Final Report

Results of a Construction Process Analysis

Structural Insulated Panels versus Stick-Building

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Table of Contents

Executive Summary

The objective of this study was to compare the construction processes of two homebuilding systems, structural insulated panels (SIPs) and conventional 2x4 stick-built. SIPs are made with insulative foam sandwiched between oriented strandboard (OSB). Energy studies have demonstrated that SIPs can produce more airtight and energy efficient homes. SIP suppliers also promise significant construction advantages, however, little scientific data is available to substantiate claims. The study focuses on the construction of two similar single-family homes, one SIP and one stick-built, built by Habitat for Humanity during Fall 1997. The study documents two key measures of construction performance, cycle time and labor man-hours. The study addresses only those activities on the construction site and focuses on the framing process (rather than finishing), since the primary impact of the building system occurs during framing.

The SIP home, built in Sedro-Woolley, Washington, was a 1,293 square-foot, four-bedroom home. The floor, walls and roof were constructed using SIPs. Panels were delivered to the construction site with many factory value-added features including pre-cut panels (length, width, gables, windows/doors openings), pre-framed window/door openings, and pre-installed splines in the wall panels. The 2x4 stick-built home, built outside Plains, Georgia, was a 1,064 square-foot, four-bedroom home. While the majority of the home was stick built on site, some sub-assemblies, including roof trusses and window frames, were completed in the Habitat "factory" in Americus. Floor framing was not required due to slab-on-grade construction.

After being normalized by the square footage in each home (to account for design differences), the data indicate that the SIP home saved 65% of the site labor when compared to the stick-built home. Cycle time savings are of similar magnitude. Volunteers were interviewed after framing the SIP house to gauge their perception of SIP construction. The results suggest that both construction professionals and other volunteers believed that SIPs reduced construction effort significantly, averaging about one-half the effort of conventional stick-built construction.

The conclusions that can be drawn from this study are limited due to sample size, different home designs, different volunteer crews, uniqueness of Habitat construction, and extensive factory value-added content for the SIPs. However, several factors discourage us from dismissing the results as a random: 1) similarity of the home designs, 2) expertise of the responsible contractors, and 3) magnitude of the observed savings. Therefore, we believe that the SIP building system can be highly efficient on the construction site, substantially reducing site framing labor and cycle time. However, attaining these benefits requires the following of the homebuilder: 1) use large panels (up to 24'x8'), 2) have panels delivered to the site ready to install (cut-to-size, framed window/door openings, installed splines) 3) use a construction crane, and 4) thoroughly plan both the home design and the construction process to capture the potential benefits. At the same time SIP manufacturers must support homebuilders by: 1) migrating construction tasks into the factory as premium, value-added product features, 2) strengthening the design-to-manufacturing link and upgrading quality systems to ensure that delivered panels meet homebuilder specifications and 3) controlling costs and prices to keep SIP homebuilding cost competitive at the systems level.

Background, Objectives and Scope

The objective of this report is to compare the construction processes of two homebuilding systems, structural insulated panels (SIPs) and conventional 2x4 stick-built. SIPs are made with insulative foam sandwiched between oriented strandboard (OSB). Energy studies have demonstrated that SIPs can produce more airtight and energy efficient homes. SIP suppliers also promise significant construction advantages, however, little scientific data is available to substantiate claims. This report summarizes findings from a study of the construction of two similar single-family homes, one SIP and one stick-built, built by Habitat for Humanity during Fall 1997. The study documents two key measures of construction performance, cycle time and labor man-hours. The study addresses only those activities on the construction site and focuses on the framing process (rather than finishing), since the primary impact of the building system occurs during framing.

The Two Homes

The SIP home was framed in Sedro-Woolley, Washington on August 15-16, 1997. The floorplan for the SIP home (Figure 1) featured 1,293 square-feet and four-bedrooms. SIPs were used to construct the floor, walls and roof. SIP plans are shown in Figures 2, 3 and 4. SIP floor panels were supported by a system of girders, creating a crawl space (Figure 2). Panels were delivered to the construction site with many factory value-added features including pre-cut panels (length, width, gables, windows/doors openings), pre-framed window/door openings, and pre-installed splines in the wall panels. Additional component and framing details are included in the construction process description in Appendix A. The 2x4 stick-built home was framed outside Plains, Georgia on October 16-18, 1997. The floorplan for the home (Figure 5) featured 1,064 square-feet and four-bedrooms. While the majority of the home was stick built on site, some sub-assemblies, including roof trusses and window frames, were completed in the Habitat "factory" in Americus. Floor framing was not required due to slab-on-grade construction. Additional component and framing details are included in the construction process description in Appendix B. Weather during the framing of both homes was excellent and did not affect framing activities.

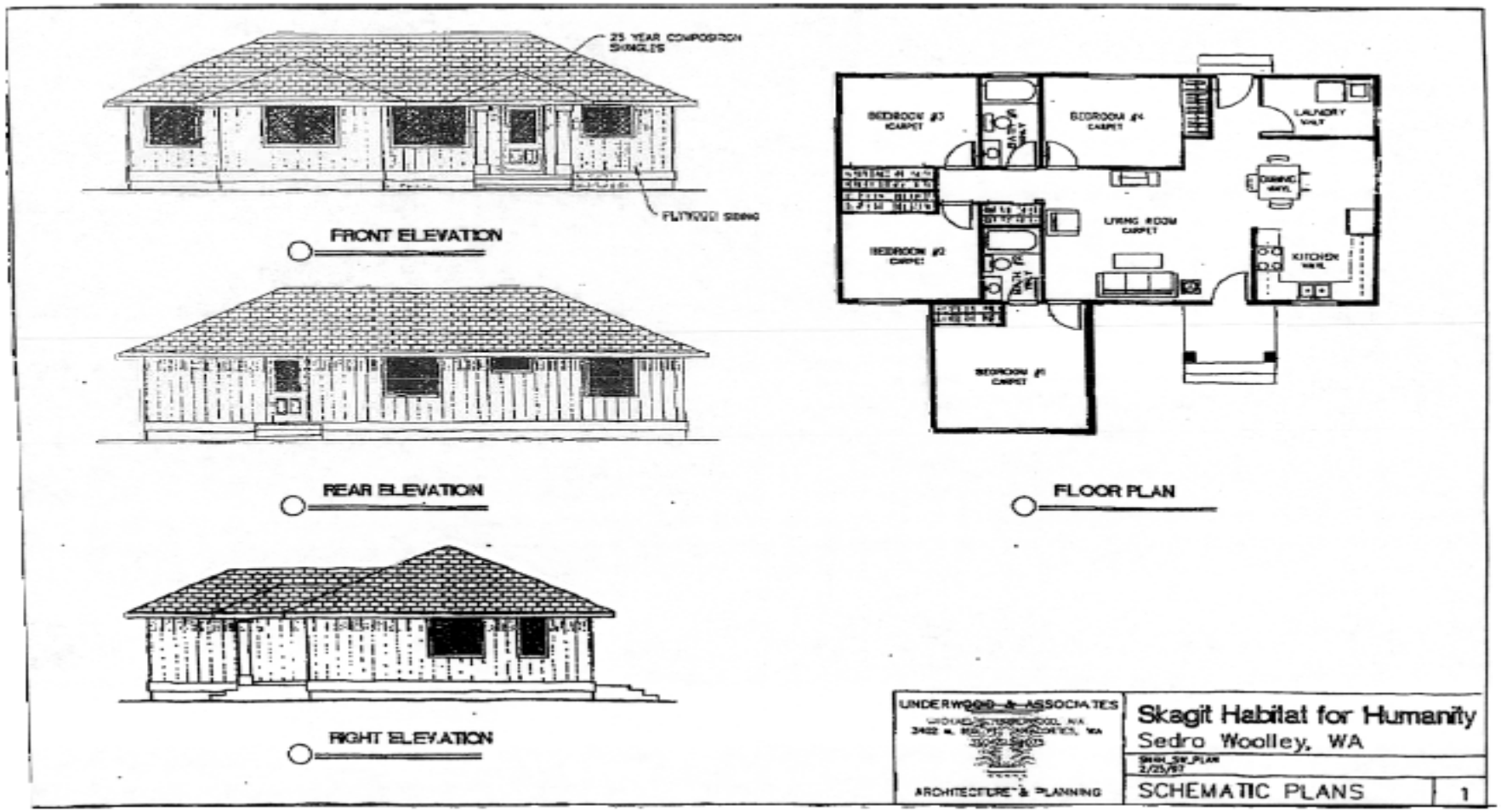

Figure 1. Sedro-Woolley SIP Home: Elevations and Floor Plan

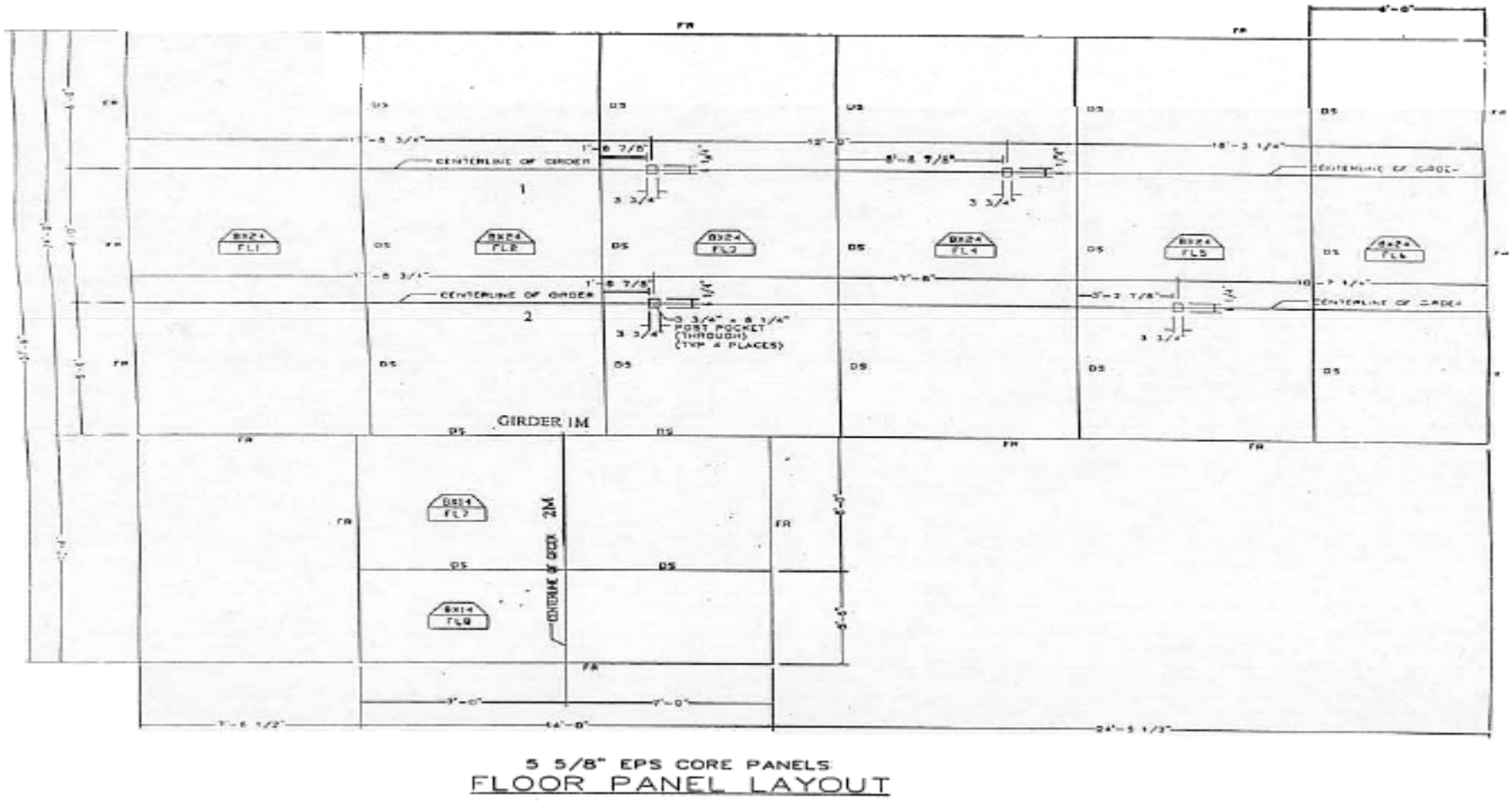

Figure 2. Sedro-Woolley SIP Home: Girder and Floor Panel Layout

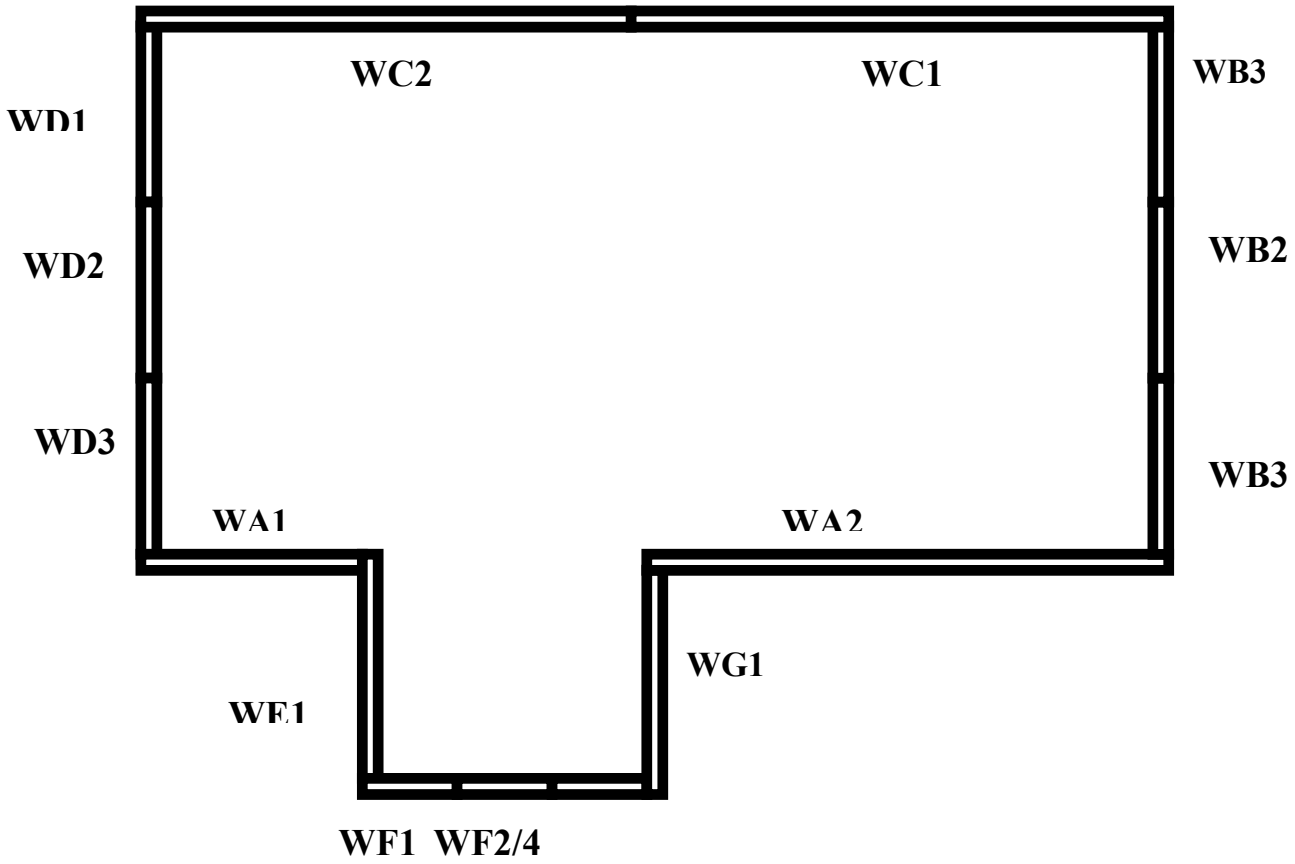

Figure 3. Sedro-Woolley SIP Home: Wall Panel Plan

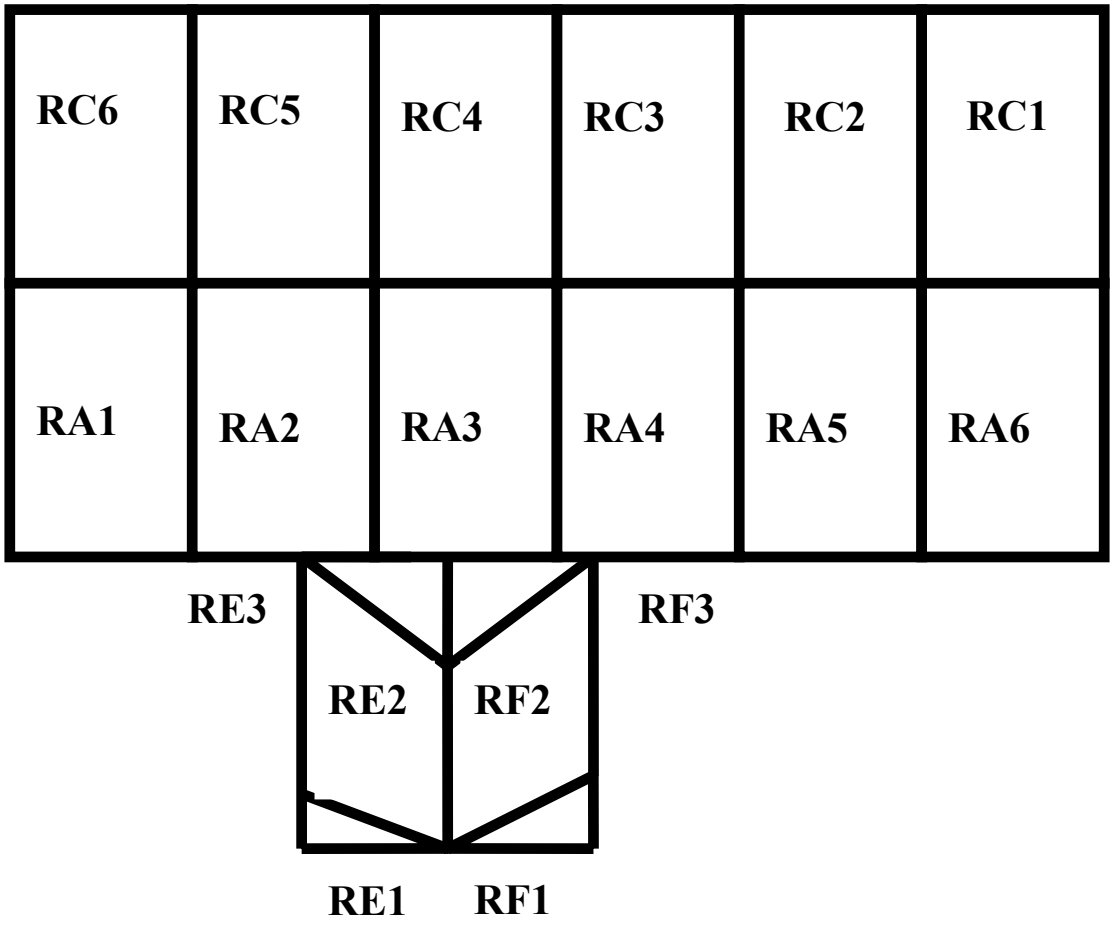

Figure 4. Sedro-Woolley SIP Home: Roof Panel Plan

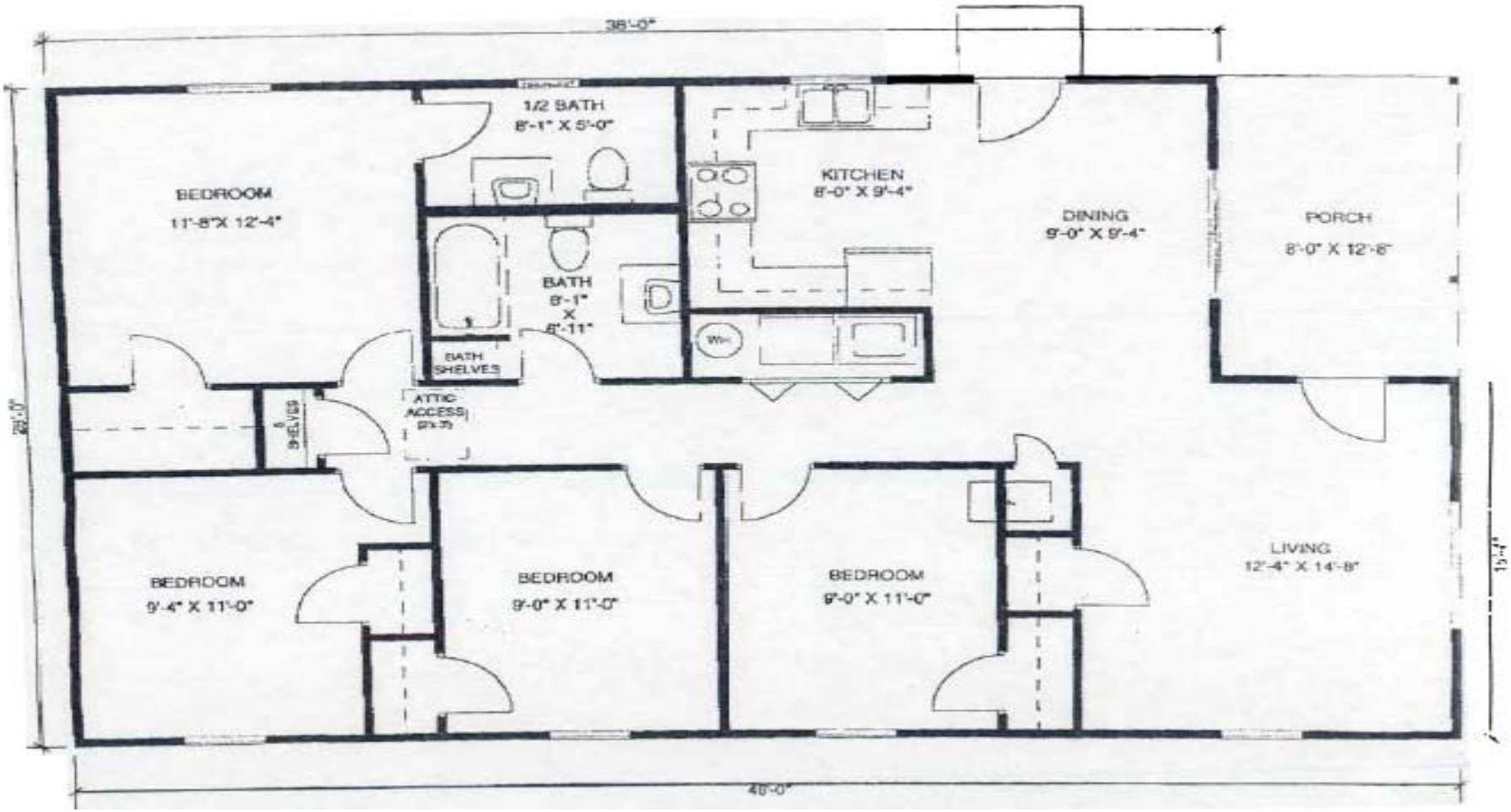

Figure 5. Plains Stick-built Home: Floor Plan

Approach and Results

Site construction processes were documented by direct observation and supplemented by video recording. Two engineers and two video cameras were active at all times. The study was limited to on-site, structural framing activities, concluding with panel erection for the SIP home and installation of exterior sheathing and insulation for the stick-built home. Interior walls for both homes were stick-built and are not included in the study. Some relevant framing activities were completed in the respective factories and were not included in the study. For the SIP home these included pre-cutting (length, width, gables, windows and doors), pre-framing for windows and doors, and pre-installation of splines in the wall panels. For the stick-built home these included sub-assembly of roof trusses and window frames.

The construction activities observed are described in Appendices A and B. Start and completion times were recorded for all activities as well as the number of personnel involved. When personnel changed during the course of an activity, the change and time of change were noted. From these data, precise estimates of activity duration (minutes) and labor (man-minutes) were developed for each activity. When more than two activities were simultaneously underway, engineers cycled frequently between activities. Detailed data are shown in Appendices C and D.

Before summarizing and discussing these results, it is important to emphasize the unique nature of Habitat construction. Volunteers build each home under the guidance of an experienced homebuilder. Construction of the SIP home was guided by a nationally recognized contractor credited with building over 600 SIP homes. An experienced Habitat builder directed construction of the stick-built home. Over 50 volunteers participated in the construction of each home, serving as workers, greeters and construction coordinators. Volunteers arrived and departed continuously throughout the process. Volunteer profiles are shown in Figures 6 and 7. Data were obtained by interviewing volunteers after framing was completed. The data indicate that both jobs had volunteers with a wide range of construction experience, from novices to highly experienced professionals. The data also suggest that the construction experience of volunteers was reasonably comparable for both jobs. An important factor not evident in the data is that the volunteers for the SIP home had no prior SIP construction experience.

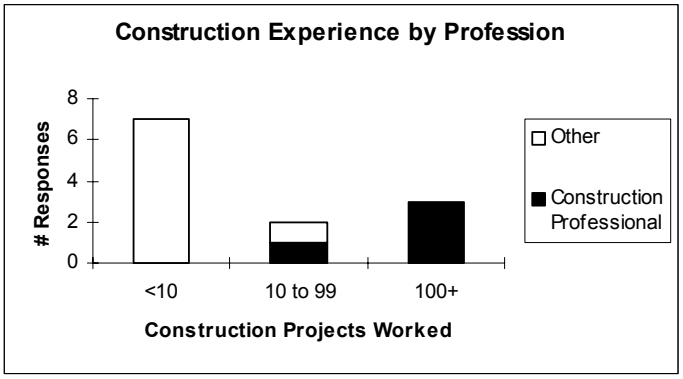

Figure 6. Construction experience of volunteers for stick-built home

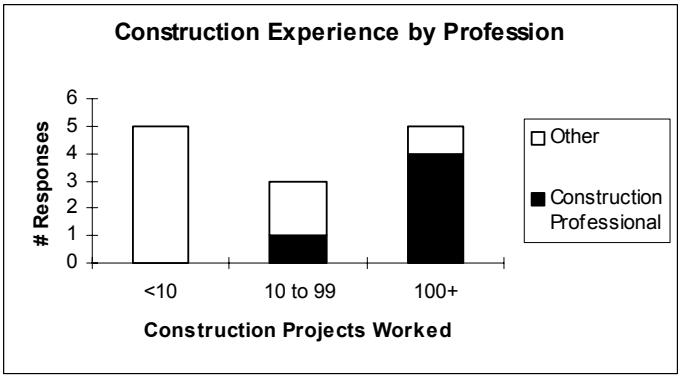

Figure 7. Construction experience of volunteers for SIP home

The unique nature of the Habitat workforce often resulted in less than ideal efficiency on the construction site. More than 10 volunteers routinely moved and positioned large SIPs, when significantly fewer could have moved the panels safely and efficiently. Construction activities were routinely accomplished in series (one-at-a-time), rather than in parallel, so that the expert could ensure both safety and quality. In several cases the expert asked volunteers to rework unacceptable product. To maximize safety (and possibly because of the abundance of labor), Habitat has a policy of limiting the use of nailguns. The only exception to this policy was a .22 caliber nailgun used to attach wall bottom plates to a concrete slab in the stick-built home.

Results for the SIP home are summarized in Table 1. The activities required a cycle time of 1,053 minutes (18 hours) and labor of 7,194 man-minutes (120 man-hours). The floor required the most effort (39%), followed by the roof (27%). Framing the support structure for the floor and roof panels accounted for over 60% of this effort.

	Framing		Panelizing		Total		
Activity	**Cycle Time**	**Labor**	**Cycle Time**	**Labor**	**Cycle Time**	**Labor**	
	(Minutes)	**(Man-Min)**	**(Minutes)**	**(Man-Min)**	**(Minutes)**	**(Man-Min)**	
Unload	0	0	205	820	205	820	11%
Floor	265	1,750	148	1,032	423	2,782	39%
Walls	0	0	279	1,678	279	1,678	23%
Roof	367	1,137	208	777	596	1,914	27%
Total	**NA**	**2,887**	**NA**	**4,307**	**1,053**	**7,194**	**100%**

Table 1. Summary results for SIP home

Results for the stick-built home are summarized in Table 2. The activities required a cycle time of 2,016 minutes (34 hours) and labor of 8,421 man-minutes (140 man-hours). The roof required 62% of the effort.

Activity	**Cycle Time**	**Labor**	
	(Minutes)	**(Man-Minutes)**	
Wall	1202	3219	38%
Roof	1026	5202	62%
Total	**2016**	**8421**	**100%**

Table 2. Summary results for stick-built home

Several factors must be considered when comparing the two sets of construction results. First, unloading of materials was not observed for the stick-built home. Second, the design of the homes, though similar, were different:

- The SIP home was over 20% larger than the stick-built home.
- The SIP home had a crawl space, requiring a framed floor. The stick-built home utilized slab-on-grade construction, which did not require a framed floor.

Since the SIP home could have used the same design specifications as the stick-built home, reducing cycle time and labor requirements, it is important to normalize results. Table 3 summarizes results for comparable activities and Table 4 shows normalized results based on square footage.

	SIP			Stick-Built		
Activity	Cycle Time	Labor		Cycle Time	Labor	
	(Minutes)	(Man-Minutes)		(Minutes)	(Man-Minutes)	
Wall	279	1678	47%	1202	3219	38%
Roof	596	1914	53%	1026	5202	62%
Total	774	3592	100%	2016	8421	100%

Table 3. Summary results for comparable activities

	SIP		Stick-Built		SIP Savings	
Activity	Cycle Time	Labor	Cycle Time	Labor	Cycle Time	Labor
	(Min./sqft)	(Man-Min./sqft)	(Min./sqft)	(Man-Min./sqft)	(Min./sqft)	(Man-Min./sqft)
Wall	0.22	1.30	1.13	3.03	.91	1.73 (57%)
Roof	0.46	1.48	0.96	4.89	.50	3.41 (70%)
Total	0.60	2.78	1.89	7.92	1.29	5.14 (65%)

Table 4. Normalized summary results for comparable activities

The normalized data indicate that the SIP home saved 65% of the site labor when compared to the stick-built home. Cycle time savings are of similar magnitude. Savings in roof construction was 70%, while wall savings totaled 57%.

Table 5 provides additional detail about panel-related construction activities for the SIP home. In addition to the effort required to frame the panel support structure for the floor and roof (described earlier in Table 1), modifying, positioning and fastening panels also required considerable effort. Modification was required on several wall panels due to a miscommunication between design and manufacturing at the manufacturing plant. Panels were fastened using splines, requiring construction adhesive and nails. Adhesive was applied using a caulking gun and nails were driven by hammer. Table 5 also provides per panel averages for all

panel-related activities.

Table 6 provides additional detail about construction activities for the stick-built home. Note that sheathing accounts for 38% of all effort, primarily due to manual handling and nailing (no nailguns). Framing accounts for another 18% the effort.

	Floor			Walls			Roof			Total		
	Cycle Time	Labor (Man-Min.)		Cycle Time	Labor (Man-Min.)		Cycle Time	Labor (Man-Min.)		Cycle Time	Labor (Man-Min.)	
	Min./Panel	Avg./Panel	Total	Min./Panel	Avg./Panel	Total	Min./Panel	Avg./Panel	Total	Min./Panel	Avg./Panel	Total
Prepare panels							4.9	8.8	159	4.9	8.8	159
Plates & splines				6.9	14.8	237	0.2	0.3	6	7.1	15.1	243
Transport panels	1.0	10.3	82	1.0	9.9	159	0.2	0.5	9	2.2	20.7	250
Modify panels				4.6	49.4	791	1.8	3.6	65	6.5	53.1	856
Position panels	4.9	45.9	367	1.8	15.5	248	3.7	15.7	283	10.4	77.1	898
Fasten panels	12.0	72.9	583	6.9	15.2	243	4.5	14.2	255	23.4	102.2	1,081
Total	NA	129.0	1,032	NA	104.9	1,678	NA	43.2	777	NA	277.0	3,487

Table 5. Detailed summary of panel-related construction activities for SIP home

	Floor			Walls			Roof			Total		
	Cycle Time	Labor (Man-Min.)		Cycle Time	Labor (Man-Min.)		Cycle Time	Labor (Man-Min.)		Cycle Time	Labor (Man-Min.)	
	Min./Panel	Avg./Panel	Total	Min./Panel	Avg./Panel	Total	Min./Panel	Avg./Panel	Total	Min./Panel	Avg./Panel	Total
Prepare	NA	NA	NA	6	9.29	65			577	NA	NA	642
Position	NA	NA	NA	4.99	30.57	214	4.6	15.7	345	NA	NA	559
Framing	NA	NA	NA	45.29	108.71	761			789	NA	NA	1,550
Fasten	NA	NA	NA	17.85	34.43	241				NA	NA	241
Sheathing	NA	NA	NA	77	201.57	1411			1,800	NA	NA	3,211
Insulate	NA	NA	NA	57	57.00	399			120	NA	NA	519
Lift Truss	NA	NA	NA				1.3	11.8	259	NA	NA	259
Erect Truss, Nail	NA	NA	NA				4.5	20.8	457	NA	NA	457
Lookout	NA	NA	NA						455	NA	NA	455
Sub-facia	NA	NA	NA						220	NA	NA	220
Other	NA	NA	NA	8.83	18.29	128			180	NA	NA	308
Total	NA	NA	NA	NA	NA	3219	NA	NA	5202	NA	NA	8,421

Table 6. Detailed summary of construction activities for stick-built home

Volunteers were interviewed after framing the SIP house to gauge their perception of SIP construction. The results (Figure 8) suggest that both construction professionals and other volunteers believed that SIPs reduced construction effort significantly, averaging about one-half the effort of conventional stick-built construction. Additional comments from the volunteer interviews are provided in Table 7. It should be noted that many volunteers had significant construction experience, including experience as professionals, but no volunteers had previous experience with SIPs.

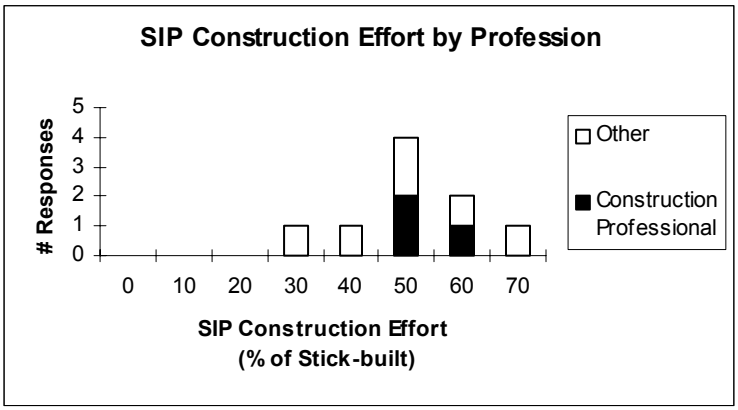

Figure 8. Volunteer perception of SIP construction effort compared to stick-built

Construction Professionals	Non-Construction Professionals
Environmentally sound; dimensional lumber more valuable for other things	Solid bottom is plus; insulation doesn=t sag and no animal infiltration
Impressive	Less squaring and nailing
Durability, especially with temperature change?	Less labor; simple to build
Remodeling?	Foam recyclable?
Quick framing; no need for additional insulation	Effect on ecology?
Strength without studs, especially with tile roof ?	Easy from organizational standpoint
Good idea	Not much learning required
Needs airflow?	Airtight
Unlimited design	More efficient, but probably more expensive
Serious contender	Wonderful construction technique
Cost-benefit analysis needed?	Water damage?
Problems with subs?	Environmental issues? Recyclable?
	Well-insulated floor
	Electrical wiring?
	Faster; maybe better
	Fewer places to adjust
	Fewer joints

Table 7. Volunteer comments and perceptions about SIP construction

Other Construction Measures

Several additional types of construction data were collected during the construction of the two homes. The first was the heavy equipment used. SIP construction required the use of a crane and a forklift was also used. The stick-built home required no heavy equipment. Heavy equipment information for the SIP construction process is shown in Table 8.

Item	Arrive on Site	Depart Site	Elapsed Time on Site (min.)	Start of Use	End of Use	Duration of Use (min.)
Forklift	Day 1, 8:00am	Day 2, 7:00pm	1027	Day 1, 9:00am	Day 2, 7:00pm	967
Crane	Day 2, 10:00am	Day 2, 7:00pm	480	Day 2, 1:46pm	Day 2, 7:00pm	314

Table 8. Heavy equipment usage during construction of the SIP home

Material usage and waste was collected during construction of the SIP home (Table 9). Material, including waste, was counted before starting and after completing framing. Waste was termed 'potential' since Habitat attempts to re-use all excess materials. Potential waste was separated into two categories: less than and greater than two feet in length. The rationale is that the longer scrap is more likely to find a use on the current or a future construction site. Since all SIP fabrication occurred in the factory, a theoretical calculation of factory trim waste is included. Material usage was less controlled on the stick-built site. Three homes were being built simultaneously and it was impossible to accurately monitor overall usage and waste. Very little waste was observed during construction of the stick-built home.

		Potential Waste					
Item	**Usage**	**Length < 2'**	**% of Use**	**Length > 2'**	**% of Use**	**Total**	**% of Use**
Construction Site:							
6"x12" Glulams							
12'	2						
16'	1						
18'	4						
Total		40"	3%	0"	0%	40"	3%
2"x10" Ganglams							
12' 5"	16	8"	0%	213"	9%	221"	9%
1/2" 4'x8' OSB	4	37 sq ft	29%	0	0%	37 sq ft	29%
2"x6"x16' lumber	47	478"	5%	245"	3%	723"	8%
2"x8"x16' lumber	38	104"	1%	397"	5%	501"	7%
2"x10"x16' lumber	1	0	0%	0	0	0	0
6" Floor SIPs	1293 sq ft	0	0%	0	0	0	0
6" Wall SIPs	1263 sq ft	0	0%	0	0	0	0
8" Roof SIPs	1742 sq ft	17 sq ft	1%	0	0	17 sq ft	1%
Adhesive 29 oz cartridge							
	6						
Factory Trim:							
6" Floor SIPs	1376 sq ft	83 sq ft	6%	0	0	83 sq ft	6%
6" Wall SIPs	1568 sq ft	305 sq ft	19%	0	0	305 sq ft	19%
8" Roof SIPs	1920 sq ft	178 sq ft	9%	0	0	178 sq ft	9%
Total Panel	4864 sq ft	566 sq ft	12%	0	0	566 sq ft	12%
2"x6"x16' lumber	We assume no factory waste since all dimensional lumber is used for shipping protection.						
2"x8"x16' lumber							
2"x10"x16' lumber							

Table 9. Material usage and potential waste for the SIP home

Conclusions

The conclusions which can be drawn from this study are limited by many factors:

- Sample size - one home for each building system
- Non-identical home designs
- Different volunteer crews
- Uniqueness of Habitat construction
  - Volunteers of various skill levels
  - Overabundance of labor
  - Limited nailgun usage
- Heavy factory value-added content for the SIPs

However, several factors discourage us from dismissing the results as a random data point.

- The similarity of the designs
- The expertise of the responsible contractors
- The magnitude of the observed savings

The SIP building system can be highly efficient on the construction site, substantially reducing site framing labor and cycle time. However, attaining these benefits requires the following of the homebuilder:

1. Use large panels of up to 24'x8'.
2. Have panels delivered to the site ready to install: cut-to-size, framed window/door openings, and installed splines.
3. Use a construction crane to install panels.
4. Thoroughly plan both the home design and the construction process to capture the potential benefits.

At the same time, SIP manufacturers must support homebuilders by:

1. Migrating construction tasks into the factory as premium, value-added product features.
2. Strengthening the design-to-manufacturing link and upgrading quality systems to ensure that delivered panels meet homebuilder specifications.
3. Controlling costs and prices to keep SIP homebuilding cost competitive at the systems level.

Appendix A
Construction Process Description for SIP Home

Unload

1. Unload 2x6 lumber: 2x6 lumber was delivered to the site on the same load as the SIPs. Lumber was unloaded using a large forklift. Four people were involved in the process. Two climbed onto the load, one supported the operation from a ladder, and one person operated the forklift. The person who was on the ladder also helped in transporting and setting down the load.

2. Unload SIPs: The structural insulated panels (SIPs) were unloaded from the delivery truck in much the same way as lumber. This operation was one of the more hazardous operations due to the size of the panels and the height and precariousness of the people on the truck. SIPs were placed in an open field on the right side of the house.

Floor

1. Lay plastic ground cover: Black polyethylene plastic was spread over the ground as a moisture barrier. The process was interrupted by a break for prayer and introductions.

2. Level: Planning involved checking the height of the nine steel Simpson post bases which were permanently mounted in the poured concrete piers. Two persons did this, one operating a theodolite and the other holding a measuring tape at the pier.

3. Prepare post for master bedroom: The post supporting the girders for the master bedroom were made by joining two 2x4s (using nails and glue). Two additional 2x4s were nailed on the sides at the top of the post to form a cavity for the girders. The post was placed on the Simpson Strong Tie post (NER393). OSB was used as shims to adjust for height.

4. Prepare remaining posts: The remaining posts were made following the same procedure.

5. Cut 2x10 laminated veneer lumber (LVLs) for girders: LVLs were cut-to-size by 2-3 persons using sawhorses and a circular saw.

6. Make girders by joining 2x10s: Girders were made by nailing and gluing two 2x10 LVLs. This operation was performed by 2-6 people. The process was lengthy because of hand nailing.

7. Transport and position girders for master bedroom : Girders were transported and positioned by hand, supported by the post and the concrete wall.

8. Modify girder 2M for master bedroom: One girder for the master bedroom was too long and had to be re-cut using a circular saw.

9. Transport and position remaining girders: Girders were transported and positioned as described previously.

10. Modify remaining girders: Some girders were too long and were trimmed using a circular saw.

11. Nail girders together: Abutting girders on a post were joined with a strap and nails.

12. Gusset girders for the master bedroom: Girders were gusseted using an OSB gusset plate placed at the T-joint formed by the girders and the post.

13. Modify sill plates: To provide a more continuous support for the floor panels, 2x4s were placed on top of sill plates and girders. To accomplish this, the sill bolts were recessed by creating a cavity in the sill plates and re-tightening the bolts. This was done by 2-3 persons using hand tools.

14. Attach 2x4s on top of girders and sill plate: 2x4s were positioned and nailed to the top of girders and sill plates to provide more continuous support for panels.

15. Transport floor panels: Floor panels were transported manually to the perimeter of the house.

16. Apply adhesive to spline: Note that the 2x6 splines were pre-assembled in the floor panels. Adhesive was applied only to the top-side of the spline.

17. Position panels: Panels were positioned and snugged using a come-along and sledge hammer.

18. Fasten panels: Ten inch screws were used to fasten panels to sill plates and nails were used for fastening panels along the splines. Note that the 2x6 splines were pre-assembled in the floor panels so that only one seam of nails was used on the top-side of the joint.

19. Tighten panel screws: Long screws were tightened to prevent interference with bottom plates.

Exterior Walls

1. Snap lines for exterior walls: Lines were snapped to position bottom plates for exterior walls. Two persons used the chalk string.

2. Attach bottom plates for exterior walls: 2x6 bottom plates were transported, measured, cut-to-size, positioned and glued/nailed to the floor panels.

3. Apply adhesive to the bottom plate and spline: Adhesive was applied to the outside side of

the bottom plate and spline using a caulking gun in preparation for setting the wall panel.

4. Transport wall panel: Each wall panel was manually carried to the point of use. This operation involved 10 or more people.

5. Set the wall panel on the bottom plate: Each wall panel was placed on top of the bottom plate after adhesive was applied. This process involved 10 or more people.

6. Snug the panel: Each wall panel was snugged to the adjacent panel using a come-along and a sledge hammer.

7. Fasten panel to bottom plate and spline: Each wall panel was attached to the bottom plate and the spline of the adjacent panel using nails and a hammer. Note that 2x6 splines were pre-assembled in the wall panels so that only one seam was nailed per joint (both inside and outside). Also note that openings for windows and doors were pre-cut and framed in the factory using 2x6s.

8. Insert corner post: One corner post was added to WD1.

9. Modify panel: Panels forming the front and rear walls of the house required modification. The ends of the panels were cut using a circular saw and foam was stripped using a hot melt tool to form a spline channel. The reason for the modifications was a last minute change in foam supplier, which led to a change in wall depth. The change was not compensated for in the manufacturing plans.

Roof

1. Snap lines for interior walls: Lines were snapped to position interior walls and holes for posts that are embedded in the walls. Two persons used the chalk string.

2. Cut holes for posts: Holes were cut in the floor panels. Cuts were made through the top OSB skin and the foam. This operation was performed using a power saw.

3. Erect posts to support ridge beams: Posts used to support the ridge beams were assembled using two 2x6s sandwiching an OSB strip. Components were moved to the point-of-use, measured, cut-to-size, and assembled using nails. Posts were then erected, leveled, and braced using temporary supports. This operation involved 5 people.

4. Place ridge beams and re-square posts: Each ridge beam was lifted from outside the house using a crane and placed between the ridge beam and the wall. A cavity for the ridge beam was pre-cut in the wall. The post was then re-leveled. The middle beam rested on two posts and was placed after the supporting posts were properly aligned.

5. Final check and adjustment of the beam: After the two beams were placed in the post, the post was again leveled and nailed using a metal strap.

6. Apply adhesive to top of wall panel: Before the roof panel was placed, adhesive was applied to the top of the wall panels. This was done by 1-2 people using a caulking gun.

7. Prepare roof panel: Before lifting, each roof panel was prepared at ground level. Preparation involved snapping lines (to facilitate final positioning), starting 10@ screws along this line, and attaching 2x4s. 2x4s were used to attach the lifting hook and to serve as a safety stop for roof workers.

8. Lift roof panel: Each panel was lifted and positioned by crane. The process required 4 people, one crane operator and three guiding and adjusting before fastening the screws. On occasion one person had to stand on a ladder from the outside and give support for fine adjustments.

9. Fasten the roof panel: The roof panel was fastened by driving the pre-started 10" screws into the wall panel and the ridge beam. The two OSB splines (per joint) were then inserted from the end into the factory-made spline channels. On several panels, splines were placed on the installed panel before the next panel was lifted. The former procedure proved to be more effective and it was adopted for the remaining panels. Some splines were inserted with adhesive applied; however, it required considerable effort to overcome the friction and the practice was discontinued on later panels. Note that no glue was used on splines for these panels. After inserting the splines, the joint was fastened using nails from the top side (2 rows of nails, one row on each panel). Note that the bottom spline was not fastened.

10. Prepare splines: Spline preparation involved the application of the glue on the spline before inserting it in the spline channel. This was not done for all splines and required one person.

11. Modifying the panel: Several panels had to be re-cut to accommodate the porch which was not in the original plan. This was done using a circular saw and a hot-melt foam cutter.

Appendix B
Construction Process Description for Stick-built Home

Walls

1. Snap lines: The location for each wall was determined using a tape measure. A chalk line was snapped on the concrete slab to mark the precise location. (2 persons)

2. Transport 2x4s: 2X4s used to frame each wall were manually carried from a lumber staging area to the wall location on the slab.

3. Frame: Each wall was framed horizontally on the slab.

4. Sweep slab: The slab where each wall was to be erected was swept using a broom. (1 person)

5. Apply sealant: After the slab was swept, silicone rubber sealant was applied to the slab using a caulking gun. (1-2 persons)

6. Erect wall frame: Each wall frame was erected manually on the slab on top of the sealant. The wall was manually held in position until 3-4 nails were fired into the slab using a .22 caliber nail gun.

7. Tie wall to the ground: After each wall was erected, it was tied to the ground using a 2x4 that was nailed to another 2x4 hammered into the ground.

8. Nail frame to slab: When the wall was secure, the nail gun was used to add nails.

9. Cut OSB for wall corners: OSB was used at wall corners for racking strength. 3/8" OSB was cut to the required dimensions using a table saw.

10. Nail OSB to the frame: Cut OSB was nailed to the corners of the wall frame using a hammer.

11. Nail anchors to the frame: Anchors (Mud Sill Anchor, No FA3) which were already attached to the slab were nailed to the wall frame using a hammer.

12. Nail horizontal 2x4s: Wall frames were connected with horizontal 2x4s to serve as a backing for the interior walls. Hammers were used.

13. Nail top plate: 2x4 top plates were used to tie wall frames. Plates were nailed by persons working on ladders using hammers. (1-2 persons)

14. Nail R3 Styrofoam as outer wall sheathing: R3 Styrofoam was nailed to the wall frame using a hammer.
15. Install batt insulation: Process not observed. Estimates obtained from local contractor.

Roof

1. Prepare beams for porch: The porch beams were prepared by nailing two 2x8s sandwiching 3/8" OSB. The 2x8s were first cut to the required size by the table saw and then they were nailed together.

2. Erect and square beams: The porch beams were manually lifted, positioned at the proper location, squared using a level, and nailed.

3. Add face plate to gable ends: The gable ends were nailed with a 2x4 face plate on top of the top plate (2" offset to the exterior edge).

4. Nail Styrofoam on the gable trusses: The gable trusses were nailed with R3 Styrofoam. The Styrofoam was nailed and then cut to match the outer truss profile using the cutter.

5. Remove gusset plates from second truss: The second gable truss had gusset plates on both sides. Gusset plates were removed from one side using a chisel and a hammer.

6. Square walls: Before installing trusses, the walls were squared using a level. When squared, the frame was nailed to the slab using an inclined 2x4 extending from the top of the wall to the slab on the inside of the frame.

7. Lift trusses: Each truss was lifted manually by 6-8 persons. It was then supported by a 2x4 until 3 topside persons could place it horizontally, resting on the walls.

8. Erect trusses: The trusses were erected manually, squared and nailed to the walls on 24" centers. A 1x4 running on top of the trusses was used for support.

9. Nail truss hangers (E.F.1, HC-1, NER-408): Once trusses were set, the trusses were joined to the walls using truss hangers.

10. Nail catwalk: 2X4s were nailed between two adjacent trusses for a catwalk.

11. Cut 2x4 for lookouts: 2x4s used to form lookouts were cut using a table saw.

12. Hang lookouts: The cut 2x4s were nailed to the gable end trusses using a hammer.

13. Cut Styrofoam for doors and windows: The Styrofoam on the exterior walls covering doors and windows was cut using a cutter.

14. Lift 2x6s and nail to the lookouts: 2x6s were attached at the outer end of the lookouts. They were lifted manually by three people and nailed using a hammer.

15. Place and nail roof sheathing: The roof sheathing, ½" OSB, was transported to the roof and

nailed. Sheathing was added in rows beginning on the outer edges. Enough OSB for one row was lifted and nailed to the trusses. ½ " roofing clips were placed between adjacent rows of OSB, 2' on center. (6 persons)

16. Install batt insulation: Process not observed. Estimates obtained from local contractor.

Appendix C
Detailed Study Results: Sedro-Woolley SIP Home

Unload Activities	Start	End	Duration	Persons	Man-Min.
Unload 2X6	9:00	9:05	5	4	20
Unload SSIC	9:05	12:25	200	4	800
Total			205		820

	Activity					
Floor Activities	Type	Start	End	Dur.	Persons	Man-Min.
Lay plastic ground cover	F	8:05	8:40	18	0 to 6	72
Level	F	9:05	9:30	25	2	50
Cut 2X10 LVLs for girders	F	9:10	10:52	102	0 to 3	119
Modify sill plates	F	9:15	9:37	22	2 to 3	51
Make girders by joining 2X10	F	9:23	11:25	122	2 to 6	670
Transport girders for the house	F	9:40	9:51	11	0 to 2	10
Make adjustments for the girder dimensions	F	10:15	10:32	17	3	51
Prepare post for the M bedroom girder	F	10:35	10:42	7	3	21
Transport and position girders for M bedroom	F	10:43	10:45	2	6	12
Modify girder 2M of M bedroom	F	10:51	11:00	9	3 to 4	30
Nail girders together	F	11:06	11:12	6	2	12
Gusset girders for M bedroom together	F	11:08	11:25	17	2	34
Prepare remaining posts	F	10:45	10:50	5	2	10
Transport and position remaining girders	F	10:50	10:55	5	5	25
Place girder1	F	10:55	11:00	5	2	10
Readjust girder1 for height	F	11:05	11:15	10	2	20
Gusset girder 1	F	11:20	11:35	15	6	90
Place the girder 2	F	12:00	12:08	8	6	48
Add OSB to the girder post to adjust height	F	12:08	12:12	4	4	16
Readjust girder 2 using shims	F	12:12	12:16	4	4	16
Gusset girder 2	F	12:16	12:28	12	4	48
Nail 2X4 to the top of the girders	F	12:28	12:50	22	6	132
Nail 2X4 on top of sill plates	F	12:03	1:00	47	3 to 5	203
Transport floor panel 1	P(T)	1:10	1:11	1	11	11
Transport floor panel 2	P(T)	1:12	1:13	1	11	11
Transport floor panel 3	P(T)	1:21	1:22	1	11	11
Transport floor panel 4	P(T)	1:25	1:26	1	11	11
Transport floor panel 6	P(T)	1:27	1:28	1	11	11

Transport floor panel 5	P(T)	1:38	1:39	1	11	11
Position panel 1	P(PO)	1:26	1:35	9	9	81
Fasten panel 1	P(F)	1:30	1:38	8	10	80
Apply adhesive to spline	P(F)	1:33	1:34	1	2	2
Position panel 2	P(PO)	1:35	1:40	5	9	45
Fasten panel 2	P(F)	1:40	1:47	7	8	56
Apply adhesive to spline	P(F)	1:39	1:40	1	2	2
Position panel 3	P(PO)	1:40	1:45	5	8 to 9	42
Fasten panel 3	P(F)	1:47	1:53	6	8	48
Apply adhesive to spline	P(F)	1:45	1:46	1	2	2
Position panel 4	P(PO)	1:46	1:52	6	9 to 10	59
Fasten panel 4	P(F)	1:53	1:59	6	9	54
Apply adhesive to spline	P(F)	1:52	1:53	1	2	2
Position panel 5	P(PO)	1:53	1:58	5	8	40
Fasten panel 5	P(F)	1:59	2:05	6	6 to 7	40
Apply adhesive to spline	P(F)	1:57	1:58	1	2	2
Position panel 6	P(PO)	1:58	2:02	4	9 to 10	38
Fasten panel 6	P(F)	2:05	2:10	5	5	25
Transport panel 1 for M bedroom	P(T)	1:49	1:50	1	8	8
Transport panel 2 for M bedroom	P(T)	2:18	2:19	1	8	8
Apply adhesive to spline	P(F)	2:15	2:16	1	1	1
Position panel 1 for M bedroom	P(PO)	2:16	2:18	2	13	26
Fasten panel 1 at corners	P(F)	2:18	2:19	1	2	2
Apply adhesive to spline	P(F)	2:18	2:19	1	1	1
Position panel 2 for M bedroom	P(PO)	2:19	2:22	3	12	36
Fasten panel 2 at corners	P(F)	2:22	2:23	1	2	2
Fasten M bedroom panels	P(F)	2:24	2:45	21	8 to 9	184
Tighten panel screws	P(F)	3:10	3:38	28	2 to 3	80
Total				423		2782

	Activity					
Wall Activities	**Type**	**Start**	**End**	**Dur.**	**Persons**	**Man-Min.**
Transport 2X6 for bottom plates	P(S)	2:25	2:30	5	2	10
Snap lines for exterior walls	P(S)	2:36	3:25	49	0 to 2	55
Glue bottom plates	P(S)	3:40	4:08	28	2 to 3	60
Nail bottom plates	P(S)	3:45	4:12	27	4	108
Apply adhesive to bottom plates	P(F)	8:35	8:36	1	1	1
Transport wall panel WD1	P(T)	8:36	8:37	1	9	9
Set wall panel on bottom plates	P(PO)	8:37	8:38	1	9	9
Snug the wall	P(PO)	8:38	8:40	2	7	14
Nail wall panel to bottom plates	P(F)	8:41	8:45	4	2	8
Insert corner post	P(S)	8:41	8:43	2	2	4
Apply adhesive for WD2	P(F)	8:41	8:42	1	1	1
Transport wall panel WD2	P(T)	8:42	8:43	1	11	11

Erect and adjust WD2	P(PO)	8:43	8:45	2	9	18
Snug the wall panel WD2	P(PO)	8:45	8:48	3	6	18
Fasten panel to bottom plates & WD1	P(F)	8:48	8:50	2	2	4
Apply adhesive for WD3	P(F)	8:47	8:48	1	1	1
Transport wall panel WD3	P(T)	8:48	8:49	1	9	9
Glue splines for WD2 & WD3	P(F)	8:49	8:50	1	1	1
Erect and adjust WD3	P(PO)	8:50	8:52	2	11	22
Snug the wall panel WD3	P(PO)	8:52	8:53	1	11	11
Fasten panel to bottom plate & WD2	P(F)	8:53	8:57	4	2	8
Apply adhesive for WA1	P(F)	8:54	8:56	2	1	2
Transport wall panel WA1	P(T)	8:57	8:58	1	7	7
Modify WA1	P(M)	8:58	8:59	1	7	7
Erect and adjust WA1	P(PO)	9:01	9:02	1	7	7
Fasten panel to bottom plate & WD3	P(F)	9:06	9:18	12	1 to 2	19
Fasten WD1 to WD2 & WD2 to WD3	P(F)	9:03	9:06	3	2	6
Transport wall panel WE1	P(T)	9:05	9:06	1	7	7
Transport wall panel WF1	P(T)	9:05	9:06	1	7	7
Transport wall panel WF2	P(T)	9:06	9:07	1	4	4
Transport wall panel WF3	P(T)	9:07	9:08	1	6	6
Transport wall panel WG1	P(T)	9:08	9:09	1	16	16
Transport wall panel WC2	P(T)	9:14	9:15	1	16	16
Transport wall panel WC1	P(T)	9:17	9:18	1	14	14
Apply adhesive for WE1	P(F)	9:33	9:34	1	2	2
Erect the wall panel WE1	P(PO)	9:34	9:36	2	7	14
Fasten panel to bottom plate & WA1	P(F)	9:43	9:50	7	3	21
Modify WC2 for foam	P(M)	9:27	9:29	2	8	16
Apply adhesive for WE1	P(F)	9:43	9:44	1	2	2
Erect the wall panel WC2	P(PO)	9:44	9:45	1	14	14
Fasten panel to bottom plate &WD1	P(F)	9:45	9:59	14	1 to 3	28
Modify WC1	P(M)	9:22	10:22	60	10 to 11	650
Apply adhesive for WC1	P(F)	10:21	10:22	1	2	2
Erect the wall panel WC1	P(PO)	10:22	10:23	1	12	12
Snug WC1	P(PO)	10:27	10:28	1	7	7
Fasten panel to bottom plate & WC2	P(F)	10:28	10:35	7	2 to 4	20
Apply adhesive for WF1	P(F)	9:52	9:53	1	1	1
Erect the wall panel WF1	P(PO)	9:53	9:54	1	5	5
Fasten panel to bottom plate & WE1	P(F)	9:54	9:55	1	4	4
Apply adhesive for WF2	P(F)	9:54	9:55	1	1	1
Erect the wall panel WF2	P(PO)	9:55	9:56	1	5	5
Apply adhesive for WF2	P(F)	9:54	9:55	1	1	1
Erect the wall panel WF3	P(PO)	9:57	9:58	1	5	5
Fasten wall panel WF2 & WF3	P(F)	9:59	10:03	4	3	12
Transport wall panel WF4	P(T)	10:20	10:21	1	3	3

Prepare scaffolds for WF4	P(F)	10:20	10:24	4	4	16
Apply adhesive for WF4	P(F)	10:23	10:24	1	1	1
Place and fasten WF4	P(F)	10:24	10:27	3	4	12
Apply adhesive for WG1	P(F)	10:30	10:32	2	1	2
Erect the wall panel WG1	P(PO)	10:34	10:37	3	10	30
Fasten panel to bottom plate & WF3	P(F)	10:38	10:42	4	3	12
Transport WA2	P(T)	10:39	10:40	1	17	17
Apply adhesive for WA2	P(F)	10:42	10:43	1	2	2
Modify WA2	P(M)	10:47	10:58	11	10 to 14	118
Erect the wall panel WA2	P(PO)	10:58	10:59	1	12	12
Snug WA2	P(PO)	10:59	11:00	1	12	12
Fasten panel to bottom plate & WG1	P(F)	11:00	11:08	8	2	16
Transport WB3	P(T)	11:02	11:03	1	11	11
Transport WB2	P(T)	11:04	11:05	1	11	11
Transport WB1	P(T)	11:06	11:07	1	11	11
Apply adhesive for WA2	P(F)	11:04	11:05	1	2	2
Erect the wall panel WB3	P(PO)	11:06	11:08	2	7	14
Fasten panel to bottom plates & WC1	P(F)	11:08	11:11	3	2 to 3	7
Apply adhesive for WB2	P(F)	11:04	11:05	1	2	2
Erect the wall panel WB2	P(PO)	11:09	11:10	1	7	7
Fasten panel to bottom plate & WB3	P(F)	11:10	11:14	4	2	8
Apply glue for WB1	P(F)	11:17	11:18	1	2	2
Erect the wall panel WB1	P(PO)	11:18	11:19	1	12	12
Fasten WB1 to WB2 and WA2	P(F)	11:19	11:27	8	2	16
Total				279		1678

	Activity					
Roof Activities	**Type**	**Start**	**End**	**DUR.**	**Persons**	**Man-Min.**
Snap line for interior walls	F	8:04	8:37	33	1 to 2	45
Cut holes for Post	F	8:43	9:30	47	1	47
Make posts for the roof	F	9:18	9:35	17	1 to 2	30
Cut ridge beam for required profile	F	10:20	1:40	170	2 to 6	640
Erect posts to support ridge beams	F	1:20	1:25	5	5	25
Place right-rear ridge beam, square, nail	F	1:46	1:54	8	4	32
Place left-rear ridge beam, square, nail	F	1:57	2:01	4	4	16
Place middle-rear ridge beam, square, nail	F	2:04	2:13	9	4	36
Square front set of posts	F	2:10	2:13	3	4	12
Place right-front ridge beam, square, nail	F	2:14	2:19	5	3	15
Place left-front ridge beam, square,	F	2:20	2:26	6	3	18

nail						
Place middle-front ridge beam, square, nail	F	2:28	2:36	8	3	24
Final check and adjustments of the beams	F	2:40	3:11	31	4 to 8	150
Apply adhesive on wall for RC1	P(F)	3:22	3:24	2	2	4
Prepare roof panel RC1	P(PR)	3:25	3:31	6	2	12
Lift roof panel RC1	P(PO)	3:31	3:32	1	4	4
Fasten roof panel RC1	P(F)	3:32	3:33	1	4	4
Prepare roof panel RA6	P(PR)	3:34	3:40	6	2	12
Apply adhesive on wall for RA6	P(F)	3:39	3:40	1	2	2
Lift roof panel RA6	P(PO)	3:41	3:43	2	4	8
Fasten roof panel RA6	P(F)	3:43	3:47	4	4	16
Prepare splines for RC1 & RC2	P(S)	3:49	3:52	3	2	6
Prepare roof panel RC2	P(PR)	3:42	3:47	5	2	10
Apply adhesive on wall for RC2	P(F)	3:49	3:51	2	2	4
Lift roof panel RC2	P(PO)	3:50	3:51	1	4	4
Fasten roof panel RC2	P(F)	3:51	4:00	9	3	27
Prepare roof panel RA5	P(PR)	3:51	3:57	6	1 to 2	11
Apply adhesive on wall for RA5	P(F)	4:00	4:01	1	2	2
Lift roof panel RA5	P(PO)	4:02	4:04	2	4	8
Fasten roof panel RA5	P(F)	4:05	4:10	5	2	10
Prepare roof panel RC3	P(PR)	4:04	4:12	8	1 to 3	13
Apply adhesive on wall for RC3	P(F)	4:11	4:12	1	2	2
Lift roof panel RC3	P(PO)	4:13	4:14	1	4	4
Fasten roof panel RC3	P(F)	4:15	4:19	4	4	16
Modify RA4	P(M)	4:02	4:11	9	2	18
Apply adhesive on wall for RA4	P(F)	4:13	4:14	1	2	2
Prepare roof panel RA4	P(PR)	4:11	4:17	6	2	12
Lift roof panel RA4	P(PO)	4:19	4:20	1	2	2
Fasten roof panel RA4	P(F)	4:20	4:24	4	4	16
Prepare roof panel RC4	P(PR)	4:24	4:30	6	2	12
Lift roof panel RC4	P(PO)	4:30	4:35	5	4	20
Fasten roof panel RC4	P(F)	4:36	4:44	8	4	32
Apply adhesive on wall for RA3	P(F)	4:44	4:45	1	2	2
Modify RA3	P(M)	4:37	4:53	16	1 to 5	32
Prepare roof panel RA3	P(PR)	4:54	5:01	7	2	14
Lift roof panel RA3	P(PO)	5:02	5:04	2	4	8
Fasten roof panel RA3	P(F)	5:05	5:09	4	2	8
Apply adhesive on wall for RC5	P(F)	5:14	5:15	1	2	2
Prepare roof panel RC5	P(PR)	5:08	5:14	6	2	12
Lift roof panel RC5	P(PO)	5:15	5:20	5	4	20
Fasten roof panel RC5	P(F)	5:20	5:23	3	4	12
Modify and prepare RA2	P(M)	5:20	5:28	8	1 to 3	15

Lift roof panel RA2	P(PO)	5:30	5:34	4	4	16
Fasten roof panel RA2	P(F)	5:34	5:37	3	4	12
Prepare roof panel RC6	P(PR)	5:30	5:35	5	2	10
Lift roof panel RC6	P(PO)	5:38	5:43	5	4	20
Fasten roof panel RC6	P(F)	5:43	5:46	3	4	12
Prepare roof panel RA1	P(PR)	5:39	5:45	6	1 to 2	10
Readjust roof panels on ground for crane	P(T)	5:42	5:45	3	3	9
Apply adhesive on wall for RA1	P(F)	5:42	5:43	1	2	2
Lift roof panel RA1	P(PO)	5:45	5:48	3	4	12
Fasten roof panel RA1	P(F)	5:48	5:51	3	2 to 5	13
Place post for ridge beam of M bedroom	F	5:56	6:02	6	3	18
Lift & position ridge beam for M bedroom	F	6:02	6:11	9	2 to 4	29
Prepare roof panel RF3	P(PR)	6:03	6:07	4	1	4
Apply adhesive for RF3	P(F)	6:18	6:19	1	1	1
Lift RF3 and attach it to RA'S	P(PO)	6:18	6:21	3	4	12
Prepare roof panel RF2	P(PR)	6:08	6:12	4	1	4
Apply adhesive for RF2	P(F)	6:21	6:22	1	1	1
Lift roof panel RF2	P(PO)	6:21	6:27	6	5	30
Fasten roof panel RF2	P(F)	6:28	6:30	2	2	4
Prepare roof panel RE3	P(PR)	6:14	6:18	4	2	8
Apply adhesive for RE3	P(F)	6:30	6:31	1	1	1
Lift roof panel RE3	P(PO)	6:30	6:32	2	5	10
Fasten roof panel RE3	P(F)	6:32	6:35	3	5	15
Prepare roof panel RE2	P(PR)	6:20	6:24	4	1	4
Apply adhesive for RE2	P(F)	6:34	6:35	1	1	1
Lift roof panel RE2	P(PO)	6:34	6:44	10	4	40
Fasten roof panel RE2	P(F)	6:44	6:48	4	4	16
Prepare roof panel RE1	P(PR)	6:25	6:28	3	3	9
Apply adhesive for RE1	P(F)	6:47	6:48	1	1	1
Lift roof panel RE1	P(PO)	6:47	6:55	8	5	40
Fasten roof panel RE1	P(F)	6:55	6:57	2	5	10
Prepare roof panel RF1	P(PR)	6:30	6:32	2	1	2
Apply adhesive for RF1	P(F)	6:53	6:54	1	1	1
Lift roof panel RF1	P(PO)	6:53	6:58	5	5	25
Fasten roof panel RF1	P(F)	6:58	7:00	2	2	4
TOTAL				**596**		**1914**

1. Activity Types Legend
   F=Framing Operation
   P(PR)= Panel (Preparation)

P(T) = Panel (Transportation)
P(M) = Panel (Modification)
P(S) = Panel (Spline & Bottom Plate)
P(PO) = Panel (Positioning)
P(F) = Panel (Fastening)

2. Duration (cycle time) is defined as clock time (min.) between the start of an activity and its end. The activity may not be continuous over the duration. Formal breaks (including overnight) are subtracted from duration.
3. A small number of activities were not observed. Estimates for these activities were made from similar activities.

Appendix D
Detailed Study Results: Plains Stick-built Home

ACTIVITY	Activity	Start	End	Dur.	Man-min.	Persons	Day	W/R
Snap line for wall 1	P	9:11	9:12	1	2	2	1	W
Bring 2x4 for wall 1	O	9:20	9:25	5	30	6	1	W
Make frame for wall 1	WF	9:26	9:32	6	42	7	1	W
Clean surface for wall1	P	9:32	9:33	1	1	1	1	W
Apply sealant for wall 1	P	9:33	9:36	3	3	1	1	W
Erect frame for wall 1	PO	9:37	9:39	2	24	12	1	W
Tie wall 1 to the ground	O	9:38	9:40	2	2	1	1	W
Nail frame to floor	FT	9:38	10:10	32	60	0 to 12	1	W
Cut OSB for wall corners	P	10:01	10:05	4	8	2	1	W
Nail OSB to the wall frame	S	10:05	10:11	6	24	4	1	W
Nail connectors to wall 1	FT	10:23	10:33	10	20	2	1	W
Snap line for wall 2	P	10:29	10:31	2	4	2	1	W
Bring 2x4 for wall 2	O	10:35	10:38	3	36	12	1	W
Make frame for wall 2	WF	10:38	10:48	10	44	2 to 6	1	W
Clean surface for wall 2	P	10:52	10:53	1	1	1	1	W
Apply sealant for wall 2	P	10:53	10:56	3	3	1	1	W
Erect frame for wall 2	PO	10:56	10:57	1	9	9	1	W
Nail frame to floor and wall 1	FT	10:57	11:06	9	24	2 to 3	1	W
Cut OSB for wall corners	O	11:01	11:03	2	4	2	1	W
Nail OSB to the wall frame	S	11:09	11:17	8	20	2 to 3	1	W
Nail connectors to wall 2	FT	11:18	11:27	9	18	2	1	W
Snap line for wall 4.1	P	10:30	10:31	1	2	2	1	W
Bring 2x4 for wall 4.1	O	10:32	10:35	3	6	2	1	W
Make frame for wall 4.1	WF	10:36	10:51	15	30	2	1	W
Clean surface for wall 4.1	P	10:51	10:52	1	1	1	1	W
Applying sealant for 4.1	P	10:52	10:53	1	1	1	1	W
Erect frame for wall 4.1	PO	10:54	10:55	1	4	4	1	W
Nail frame to floor and wall 1	FT	10:55	11:06	11	12	0 to 2	1	W
Cut OSB for wall corners	O	11:06	11:07	1	1	1	1	W
Nail OSB to the wall frame	S	11:08	11:48	40	65	1 to 2	1	W
Snap line for wall 4.3	P	10:55	10:56	1	1	1	1	W
Bring 2x4 for wall4.3	P	10:56	10:59	3	6	2	1	W
Make frame for wall 4.3	WF	11:01	11:10	9	33	1 to 6	1	W
Clean surface for 4.3	P	11:18	11:20	2	2	1	1	W
Applying sealant for 4.3	P	11:20	11:22	2	2	1	1	W
Erect frame for wall 4.3	PO	11:22	11:24	2	16	8	1	W
Nail wall frame to the ground	FT	11:24	11:34	10	30	3	1	W
Cut OSB for wall corners	O	11:30	11:33	3	3	1	1	W
Nail OSB to the wall frame	S	11:33	*12:55	52	132	0 to 3	1	W

Nail connector to 4.3	FT	12:58	1:05	7	14	2	1	W
snap lines for 4.2	P	11:27	11:28	1	2	2	1	W
Bring 2x4 for wall 4.2	P	11:28	11:30	2	4	2	1	W
Make frame for wall 4.2	WF	11:30	11:40	10	32	1 to 5	1	W
Clean surface for 4.2	P	11:40	11:41	1	1	1	1	W
Apply sealant for 4.2	P	11:41	11:42	1	2	2	1	W
Erect frame 4.2	PO	11:44	11:45	1	5	5	1	W
Nail the frame to the ground	FT	11:45	11:51	6	16	1 to 3	1	W
Cut OSB for wall corners	O	12:45	12:46	1	1	1	1	W
Nail OSB to the wall frame	S	12:46	1:22	36	65	1 to 2	1	W
Snap line for wall 3	P	11:25	11:26	1	2	2	1	W
Bring 2x4 for 3.2	P	11:24	11:28	4	8	2	1	W
Make frame for 3.2	WF	11:29	11:41	12	42	2 to 5	1	W
Clean surface for 3.2	P	11:44	11:46	1	2	2	1	W
Apply sealant for 3.2	P	11:48	11:49	1	1	1	1	W
Erect frame 3.2	PO	12:51	12:52	1	7	7	1	W
Nail frame 3.2	FT	12:56	1:10	14	21	1 to 2	1	W
Cut OSB for wall 3 corners	O	12:59	1:02	3	3	1	1	W
Nail OSB to the wall frame	S	2:00	2:12	12	20	1 to 2	1	W
Nail connectors to 3.2	FT	1:12	1:15	3	3	1	1	W
Bring 2x4 for 3.1	O	1:49	1:53	4	7	1 to 2	1	W
Make frame for 3.1	WF	1:53	2:01	8	28	2 to 4	1	W
Clean surface for 3.1	P	2:01	2:02	1	1	1	1	W
Apply sealant for 3.1	P	2:02	2:05	3	5	1 to 2	1	W
Erect 3.1 frame	PO	2:05	2:13	8	38	2 to 8	1	W
Nail 3.1	FT	2:13	2:22	9	18	2	1	W
Nail OSB to the wall frame	S	2:22	2:28	6	18	3	1	W
Nail connector to 3.1	FT	2:30	2:35	5	5	1	1	W
Connect horizontal 2x4 in 3	WF	2:40	3:45	65	100	1 to 2	1	W
Connect horizontal 2x4 in 1	WF	12:55	1:30	35	60	1 to 2	1	W
Connect horizontal 2x4 in 2	WF	12:40	1:10	30	50	1 to 2	1	W
Day 2								
Place a 2x4 for top plate on 1	WF	11:10	11:47	37	100	1 to 3	2	W
Place a 2x4 for top plate on 2	WF	12:40	12:55	15	60	4	2	W
Place a 2x4 for top plate on 3	WF	12:45	1:10	25	60	1 to 3	2	W
Place a 2x4 for top plate on 4	WF	1:10	1:50	40	80	2	2	W
Nailing R3 Styrofoam outer sheathing to wall 4	S	2:09	2:24	15	30	2	2	W
Nailing R3 Styrofoam outer sheathing to wall 2	S	2:24	3:04	40	120	3	2	W
Nailing R3 Styrofoam outer sheathing to wall 3	S	2:24	3:11	57	99	0 to 7	2	W
Nailing R3 Styrofoam outer sheathing to wall 1	S	2:55	3:52	57	188	2 to 4	2	W

Prepare beam for porch	P	10:00	10:45	45	45	1	2	R
Erect and square beams	PO	11:20	1:31	101	345	3 to 4	2	R
Put a face plate on one Gable end	RF	11:08	11:40	32	64	2	2	R
Put a face plate on another Gable end	RF	2:10	2:38	28	56	2	2	R
Nail Styrofoam to Gable truss 1	P	9:37	10:04	27	110	3 to 5	2	R
Remove Gusset plates from the second truss	P	10:04	11:05	61	330	5 to 6	2	R
Nail R3 Styrofoam to Gable truss 2	P	11:08	11:32	24	76	3 to 4	2	R
Square wall 1	PO	2:01	2:04	3	18	6	2	W
Square wall 2	PO	2:05	2:10	5	35	7	2	W
Square wall 3	PO	2:10	2:14	4	20	5	2	W
Square wall 4.1	PO	2:15	2:17	2	10	5	2	W
Square wall 4.2	PO	2:17	2:19	2	10	5	2	W
Square wall 4.3	PO	2:19	2:22	3	18	6	2	W
Lift Gable truss 1	LT	3:53	3:54	1	7	7	2	R
Lift truss 2	LT	3:54	3:55	1	8	8	2	R
Lift truss 3	LT	3:55	3:56	1	8	8	2	R
Lift truss 4	LT	3:56	3:57	1	8	8	2	R
Lift truss 5	LT	3:57	4:00	3	24	8	2	R
Lift truss 6	LT	4:00	4:03	3	24	8	2	R
Lift truss 7	LT	4:03	4:05	2	18	9	2	R
Lift truss 8	LT	4:05	4:07	2	16	8	2	R
Lift truss 9	LT	4:07	4:08	1	10	10	2	R
Lift truss 10	LT	4:08	4:09	1	10	10	2	R
Lift truss 11	LT	4:09	4:10	1	10	10	2	R
Lift truss 12	LT	4:10	4:11	1	10	10	2	R
Lift truss 13	LT	4:11	4:12	1	10	10	2	R
Lift truss 14	LT	4:13	4:14	1	10	10	2	R
Lift truss 15	LT	4:14	4:15	1	10	10	2	R
Lift truss 16	LT	4:15	4:16	1	11	11	2	R
Lift truss 17	LT	4:16	4:17	1	12	12	2	R
Lift truss 18	LT	4:17	4:18	1	11	11	2	R
Lift truss 19	LT	4:18	4:19	1	11	11	2	R
Lift truss 20	LT	4:19	4:20	1	10	10	2	R
Lift truss 21	LT	4:20	4:21	1	9	9	2	R
Lift truss 22	LT	4:21	4:22	1	12	12	2	R
Day 3								
Prepare scaffolds and fix ladder for truss erection	P	8:30	8:34	4	16	4	3	R
Lift first gable truss and fix it	ETN	8:40	8:49	9	39	3 to 6	3	R
Lift second gable truss and fix it	ETN	8:48	8:55	7	58	3 to 10	3	R

Erect truss 22 and fix with gable truss using 1x4	ETN	8:59	9:05	6	36	6	3	R
Erect truss 21 and nail to 1x4 and top plate	ETN	9:05	9:13	8	22	2 to 6	3	R
Erect truss 20 and nail to 1x4 and top plate	ETN	9:06	9:16	10	31	2 to 5	3	R
Erect truss 19 and nail to 1x4 and top plate	ETN	9:15	9:22	7	26	2 to 6	3	R
Erect truss 18 and nail to 1x4 and top plate	ETN	9:21	9:23	2	12	6	3	R
Erect truss 17 and nail to 1x4 and top plate	ETN	9:25	9:27	2	12	6	3	R
Erect truss 16 and nail to 1x4 and top plate	ETN	9:27	9:31	4	24	6	3	R
Readjust 16 th truss for chimney	O	9:31	9:39	8	48	6	3	R
Erect truss 15 and nail to 1x4 and top plate	ETN	9:31	9:35	4	12	3	3	R
Erect truss 14 and nail to 1x4 and top plate	ETN	9:39	9:42	3	12	4	3	R
Resquare gable truss of the far end	O	9:38	10:03	25	50	2	3	R
Erect truss 13 and nail to 1x4 and top plate	ETN	9:42	9:46	4	24	6	3	R
Erect truss 12 and nail to 1x4 and top plate	ETN	9:46	9:47	1	6	6	3	R
Erect truss 11 and nail to 1x4 and top plate	ETN	9:47	9:49	2	12	6	3	R
Erect truss 10 and nail to 1x4 and top plate	ETN	9:50	9:51	1	6	6	3	R
Erect truss 9 and nail to 1x4 and top plate	ETN	9:51	9:54	3	15	5	3	R
Erect truss 8 and nail to 1x4 and top plate	ETN	9:54	10:00	4	24	6	3	R
Erect truss 7 and nail to 1x4 and top plate	ETN	10:00	10:01	1	6	6	3	R
Erect truss 6 and nail to 1x4 and top plate	ETN	10:01	10:03	2	8	4	3	R
Erect truss 5 and nail to 1x4 and top plate	ETN	10:03	10:07	4	16	4	3	R
Erect truss 4 and nail to 1x4 and top plate	ETN	10:07	10:10	3	12	4	3	R
Erect truss 3 and nail to 1x4 and top plate	ETN	10:10	10:12	2	8	4	3	R
Erect truss 2 and nail to 1x4 and top plate	ETN	10:17	10:23	6	24	4	3	R

Erect truss 1 and nail to 1x4 and top plate	ETN	10:37	10:40	3	12	4	3	R
Readjust truss 2 and 3	O	10:28	10:41	13	52	4	3	R
Nailing truss hangers	RF	9:57	12:53	151	391	0 to 5	3	R
Nail catwalk	RF	10:11	12:03	71	98	0 to 2	3	R
Cut 2x4 for lookouts	LO	10:30	10:50	20	40	2	3	R
Hang lookouts for front end	LO	10:52	11:20	28	98	2 to 5	3	R
Hang lookouts for far end	LO	11:25	12:36	46	138	3	3	R
Nail 2x4 between adjoining trusses	RF	11:55	12:58	63	180	0 to 6	3	R
Cut wall Styrofoam for door and window opening	O	1:00	1:15	15	30	2	3	R
Lift 2x6 and nail it to look out for the front end	LO	1:35	2:01	26	98	4 to 6	3	R
Lift 2x6 and nail it to look out for the far end	LO	2:04	2:24	20	81	3 to 5	3	R
Put sub facia on front end	SF	2:25	3:00	35	141	3 to 5	3	R
Put sub facia on far end	SF	3:05	3:35	30	79	2 to 4	3	R
Day 4								
Place roof sheathing	S	8:30	2:00	300	1800	6	4	R
Day 5								
Sealing exterior walls from inside	O	9:30	10:05	35	35	1	5	W
Place additional Styrofoam to seal between wall and roof	O	9:30	1:30	210	630	3	5	W
					7902			
P=PREPARE								
WF=WALL FABRICATE								
PO=POSITION								
FT=FASTEN								
O=OTHERS								
S=SHEATHING								
RF=ROOF FABRICATION								
LT=LIFT TRUSS								
ETN=ERECT TRUSS AND NAIL								
LO=LOOK OUT								
SF=SUB FACIA								
W=WALLS								
R=ROOF								

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