modified by appropriate Eugene, OR location multipliers taken from *Means*.

2.1 SSIC Panel Cost Survey

A survey of panel manufacturers across the country was made in June 1994 to determine an average cost per square foot for SSIC panels. Prices were gathered for the three panel thicknesses used, although actual panel thicknesses varied slightly by producer. The standard product is an OSB / EPS / OSB "builder" panel. Several manufacturers also sold more complete panels which included finishes, windows and doors. Additional costs for special panel materials and cuts, such as gable panels, are discussed in the section on walls.

Suppliers indicated that price was highly dependent on panel dimensions, with larger panels having a lower cost per square foot except for 4' x 8' panels which are mass produced and therefore cost the least. For each supplier, an average square foot price was determined.

All suppliers indicated that price reductions were given for large orders. Although this price is determined by the scale of the job and the negotiating skills of the buyer, one representative suggested that 10% - 15% reductions were possible. The results of our survey gave average panel prices per square foot of $2.65 for 5 1/2" (14.0cm) core panels, $2.95 for 7 1/4" (18.4cm) core panels, and $3.37 for 10" (23.5cm) core panels. All prices were quoted F.O.B., so panel transportation costs are included as separate lines in the cost estimates. A Washington state supplier estimated that a complete shipment of panels to Eugene, OR would cost about $600. Building sites located closer to suppliers would obviously have lower shipment costs.

2.2 Comparative Analysis

The amount of on-site labor required for Demonstration House construction systems is significantly lower than that for the Reference House, which makes the latter more susceptible to fluctuations in skilled labor costs. The Demonstration House benefits from the use of factory manufactured SSIC panels which are produced by a semi-automated process using less costly off-site labor. Each system comparison was analyzed for its sensitivity to variation in on-site labor rates. A review of construction costs in *Means* shows a greater overall inflation in labor rates versus material costs in the last ten years. If this trend continues, the cost margin between the two house systems should increase over time. Another sensitivity analysis run on each system was based on learning curves. The labor hours for the Reference House are based on industry averages for common practices and therefore should remain constant. The innovative design systems in the Demonstration House were first-time processes for the building crew. It is expected that productivity would rise in subsequent construction. An 80% learning curve is considered a benchmark for systems with high human versus machine labor (Belkaoui, p.5). This equates to 20% pacing reduction factor as used in our analysis.

Other sensitivity studies examine the effects of location specific cost factors, using city indices from *Means*; decreasing SSIC panel prices; and lumber price variation, using historical price fluctuations as a benchmark. Some system specific analyses were also run, such as change in cost resulting from increasing foundation depth.

Each sensitivity analysis was performed by varying one parameter only. To give all these comparative analyses more meaning, present and future scenarios were developed to illustrate the combined effects of several factors based on predictions about learning curves, panel prices, inflation, city cost indices and other factors. All present scenarios were based on using a crew that had built with panels before, and therefore a learning curve adjustment of 20% was applied to only the new building processes taped in the Demonstration House construction. This equates the results with the Reference House data which are based on experienced crew productivity rates. The future scenarios were all set in the year 2000 and assumed a more experienced panel building crew with a predicted 25% pacing reduction factor for the new process productivity rates. Material and labor inflation rates were based on averages determined by a review of construction cost increases as found in *Means* over the past ten years. An effort was made using the city indices to show examples of both high and low building cost differences.

3. BUILDING ENCLOSURE SYSTEMS

3.1 Floor and foundation

The Demonstration House first floor is composed of 5 1/2" core, R-22 (3.87 $K \cdot m^2/W$) SSIC panels built on a concrete and wood trestle foundation. This system was estimated to be almost $200 less expensive to build and require almost 30% fewer labor hours than the foundation wall and conventionally framed floor of the Reference House. Most of the procedures in this construction system were new for the builders and will benefit greatly from repeat performance. Strong learning curves are thus predicted to reduce labor hours even more. If the trend of faster growing labor costs as compared to materials costs continues, the overall cost savings will also continue to grow.

Foundation depth and SSIC panel costs were also shown to be important factors affecting the system's cost. A set of future scenarios incorporating pacing reduction factors (learning curve benefit) and anticipating a stabilized panel market with local suppliers predicts cost savings of $550 to $2250 depending on local construction cost indices and required foundation depths. The six-foot-deep piers of the Demonstration House foundation are sufficient for all frost depth requirements. Therefore in colder climates where the Reference House crawl space foundation must get deeper, the cost difference increases.

3.2 Walls

Demonstration House walls are assembled from 7 1/4" core, R-30 (5.28 K•m²/W) SSIC panels specially manufactured with an outer skin of finish siding instead of OSB. Construction labor hours were estimated to be almost 38% fewer labor hours than for the Reference House walls. Again, a large percentage of the procedures in this system were new, and strong learning curves are thus predicted to reduce labor hours even more.

Panel costs for the walls were especially high because of the number of different panel sizes and shapes that resulted from our design study goals. The wall panel costs were adjusted up from the survey to account for the difference in using Duratemp siding in place of OSB and for the expense of special factory cuts. The future scenario analyses predict cost savings of $100 to $1500 depending on local construction cost indices.

3.3 Roof

The Demonstration House roof is assembled from 9 1/4" core, R-38 (6.69 K•m²/W) SSIC panels. This system was estimated to be over $220 less expensive to build and require almost 34% fewer labor hours than the Reference House. Again, a large percentage of the procedures in this system were new, and strong learning curves are expected to reduce labor hours even more. The high density insulation requirements of the ventilated roof in the frame construction Reference House contributed greatly to the cost differential. Of the three building elements reviewed here, then SSIC panels represent the greatest percentage of system material cost (41%) for the roof systems. Figure 3 illustrates the sensitivity of the roof systems to the price of SSIC panels. (Note that the Reference House cost is constant because it does not use panels.)

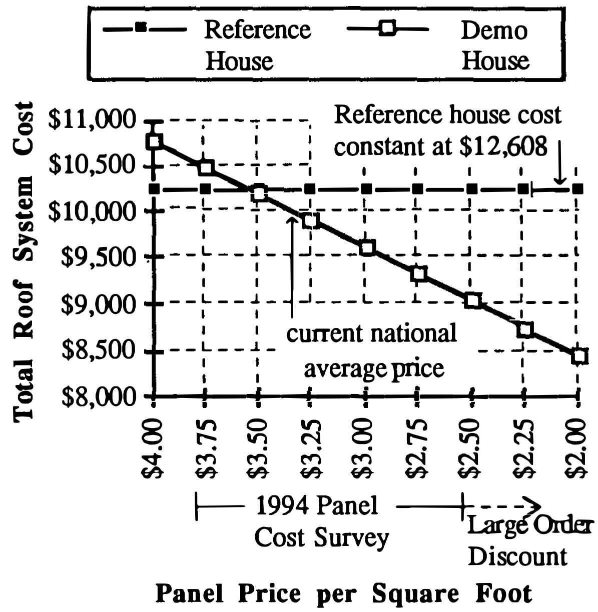


Fig. 3 Roof system cost sensitivity to panel price

For the roof systems, as with the walls and floors, site labor costs provided the most dramatic cost comparison between the two construction methods. In the Reference House they represented 45% of the total system cost, as contrasted to 30% in the Demonstration House. Therefore the Reference House is more sensitive to changes in construction labor rates. Figure 4 shows that if labor rates increase to 40% more than present-day Eugene rates the SSIC panel roof becomes $800 less expensive than using the conventional system. For comparison, labor rates in Boston are indexed at about 30% more than Eugene. Similar sensitivity analyses were prepared for each of the building envelope elements.

The reduced labor hours not only decrease direct labor costs but also cut down on the total elapsed project time, which for the roof alone saved $77 in construction carrying costs.

The difference in total labor hours required for each construction system will have a greater impact on cost if labor costs continue to grow faster than material costs.

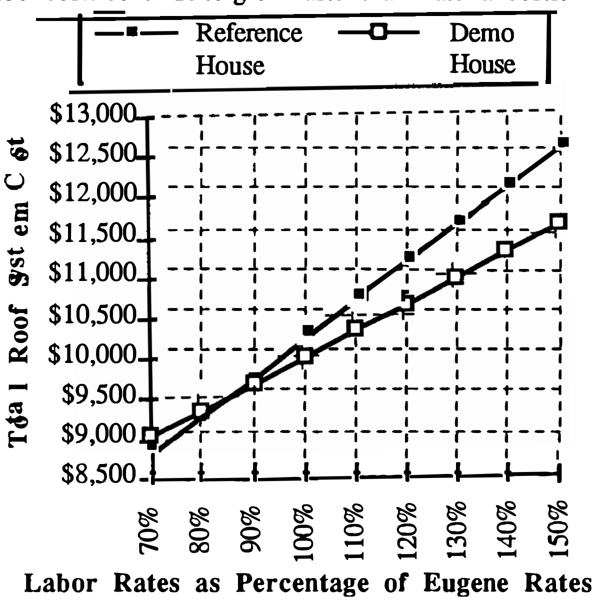


Fig. 4 Roof system sensitivity to labor rate variation

4. TOTAL BUILDING ENVELOPE

Combining the estimates derived for the three enclosure elements gives a baseline cost comparison for the total envelope system of both study houses. This baseline analysis shows the Demonstration House to require 52% less on-site construction labor before learning curve benefits are applied. The primary cost benefit of the Demonstration House is thus found in the reduced amount of on-site labor hours necessary through the use of SSIC panels.

Material quantities tables demonstrate that panels reduce the amount of framing lumber by 49% (5597 BF in the Reference House vs. 2858 BF in the Demonstration House). In the Demonstration House the total panel costs were estimated to be $10,300, which represents 34% of the total enclosure cost. Therefore, the cost of the building envelope is highly variable with respect to actual panel prices. As the SSIC panel market grows and spreads more evenly across the country, prices are predicted to increase at a slower rate than other building materials.

Figure 5 illustrates total envelope cost differences as based on six different scenarios developed in the report to illustrate how various assumptions effect present and future cost comparisons.

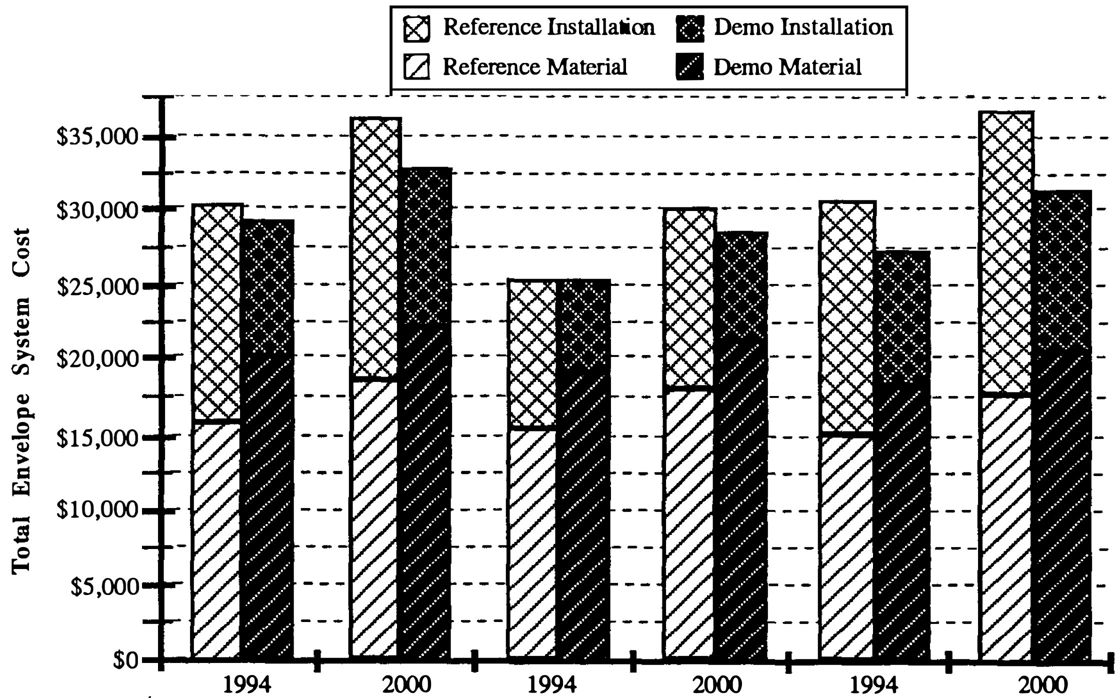
The cost of the Demonstration House envelope system is estimated to be $985 less than that of the Reference House, based on Eugene prices and a conservative 20% first time labor pacing reduction. Time savings were estimated to be 13.6 days of total elapsed project time.

Not included in the cost results of figure 5 is the increased profit benefit garnered from the faster production rate of the Demonstration House. The shorter construction time translates into increased profit potential for the contractor or developer as more houses with nearly the same profit gain can be built in a single year. If we assume that completing the remainder of each house takes 50 days and adds another $60,000 in cost, then based on a 10% profit margin and a sequential building cycle, a 14% increase in yearly profit benefit accrues to the builder of Demonstration House system houses.

For contractors who construct only enclosure systems or builders who run projects simultaneously and are thus concerned with the profit benefits of a construction system viewed independently, the following yearly profit benefit accrues to the builder of Demonstration House system enclosure system.

TABLE 1. YEARLY PROFIT BENEFIT FOR BUILDER OF DEMO HOUSE ENCLOSURE SYSTEMS

	System Cost	Project Days	Profit per Enclosure	Enclosures Built per Year	Yearly Profit
Demo House	$29,262	27.1	$2,926	13.5	$39,409
Reference House	$30,247	40.7	$3,025	9.0	$27,128
Additional Profit Benefit					$12,281



City Cost Index:	Eugene, OR	Orlando, FL	Detroit, MI
Reference House Foundation Depth:	14"	12"	30"

Panel costs ($/sf)	1994	2000	1994	2000	1994	2000
Floor	2.65	2.80	2.31	2.60	2.31	2.60
Walls	3.27	3.40	3.14	3.30	2.86	3.10
Roofs	3.35	3.50	3.00	3.30	3.04	3.30
Total shipping cost	$600	$350	$600	$350	$300	$350
Pacing reduction	20%	25%	20%	25%	20%	25%
Material inflation	-	17.5%	-	17.5%	-	17.5%
Labor inflation	-	21.8%	-	21.8%	-	21.8%

Fig. 5 Comparison of total envelope costs for Demonstration House and Reference House construction systems based on present and future scenarios

ACKNOWLEDGEMENTS

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