ON-GRADE INSULATED PANEL FLOOR SYSTEM PRELIMINARY REPORT

ENERGY STUDIES IN BUILDINGS LABORATORY
CENTER FOR HOUSING INNOVATION
UNIVERSITY OF OREGON

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ENERGY EFFICIENT INDUSTRIALIZED HOUSING RESEARCH PROGRAM

ENERGY STUDIES IN BUILDINGS LABORATORY
CENTER FOR HOUSING INNOVATION
UNIVERSITY OF OREGON
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Research Team

Kevin Aires

Rudy Berg

John Briscoe

G. Z. Brown

Jeff Kline

Paul Larocque

Zhunqin Wang

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1.0 EXECUTIVE SUMMARY

During 1993-94 the Energy Studies in Buildings Laboratory designed and subsequently performed energy testing and monitoring on a stressed skin insulated core (SSIC) panel Demonstration House built in Springfield, Oregon. One out come of that project was an idea for an on-grade insulated panel floor system. This report describes a preliminary examination of that idea, and a proposal for its evaluation.

The "on grade floor system" described here incorporates foundation, perimeter drains, moisture barrier, insulation, wiring chase and structural floor minus finish. It is designed to be installed in one day, without concrete specialty trades. For cost study purposes its design details (Figures 3-2 through 3-7) were developed for the 20' x 36' SSIC Demonstration House design (Figure 3-1). Its projected cost (for three variations) is compared to that of a comparable insulated concrete slab floor (Figure 3-8), the (panel and pier-based) Demonstration House floor (Figure 3-9) and a similar but conventionally framed Reference House (Figure 3-10) floor. In each case the energy related details follow Bonneville Power Administration Long Term Super Good Cents prescriptive standards or projected performance equivalents. The cost estimates for these systems are summarized below:

System	Floor and Foundation Cost
Foam Footer (Fig. 3-7)	$4015
On-grade Floor with Trenched Footing (Fig. 3-2)	$4354
Site-built Footer/No Trench (Fig. 3.5)	$4481
Prefabricated Footer/No Trench (Fig. 3-6)	$4673
Insulated Concrete Slab Floor (Fig. 3-8)	$4773
Plenum Floor (Fig. 3-12)	$6813
Demonstration House (Fig. 3-9)	$7206
Reference House Foundation/Floor (Fig. 3-10)	$7465

Projected total house cost *savings* (in addition to the floor system) for both the concrete and on-grade floors would be about $250, compared to the costs for the Demonstration and Reference Houses, whose elevated crawl space design necessarily involves raised porches, entry stairs and handrails plus related

finishing costs. Reduced structural costs due to lower slab floor building silhouette and diminished wind loads, however, have not been addressed.

Preliminary examinations and cost studies suggest that the insulated panel on-grade floor system offers improvements over other systems in construction speed at a competitive cost. This system combines the energy and environmental advantages recognized for the frost-protected shallow foundation system (now CABO approved), the constructability advantages of the all-weather wood foundation, and the production technology of the SSIC panel. It addresses the recommendations of NAHB Research Center (NAHB, 1993, p. 21) to "Demonstrate alternative materials, methods, and insulation products for use with the FPSF technology" and expand the realm of testing.

Three recognized needs in U. S. housing are reduced cost (including reduced construction time), improved energy performance and improved accessibility. The panel slab floor appears to address these three needs plus offering marketability — resilience, warmth and compatibility with a variety of floor finishes including hardwood. House structural requirements due to wind loads are minimized, and siting opportunities are expanded because the lower house profile reduces solar impact on neighboring lots. A testing program will help determine whether the presumed advantages of the panel slab floor can be realized.

2.0 INTRODUCTION

Background

During 1993 and 1994 the Energy Studies in Buildings Laboratory designed, built and performed energy testing and monitoring on a stressed skin insulated core (SSIC) panel Demonstration House built in Springfield, Oregon. During that project a number of ideas emerged which appeared worth investigating in future studies — changes in panel composition, size and joinery; alternate roof structures; and refinements in the electrical distribution system among other ideas.

A group of experts from related fields was subsequently assembled to assess the potential of these ideas, and to propose other ideas related to the parent project. One of the most promising results of this process was a proposed "on-grade" floor system based on stressed skin panel construction. This report describes a preliminary examination of that idea, and a proposal for its evaluation.

Rationale

The on-grade floor system is meant to provide an economical, comfortable, marketable energy efficient floor. It combines the energy and environmental advantages recognized for the frost-protected shallow foundation system (now CABO approved), the constructability advantages of the all-weather wood foundation, and the production technology of the SSIC panel. Its low height promotes accessibility. Architecturally, it helps connect indoor and outdoor spaces. House structural requirements due to wind loads are minimized, and siting opportunities are expanded because the lower house profile reduces solar impact on adjacent lots.

The complete system incorporates foundation, perimeter drains, moisture barrier, insulation, utility chase, framing and subfloor. It is designed to be installed in one day without concrete specialty trades, thus reducing impact on remote or sensitive sites, while reducing the construction period and related financing costs. Because the floor can be built more quickly than can competing systems, and because cold weather is not an obstacle, the building season is expanded.

Three recognized needs in U. S. housing are reduced cost (including reduced construction time), improved energy performance and improved accessibility. The on-grade floor appears to address these three needs plus offering marketability — resilience, warmth and compatibility with a variety of floor finishes including hardwood.

A testing program will help determine whether the presumed advantages of the on-grade floor can be realized. It will address the recommendations of NAHB Research Center (NAHB, 1993, p. 21) to "Demonstrate alternative materials, methods, and insulation products for use with the FPSF technology" and expand the realm of testing.

Report Organization

On-grade floor design details are described in Section 3. These were developed in the context of the SSIC Demonstration House design and Springfield, Oregon site conditions. The design employs construction techniques and materials common to the Demonstration House, to make comparisons valid.

In Section 4 the on-grade floor (four variant designs) projected costs are compared to that of an insulated concrete slab floor, the Demonstration House floor and foundation and a similar but conventionally framed Reference House. In each case energy related details follow Bonneville Power Administration Super Good Cents program prescriptive standards or projected performance equivalents.

Section 5 describes projected energy performance of the alternates examined, again based on the particulars of the Demonstration House, and Section 6 outlines questions and issues to be resolved through testing. The details of the testing protocol will be presented in a subsequent report.

3.0 SYSTEM DESCRIPTION

On-Grade with Trenched Footing

Figures 3-1 through 3-4 show the details of the basic on-grade system as it has been developed. Initial site preparation consists of scraping turf from the building footprint plus 2' beyond the building lines. A 12" deep by 18" wide footing trench is excavated (Code required footing depth at the Springfield, Oregon site is 12"). Under-floor utilities are installed and stubbed up above finish floor height. Pressure treated 2 x 2 grade stakes are driven in the footing trench on 4' centers, and their tops trimmed level with the finish footing top grade. A drained, leveled, compacted gravel footing is installed in the trench to the height of these stakes.

A preservative treated perimeter beam made of full length pieces of laminated veneer lumber 1-3/4" x 7-1/4" is assembled with a double footer plate of treated 2 x lumber. The layering of these elements provides structural continuity, including at the foundation corners, and allows the LVL beam depth to be minimized for economy.

The foundation beams are aligned on the compacted gravel footings, nailed to the grade stakes and nailed together at the building corners. Auger-type ground anchors (Figures 3-13 and 3-14) are installed at the corners for uplift and seismic resistance. Perimeter insulation of 2-1/2" EPS is installed as shown in Figure 3-2.

Fill consisting of 1/4" minus crushed rock is installed, screeded to 4-1/2" below the top of the perimeter beam (the height of the perimeter insulation) and compacted. Additional bracing is added as required to keep the perimeter beams in position. A moisture barrier of 6 mil polyethylene is installed, its seams and utility penetrations taped, and it is draped up over the perimeter beam.

The floor panels (sheets of 4-1/2" EPS foam laminated to 7/16" OSB on one side only) are installed and screwed to the perimeter beam. While code required clearance of 8" to untreated lumber is not met with this design, it is believed that use of moisture barrier and insecticide-treated foam insulation (*Journal of Light Construction*, July, 1994) will provide adequate protection. This idea will be examined in the testing process. 1/2 inch plywood structural underlayment will

be added later, spanning panel joints, and fastened with screws and adhesive. This process completes the basic floor.

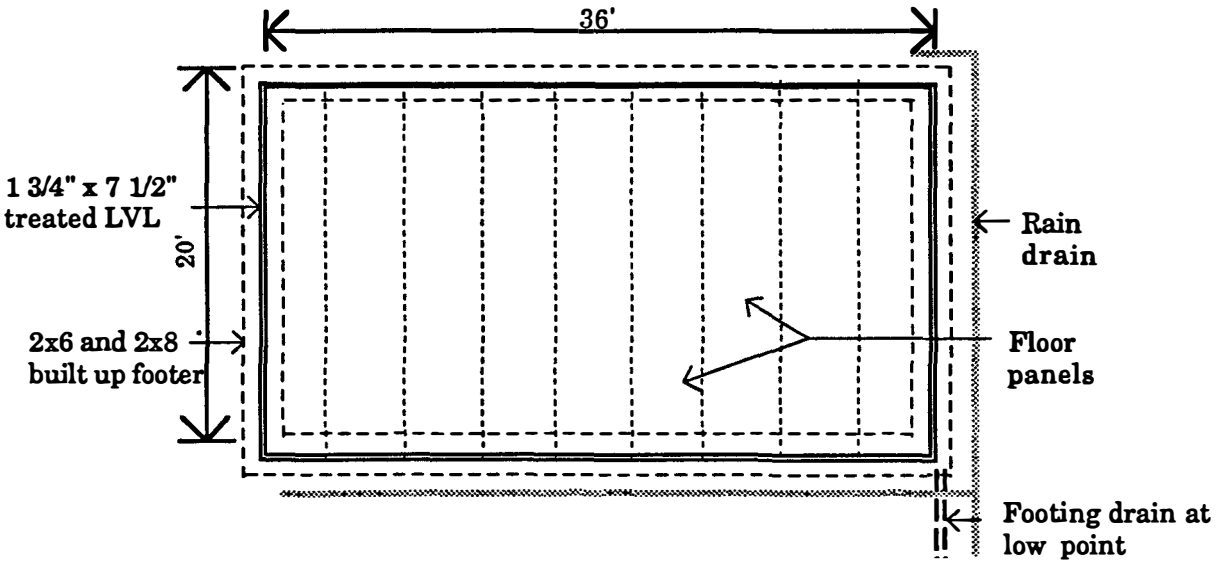

Figure 3-1 Demonstration House Floor Plan

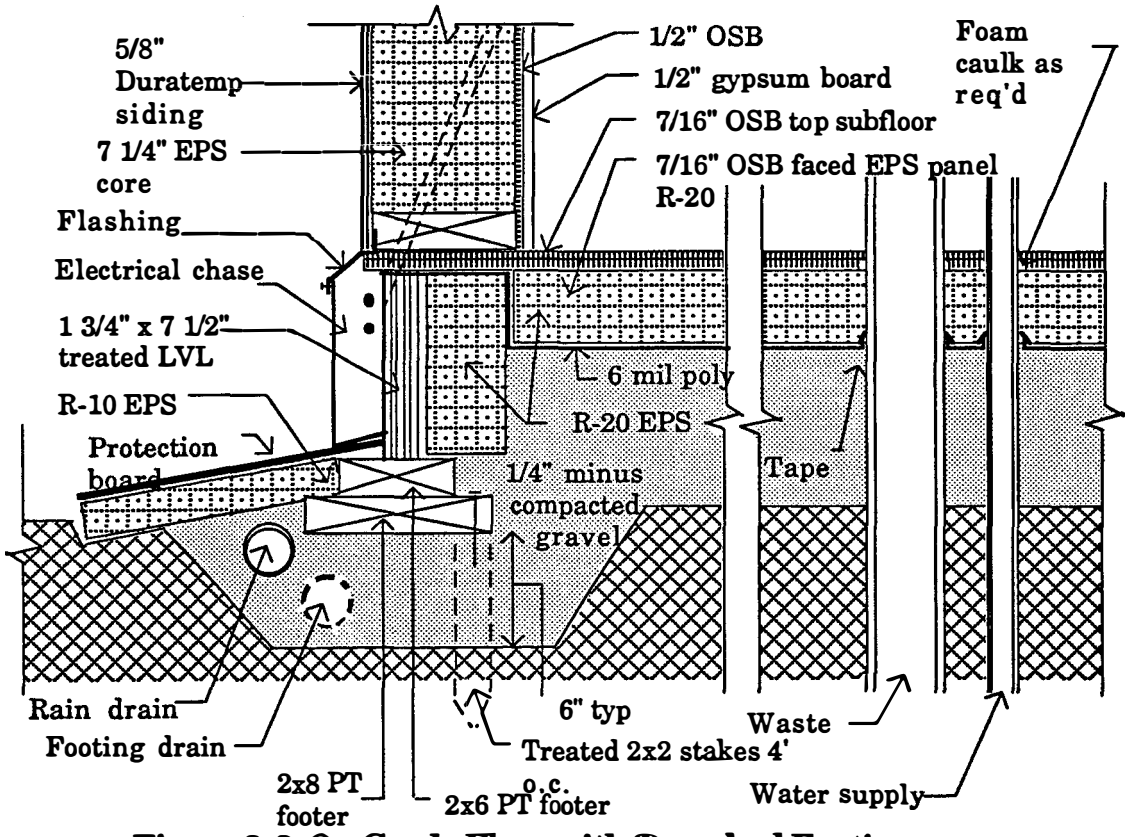

Figure 3-2 On-Grade Floor with Trenched Footing

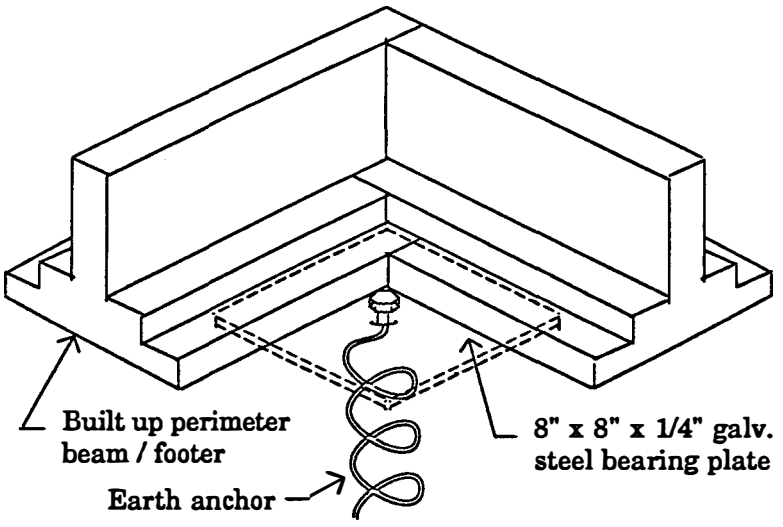

Figure 3–3
Corner/Tie Down Detail

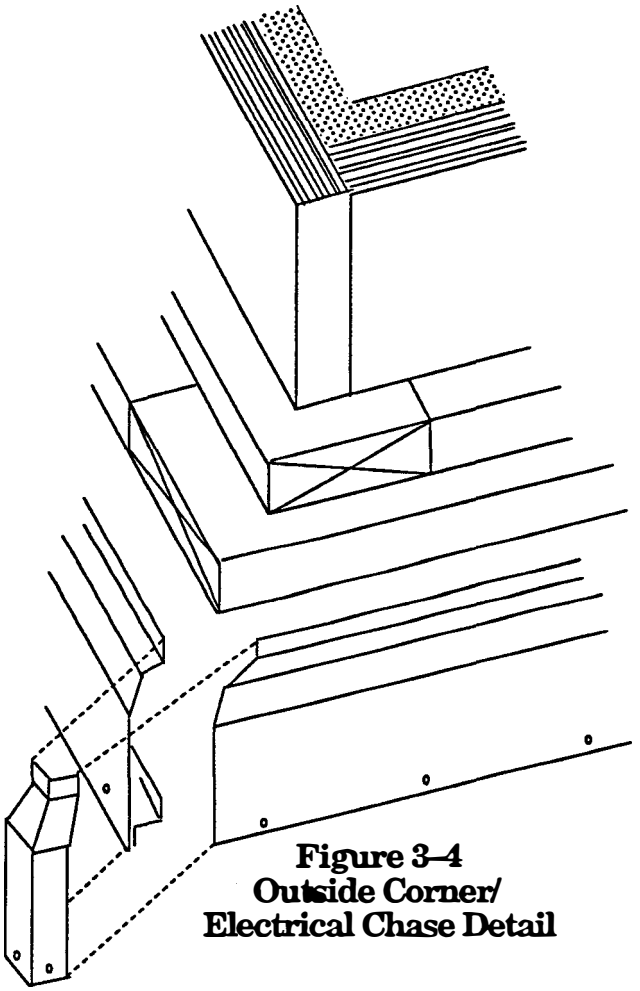

Figure 3–4
Outside Corner/
Electrical Chase Detail

No Trench Footing This simplified version (Figures 3-5 through 3-6) assumes that the use of "wing" insulation will permit reduction of the footing depth, eliminating the footing trench as shown. Versions of the perimeter beam are shown using treated sawn lumber (Figure 3-5), and treated LVL (Figure 3-6).

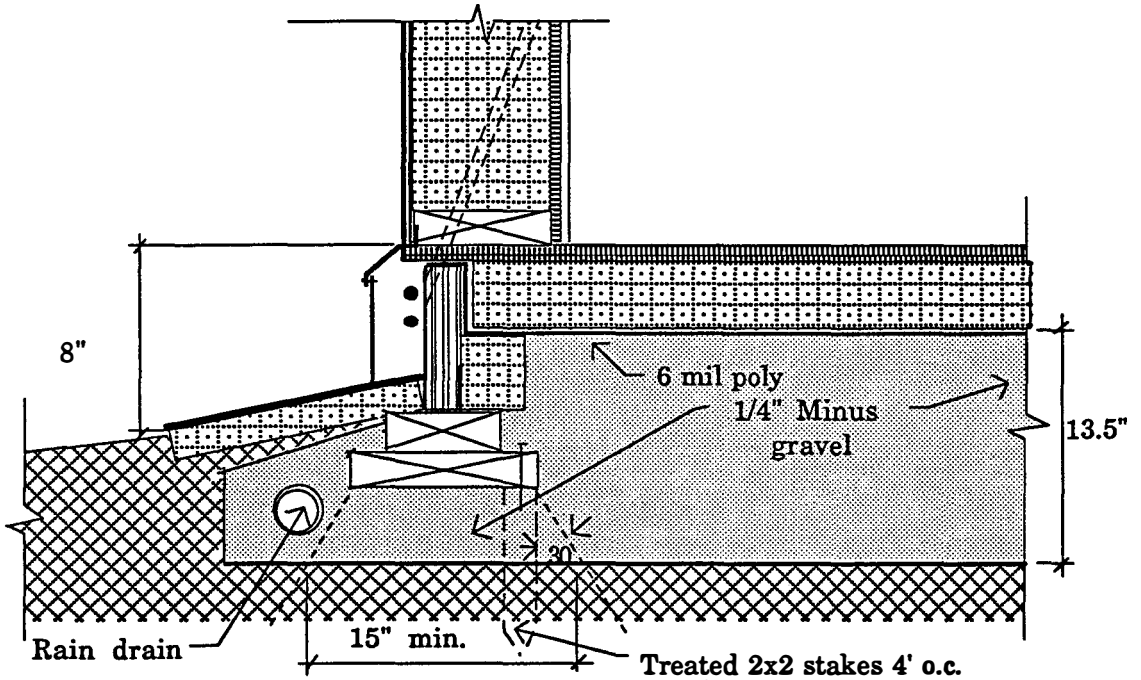

Figure 3-5 Site-Built Footer/No Trench

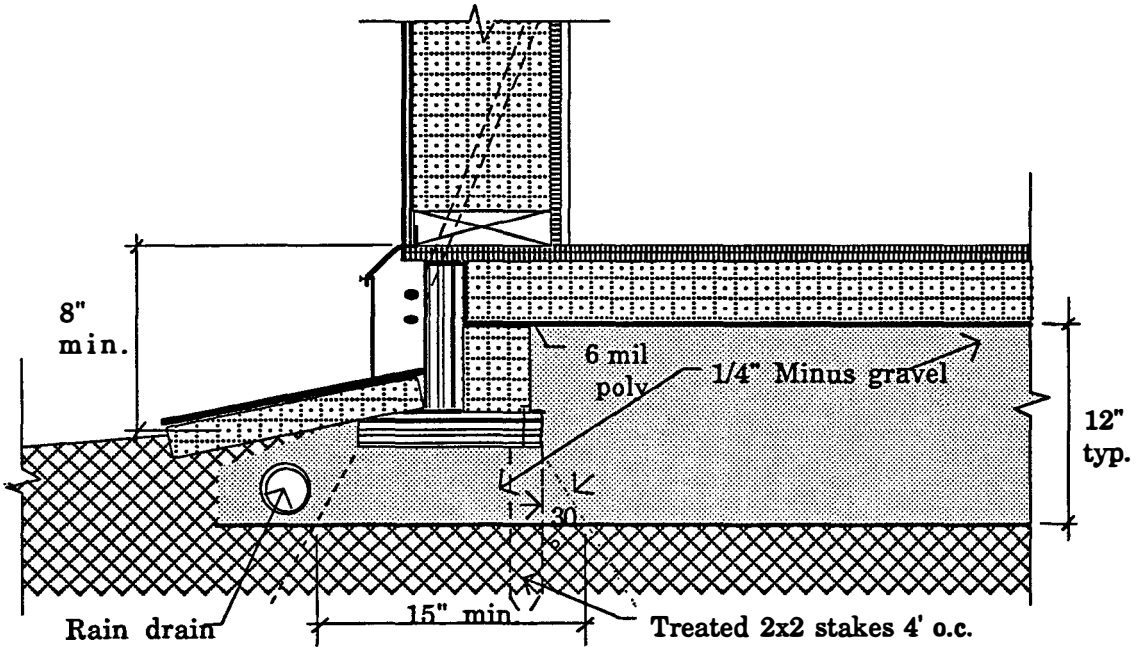

Figure 3-6 Prefabricated Footer/No Trench

Foam Footer

A trenched version of the on-grade floor with rigid foam insulation beneath the footer is shown in Figure 3-7.

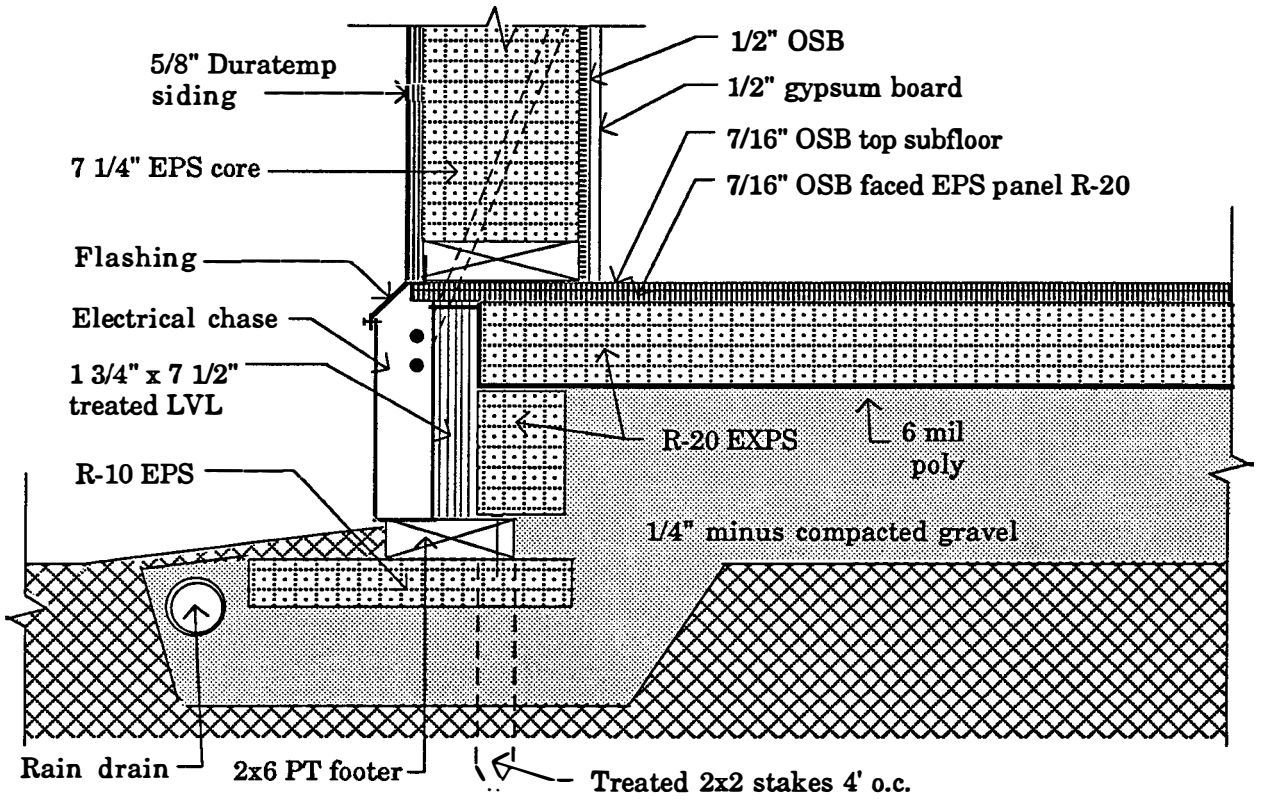

Figure 3-7 Foam Footer

Plenum Floor The basic foundation and floor design, while developed as an "on-grade floor," was also examined for its potential to provide a shallow heating plenum (Figures 3-11 and 3-12). The exploration reflects a number of factors: if stressed skin (double sided) panels were used, the fill gravel could be eliminated. ESBL's experience with point supports and two-way spans in the Demonstration House project invited further use of this strategy. And related work by John Talbott in Washington state and and Lars Eckstrom in Sweden (Talbott, 1963 and "Climate Controlled Foundation," 1995) informed the plenum floor design.

Two layers of reflective plastic bubble film (each R=7 in this application) are spread over the cleared undisturbed soil, its seams are taped (gaps are left in low spots to permit drainage of leaked moisture) for air tightness, and it is stapled to

the perimeter beam. Small pads of quick-setting mortar or concrete are placed 4' on center on center on the plastic film insulation/moisture barrier, and concrete paver bearing blocks are placed on these and tapped to finish grade before the concrete sets — the perimeter beam provides a screed for leveling these blocks.

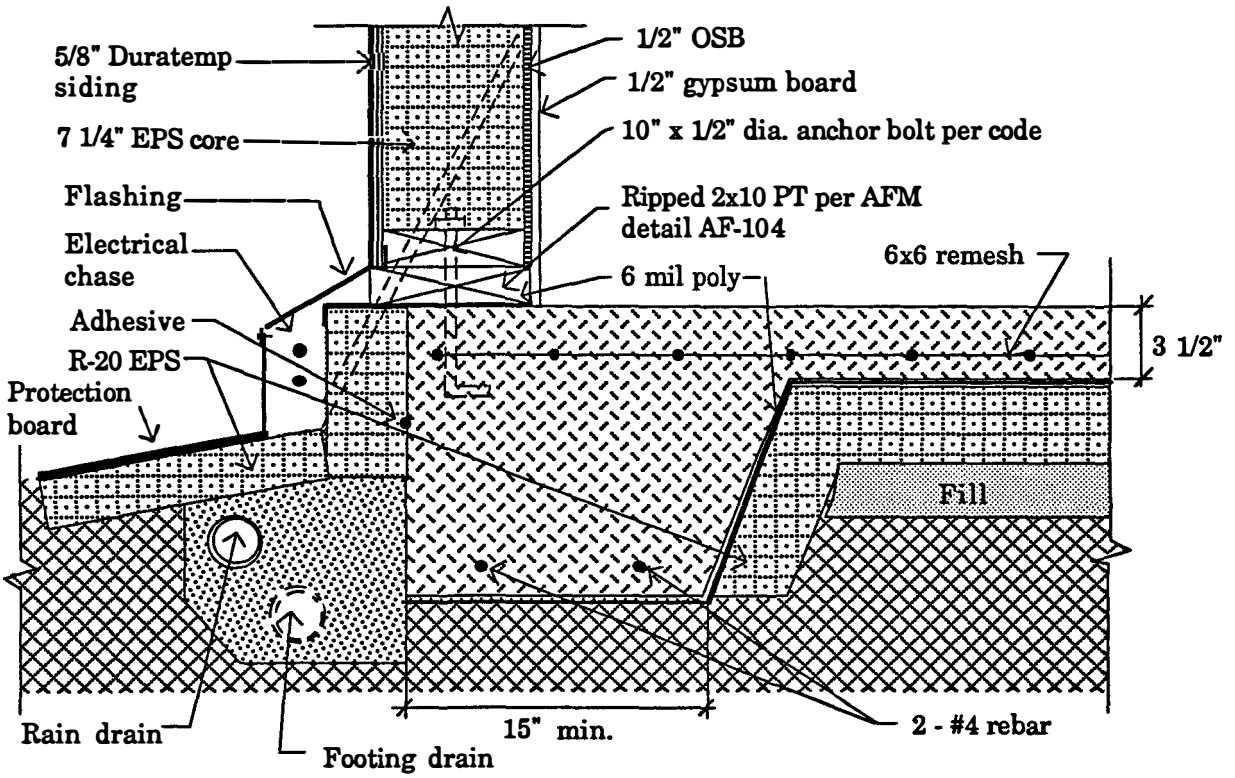

Figure 3–8
Insulated Concrete Slab Floor

While the concrete sets a layer of rigid foam "wing" and vertical insulation is installed, a roof drain system is installed and a thin layer of backfill is placed to protect the foam and drain. When the mortar under the bearing pads has set the floor panels are installed. Construction adhesive is applied to the bearing pads and ledger as the panels are placed. The floor panels span the full 20' depth of the house. Floor spans are 4' so minimal panel core thickness is needed. The panel core need not provide any insulation value, since heat transfer through the floor is a design feature. The functions of the panel core are to provide enough structural capacity for 4' floor spans over multiple supports plus point loads.

Air tightness in the panel joints and at the floor perimeter is not required; all sealing of the plenum is taken care of by taping the reflective plastic insulation and subsequent sealing of the wall to floor joint.

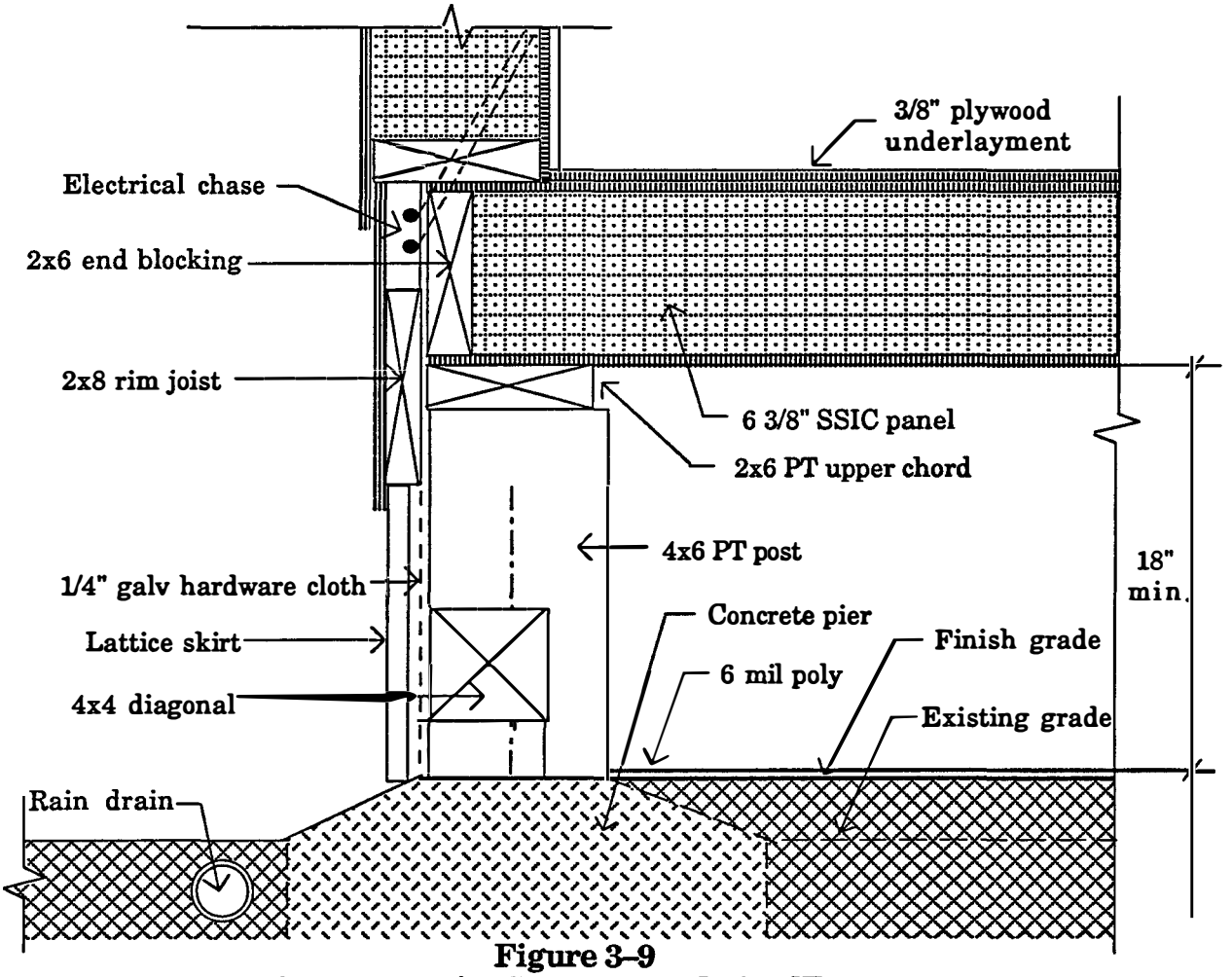

Figure 3-9
Demonstration House Foundation/Floor

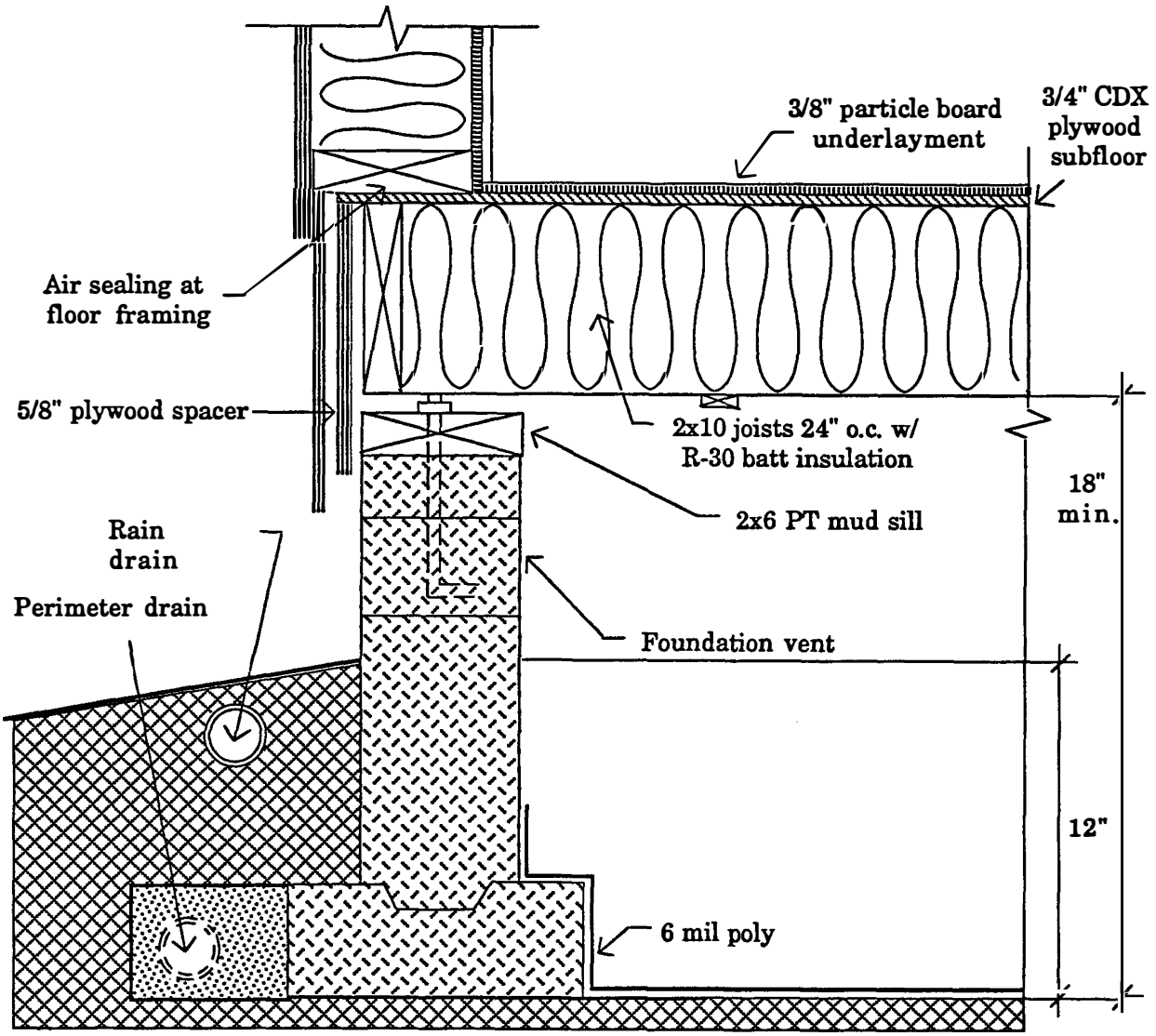

Figure 3–10
Reference House Foundation/Floor

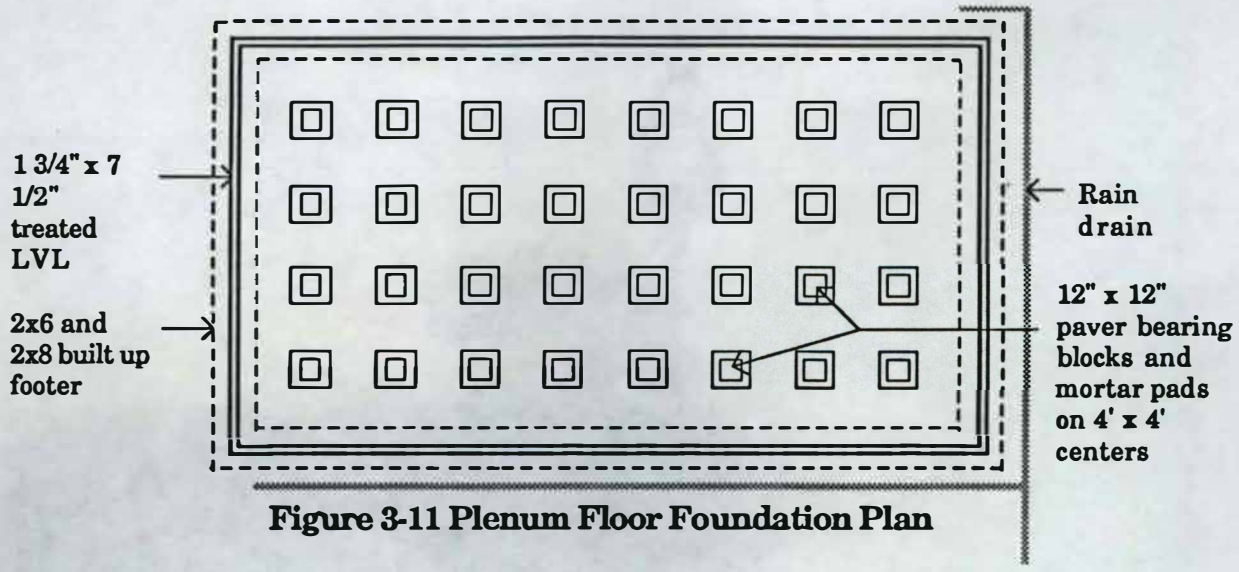

Figure 3-11 Plenum Floor Foundation Plan

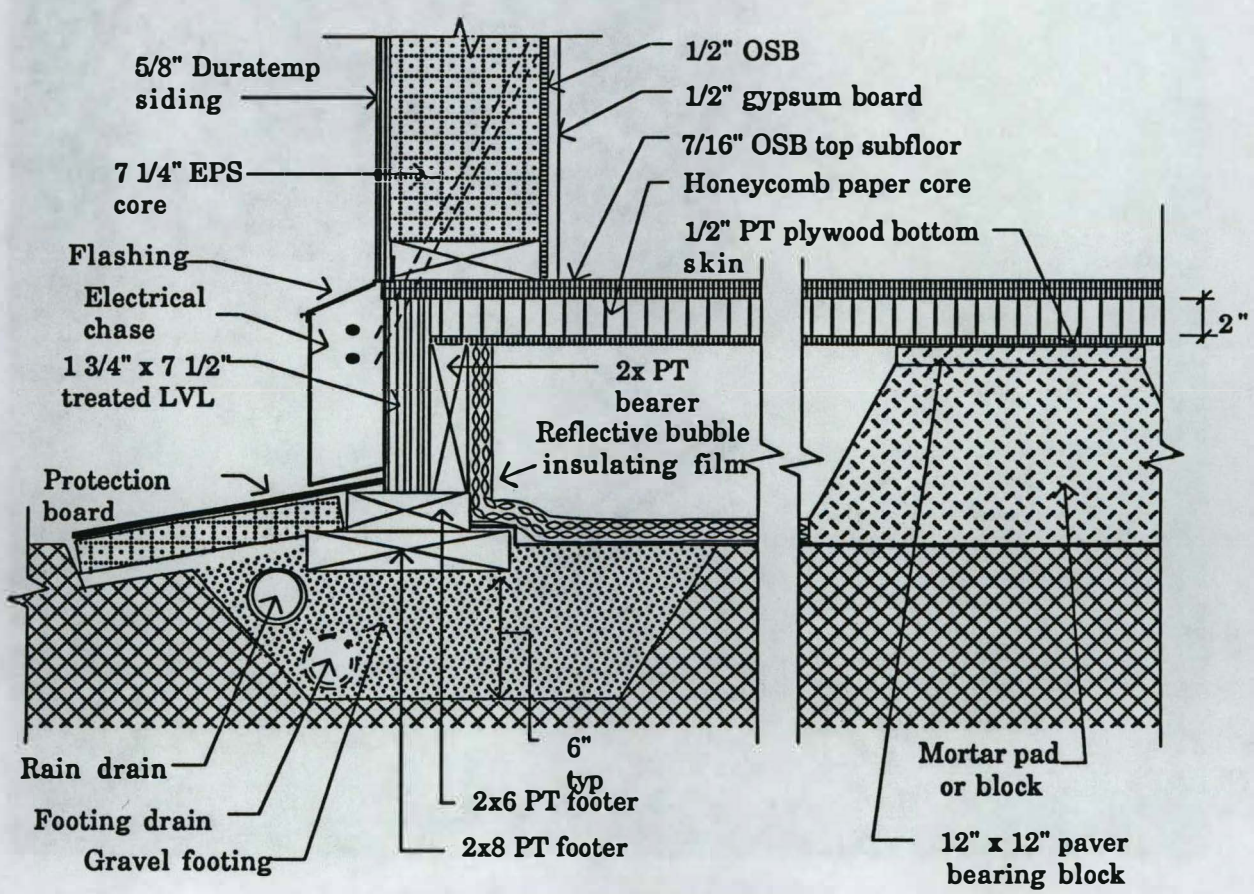

Figure 3-12 Plenum Floor

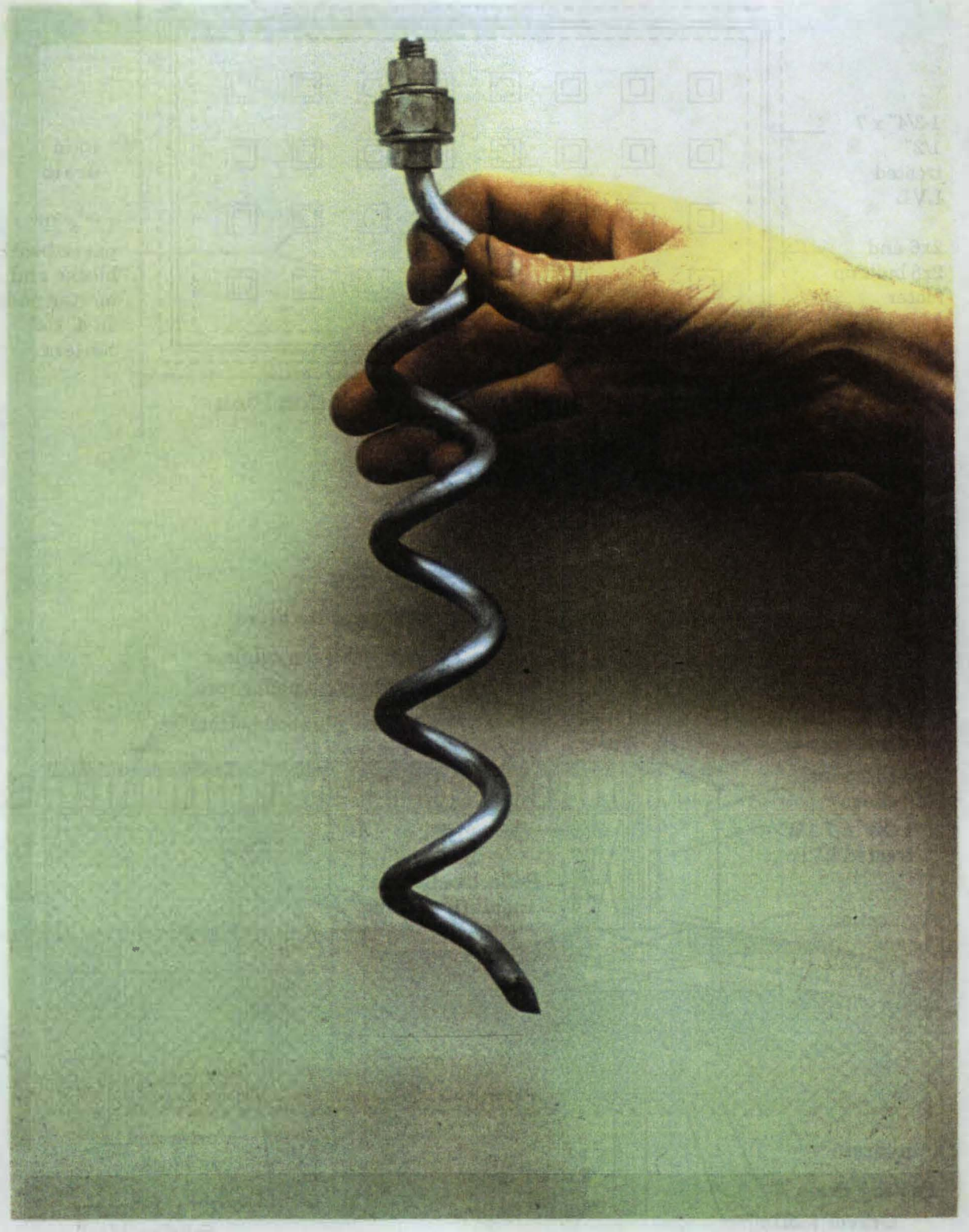

Figure 3-13 Auger-Type Ground Anchor

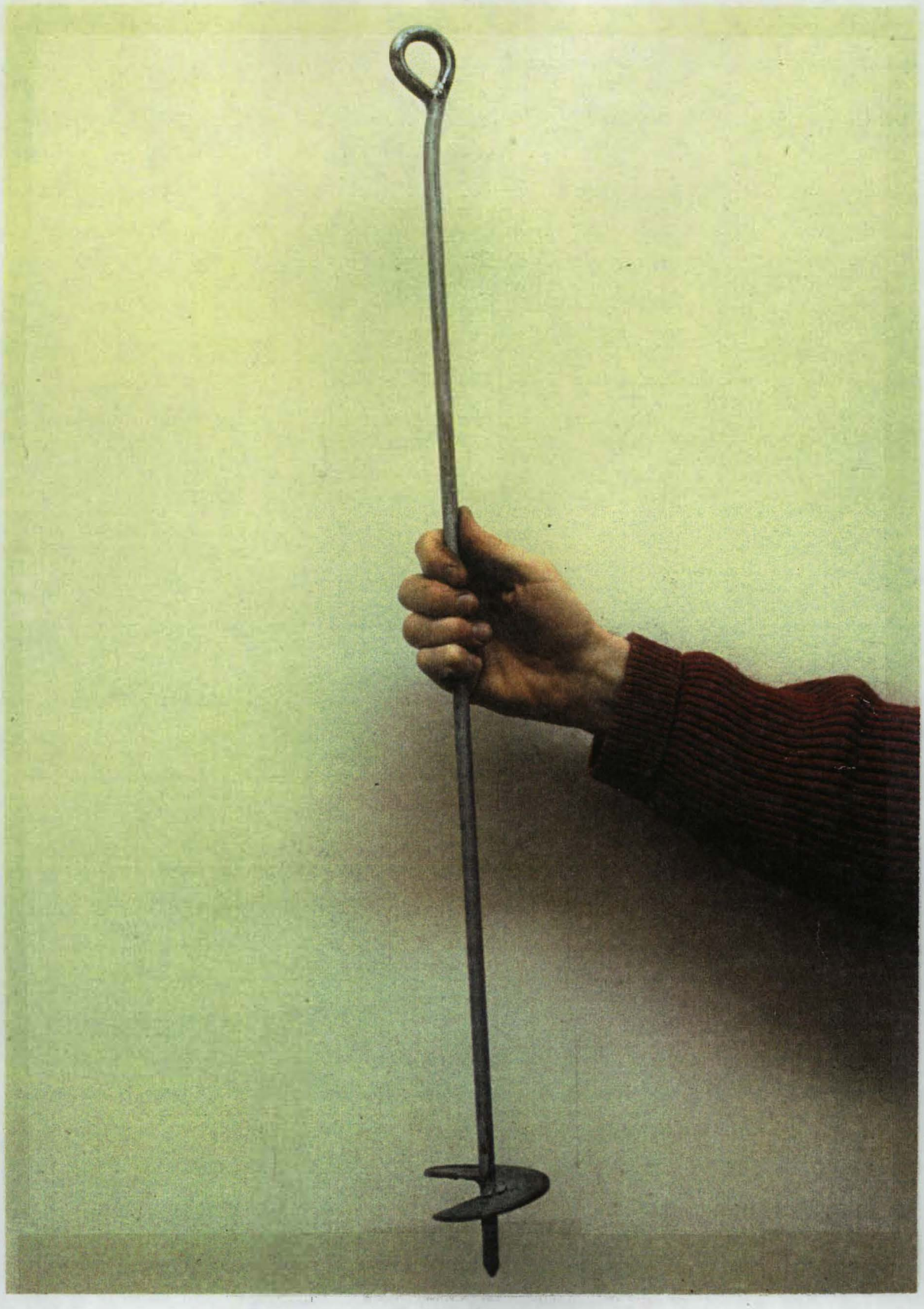

Figure 3-14 Helical Ground Anchor

4.0 ESTIMATED COSTS

Tables 4-1 through 4-8 list the detailed cost estimates for the on-grade floor and its variants, as well as the Demonstration House, Reference House and concrete slab floor systems. For cost study purposes the design details were developed in the context of the 20' x 36' SSIC Demonstration House design. In each case the energy related details follow Bonneville Power Administration Long Term Super Good Cents prescriptive standards or projected performance equivalents. The cost estimates for these systems are summarized below:

System	Floor and Foundation Cost
Foam Footer (Fig. 3-7)	$4015
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Demonstration House (Fig. 3-9)	$7206
Reference House Foundation/Floor (Fig. 3-10)	$7465

The cost advantage of panel over concrete slab floors would be magnified if hardwood finish floor costs were included. For the concrete slab treated sleepers or a "floating floor" system would have to be employed, while the on-grade would Projected total house cost *savings* for both of the low-profile (concrete and panel) slab floors would be about $250 additional, compared to the costs for the Demonstration and Reference Houses, whose elevated crawl space design necessarily involves raised porches, entry stairs and handrails plus related finishing costs. Reduced structural requirements due to lower slab floor building silhouette and diminished wind loads, however, have not been addressed.

Cost Comparison

The spreadsheets on the following pages give a component breakdown cost analysis of the floor and foundation systems. The general format was developed for use in analyzing the construction costs of the SSIC panel Demonstration House. For each entry in the spreadsheet, crew composition, material quantity,

type and cost are given, followed by labor hours, type and cost along with any equipment use and cost. All production and cost rates are also shown to indicate how expenses were determined. The following notes apply to the estimate sheets:

(1) Labor cost values include worker's compensation, overhead and profit as applied to the labor rates.

(2) In the cost source column, 'M' signifies that data was taken from the Unit Price Section of *Means Residential Cost Data 1994* and and the number refers to its CSI designation as given there. 'DF' refers to the category developed for the Demonstration House as noted in the Video Analysis section of *Cost Analysis - Stressed Skin Insulating Core Panel Demonstration House* (Aires et al, 1994).

(3) Treated lumber prices are based on M-061-127.

(4) Panel installation location modifier is set as same as that for wood and plastics.

(5) Panel transportation costs are estimated by dividing total Demonstration House panel and shipping cost by three (assuming equal spread of expense over roof, wall and floor panels).

(6) The underlayment used over the panel floor in the Demonstration House was 1/2" plywood for structural reasons. In the Reference House, a standard 3/8" underlayment was assumed. Floor finishes are assumed to be the same for both houses and therefore have been excluded from the scope of this study.

(7) Neither the cedar lattice skirt in the Demonstration House nor the foundation wall in the Reference House were originally specified to be painted. Estimated costs for painting both showed that the expense for the lattice skirt to be about $10-$15 more.

(8) Loan carrying costs are based only on the first draw amount ($12,500)

of and assumed $50,000 construction loan set at 9.5%. Number of days of carrying this loan are determined by the projected elapsed building time (calculated in the next section) for this system plus weekends.

(10) Overhead related to total project insurance are derived only from builders' risk insurance and public liability. *Means* gives estimates of 1.5% for public liability insurance. Builders' Risk insurance covering fire, vandalism etc. for frame construction is averaged at 0.553%. Assuming annual coverage for a $60,000 project, the sum of these two insurances for the developer/contractor would be approximately $1200 or $3.30 per day.

(11) Field expenses are overhead costs related to running an on-site building operation. *Means* (R010-050) suggests 0.8% of direct costs for field expenses (office, shed, etc.) which for a $60,000 project would be about $1.30 per day. This number does not reflect any main office expenses or field supervision costs as this number is highly variable depending on the size of the builder.

(12) The footer beam consists of a pressure treated LVL beam 1 3/4" x 7 1/2" supplied in full length (20' and 36') pieces. Costs are June, 1995 prices from local suppliers (LVL from Trus Joist MacMillan, Eugene, OR; treatment from Perma Post, Hillsboro, OR).

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q		
Component	S. C.	Material Quantity	Unit	Material Type	Cost per un. ($/un.)	Mat. L.M.	Material Cost [CxFxG]	Man-Hours per unit	Base Labor Hours [CxI]	Inst. L.M.	Labor Type	Labor Rate ($/hr)	Labor Cost (1) [JxKxM]	Equipment Type	Equip. Rate ($/hr)	Equipment Cost [JxKxP]	Total Cost	Cost Source (2)
SITE WORK																		
clear & grub	A-1	0.44	acre		0.00	0.937	$0.00	32.000	14.1	1.111	laborer	20.35	$318.33	power tool	8.03	$125.61	$443.94	M-021-108-0010
trench for footing	B11C	6.2	cy	112' trench 18" x 12"	0.00	0.937	$0.00	0.107	0.7	1.111	Clab	23.60	$17.46	backhoe	13.72	$10.15	$27.60	M-022-254-0050
install 6" gravel footing fill	B-37	168	sf	compact under floor slab	0.15	0.937	$23.61	0.006	1.0	1.111	see B-37	21.84	$24.46	roller	3.10	$3.47	$51.54	M-022-262-0600
build footer beam	Clab	112	lf	1-3/4"x 7-1/4" pt assy	3.64	0.937	$382.00	0.020	2.2	1.111	carp/lab	24.27	$60.40	power tool	1.27	$3.16	$445.56	note 12
install footer	Clab	112	lf	assy + stakes	0.00	0.937	$0.00	0.016	1.8	1.111	carp/lab	24.27	$48.32	power tool	1.27	$2.53	$50.85	note 12
perimeter insulation	Carp	112	lf	5" EPS (M-072-203-2130	0.62	1.109	$77.01	0.012	1.3	1.054	laborer	27.50	$38.96		0.00	$0.00	$116.96	M-072-109
exc. & backfill for per./gutter	Clab	80	lf		0.00	0.937	$0.00	0.020	1.6	1.111	laborer	20.35	$36.17	shovel	0.00	$0.00	$36.17	M-022-258/est.
lay per./gutter drain pipe	B-20	80	lf	4" diam. PVC	0.75	0.937	$56.22	0.040	3.2	1.111	laborer	21.50	$76.44		0.00	$0.00	$132.66	M-027-168-2000/est
install fill	B-37	638	sf	6" deep, compacted	0.15	0.937	$89.67	0.006	3.8	1.111	see B-37	21.84	$92.88	roller	3.10	$13.18	$195.74	M-022-262-0600
install moist. barrier/ins	1 carp	800	sf	6 mil poly	0.04	0.937	$29.98	0.002	1.6	1.111	carpenter	27.50	$48.88		0.00	$0.00	$78.87	M-071-922-0901
																Subtotal	$1,579	
INSTALL FLOOR PANELS																		
unload and store panels	DM2*	1	time		0.00	1.000	$0.00	1.667	1.7	1.163	laborer, oper.	23.60	$45.75	forklift	10.98	$21.29	$67.04	DF-13
lay panels	F-2*	720	sf	panel cost below	0.00	1.000	$0.00	0.005	3.6	1.163	carp. & helper	24.27	$101.61		0.00	$0.00	$101.61	M-072-203-2420 &
floor panels		720	sf	comp. 5" EPS, 7/16" OSB	1.20	1.000	$864.00	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$864.00	M-072-203-2110
panel transportation costs (5)		0.33	ship.	assume local distrib.	600.00	1.000	$200.00	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$200.00	cost survey
install top subfloor	F-2*	720	sf	7/16" x 8 x 24' OSB	0.45	0.936	$303.26	0.008	5.9	1.163	carp. & helper	24.27	$167.66	power tools	1.27	$8.77	$479.70	M-061-168/est.
wing insulation	F-2*	240	sf	2-1/2" EPS	1.45	0.936	$325.73	0.013	3.1	1.163	laborer	20.35	$73.84	power tools	1.27	$4.61	$404.18	est.
install flashing/prot/chase	Clab	112	lf	Insul-Guard assy		0.936	$323.25		6.0	1.163	laborer	20.35	$142.00	power tools	1.27	$8.86	$474.11	est
nails / staples		1	ea.		50.00	0.936	$46.80	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$46.80	est.
																Subtotal	$2,637	
INSTALL TIE DOWNS																		
install tie downs		4	ties	6" x 24" steel auger	15.00	0.936	$56.16	0.50	2	1.163	laborer	20.35	$47.33		0.00	$0.00	$103.49	est
CARRYING COSTS																		
Construction Loan Interest (9)		3.4	days	9.5% on $12,500	3.25												$10.90	
Insurance Expenses (10)		3.4	days	bldr risk & liability	3.30												$11.07	
Field Expenses (11)		3.4	days	toilet, site rentals	3.50												$11.74	
																Subtotal	$34	
TOTALS							$2,778		53.7				$1,341			$202	$4,354	

Table 4-1
On-grade Floor with
Trenched Footing
Site Built Footer
(Figure 3-2)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q		
Component	S. C.	Material Quantity	Unit	Material Type	Cost per un. ($/un.)	Mat. L.M.	Material Cost [CxFxG]	Man-Hours per unit	Base Labor Hours [CxI]	Inst. L.M.	Labor Type	Labor Rate ($/hr)	Labor Cost (1) [JxKxM]	Equipment Type	Equip. Rate ($/hr)	Equipment Cost [JxKxP]	Total Cost	Cost Source (2)
SITE WORK																		
clear & grub	A-1	0.44	acre		0.00	0.937	$0.00	32.000	14.1	1.111	laborer	20.35	$318.33	power tool	8.03	$125.61	$443.94	M-021-108-0010
install 6" gravel footing fill	B-37	168	sf	compact under floor slab	0.15	0.937	$23.61	0.006	1.0	1.111	see B-37	21.84	$24.46	roller	3.10	$3.47	$51.54	M-022-262-0600
build footer beam	Clab	112	lf	1-3/4"x 7-1/4" pt assy	3.64	0.937	$382.00	0.020	2.2	1.111	Carp/lab	24.27	$60.40	power tool	1.27	$3.16	$445.56	note 12
install footer	Clab	112	lf	assy + stakes	0.00	0.937	$0.00	0.016	1.8	1.111	carp/lab	24.27	$48.32	power tool	1.27	$2.53	$50.85	note 12
perimeter insulation	Carp	112	lf	6" EPS (M-072-203-2130	0.62	1.109	$77.01	0.012	1.3	1.054	laborer	27.50	$38.96		0.00	$0.00	$115.96	M-072-109
exc. & backfill for per./gutter	Clab	80	lf		0.00	0.937	$0.00	0.020	1.6	1.111	laborer	20.35	$36.17	shovel	0.00	$0.00	$36.17	M-022-258
lay per./gutter drain pipe	B-20	80	lf	4" diam. PVC	0.75	0.937	$56.22	0.040	3.2	1.111	laborer	21.50	$76.44		0.00	$0.00	$132.66	M-027-168-2000/est
install fill	B-37	638	sf	12" deep, compacted	0.35	0.937	$209.23	0.008	5.1	1.111	see B-37	21.84	$123.84	roller	3.10	$17.58	$350.66	M-022-262-0800
install moist. barrier/ins	1 carp	800	sf	6 mil poly	0.04	0.937	$29.98	0.002	1.6	1.111	carpenter	27.50	$48.88		0.00	$0.00	$78.87	M-071-922-0901
																Subtotal	$1,706	
INSTALL FLOOR PANELS																		
unload and store panels	DM2*	1	time		0.00	1.000	$0.00	1.667	1.7	1.163	laborer, oper.	23.60	$45.75	forklift	10.98	$21.29	$67.04	DF-13
lay panels	F-2*	720	sf	panel cost below	0.00	1.000	$0.00	0.005	3.6	1.163	carp. & helper	24.27	$101.61		0.00	$0.00	$101.61	M-072-203-2420/est
floor panels		720	sf	comp. 5" EPS, 7/16" OSE	1.20	1.000	$864.00	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$864.00	M-072-203-2110/est
panel transportation costs (5)		0.33	ship.	assume local distrib.	600.00	1.000	$200.00	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$200.00	cost survey
install top subfloor	F-2*	720	sf	7/16" x 8 x 24' OSB	0.45	0.936	$303.26	0.008	5.9	1.163	carp. & helper	24.27	$167.66	power tools	1.27	$8.77	$479.70	M-061-168/est.
floor bed insulation	F-2*	240	sf	2-1/2" EPS	1.45	0.936	$325.73	0.013	3.1	1.163	laborer	20.35	$73.84	power tools	1.27	$4.61	$404.18	est.
install flashing/prot/chase	Clab	112	lf	Insul-Guard assy		0.936	$323.25		6.0	1.163	laborer	20.35	$142.00	power tools	1.27	$8.86	$474.11	est
nails / staples		1	ea.		50.00	0.936	$46.80	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$46.80	est.
																Subtotal	$2,637	
INSTALL TIE DOWNS																		
install tie downs		4	ties	6" x 24" steel auger	15.00	0.936	$56.16	0.50	2	1.163	laborer	20.35	$47.33		0.00	$0.00	$103.49	est
CARRYING COSTS																		
Construction Loan Interest (9)		3.4	days	9.5% on $12,500	3.25												$11.03	
Insurance Expenses (10)		3.4	days	bldr risk & liability	3.30												$11.20	
Field Expenses (11)		3.4	days	toilet, site rentals	3.50												$11.88	
																Subtotal	$34	
TOTALS							$2,897		54.3				$1,354			$196	$4,481	

Table 4-2
On-grade Floor with
No Trench Footing
Site Built Footer
(Figure 3-5)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q		
Component	S. C.	Material Quantity	Unit	Material Type	Cost per un. ($/un.)	Mat. L.M.	Material Cost [CxFxG]	Man-Hours per unit	Base Labor Hours [CxI]	Inst. L.M.	Labor Type	Labor Rate ($/hr)	Labor Cost (1) [JxKxM]	Equipment Type	Equip. Rate ($/hr)	Equipment Cost [JxKxP]	Total Cost	Cost Source (2)
SITE WORK																		
clearing (brush w/ br. saw)	A-1	0.44	acre		0.00	0.937	$0.00	32.000	14.1	1.111	laborer	20.35	$318.33	power tool	8.03	$125.61	$443.94	M-021-108-0010
install 6" gravel footer fill	B-37	168	sf	compact under floor slab	0.15	0.937	$23.61	0.006	1.0	1.111	see B-37	21.84	$24.46	roller	3.10	$3.47	$51.54	M-022-262-0600
install grade beam assy	Clab	112	lf	1-3/4"x 7-1/4" pt LVL tee			$638.00	0.016	1.8	1.111	Carp/lab	24.27	$48.54	powertool	1.27	$2.54	$689.07	note 12
perimeter insulation	Carp	112	lf	5" EPS (M-072-203-2130	0.62	1.109	$77.01	0.012	1.3	1.054	laborer	27.50	$38.96		0.00	$0.00	$115.96	M-072-109
exc. & backfill for perJgutter	Clab	80	lf		0.00	0.937	$0.00	0.020	1.6	1.111	laborer	20.35	$36.17	shovel	0.00	$0.00	$36.17	M-022-258/est.
lay perJgutter drain pipe	B-20	80	lf	4" diam. PVC	0.75	0.937	$56.22	0.040	3.2	1.111	laborer	21.50	$76.44		0.00	$0.00	$132.66	M-027-168-2000/est
install fill	B-37	638	sf	12" deep, compacted	0.35	0.937	$209.23	0.008	5.1	1.111	see B-37	21.84	$123.84	roller	3.10	$17.58	$350.66	M-022-262-0800
install moist. barrier/ins	Carp	800	sf	6 mil poly	0.04	0.937	$29.98	0.002	1.6	1.111	carpenter	27.50	$48.88		0.00	$0.00	$78.87	M-071-922-0901
																Subtotal	$1,899	
INSTALL FLOOR PANELS																		
unload and store panels	DM2	1	time		0.00	1.000	$0.00	1.667	1.7	1.163	laborer, oper.	23.60	$45.75	forklift	10.98	$21.29	$67.04	DF-13
lay panels	F-2*	720	sf	panel cost below	0.00	1.000	$0.00	0.005	3.6	1.163	carp. & helper	24.27	$101.61		0.00	$0.00	$101.61	M-072-203-2420/est
floor panels		720	sf	comp. 5" EPS, 7/16" OSE	1.20	1.000	$864.00	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$864.00	M-072-203-2110/est
panel transportation costs (5)		0.33	ship.	assume local distrib.	600.00	1.000	$200.00	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$200.00	cost survey
install top subfloor	F-2*	720	sf	7/16" x 8 x 24' OSB	0.45	0.936	$303.26	0.008	5.9	1.163	carp. & helper	24.27	$167.66	power tools	1.27	$8.77	$479.70	M-061-168/est.
wing insulation	F-2*	240	sf	2-1/2" EPS	1.45	0.936	$325.73	0.013	3.1	1.163	laborer	20.35	$73.84	power tools	1.27	$4.61	$404.18	est.
install flashing/prot/chase	Clab	112	lf	Insul-Guard assy		0.936	$323.25		6.0	1.163	laborer	20.35	$142.00	power tools	1.27	$8.86	$474.11	est
nails / staples		1	ea.		50.00	0.936	$46.80	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$46.80	est.
																Subtotal	$2,637	
INSTALL TIE DOWNS																		
install tie downs		4	ties	6" x 24" steel auger	15.00	0.936	$56.16	0.50	2	1.163	laborer	20.35	$47.33		0.00	$0.00	$103.49	est
CARRYING COSTS																		
Construction Loan Interest (9)		3.3	days	9.5% on $12,500	3.25												$10.58	
Insurance Expenses (10)		3.3	days	bldr risk & liability	3.30												$10.74	
Field Expenses (11)		3.3	days	toilet, site rentals	3.50												$11.39	
																Subtotal	$33	
TOTALS							$3,153		52.1				$1,294			$193	$4,673	

Table 4-3
On-grade Floor with
No Trench Footing
Prefabricated Footer
(Figure 3-6)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q		
Component	S. C.	Material Quantity	Unit	Material Type	Cost per un. ($/un.)	Mat. L.M.	Material Cost [CxFxG]	Man-Hours per unit	Base Labor Hours [CxI]	Inst. L.M.	Labor Type	Labor Rate ($/hr)	Labor Cost (1) [JxKxM]	Equipment Type	Equip. Rate ($/hr)	Equipment Cost [JxKxP]	Total Cost	Cost Source (2)
SITE WORK																		
clearing (brush w/ br. saw)	A-1	0.44	acre		0.00	0.937	$0.00	32.000	14.1	1.111	laborer	20.35	$318.33	power tool	8.03	$125.61	$443.94	M-021-108-0010
trench for footing	B11C	6.2	cy	112' trench 18" x 12"	0.00	0.937	$0.00	0.107	0.7	1.111	Clab	23.60	$17.46	backhoe	13.72	$10.15	$27.60	M-022-254-0050
install 6" gravel footer fill	B-37	168	sf	compact under floor slab	0.15	0.937	$23.61	0.006	1.0	1.111	see B-37	21.84	$24.46	roller	3.10	$3.47	$51.54	M-022-262-0600
build footer beam (LVL & 2x6)		112	lf	1-3/4" x 7-1/4" PT LVL	3.08	0.937	$323.23										$323.23	note 12
lay foam grade beam assy	Clab	146	sf	3" high density EPS	0.78	0.937	$106.71	0.020	2.9	1.111	Carp/lab	24.27	$78.73	power tool	1.27	$4.12	$189.56	note 12
install grade beam assy	Clab	112	lf	assy				0.016	1.8	1.111	Carp/lab	24.27	$48.54	power tool	1.27	$2.54	$51.07	note 12
perimeter insulation	Carp	112	lf	5" EPS (M-072-203-2130	0.62	1.109	$77.01	0.012	1.3	1.054	laborer	27.50	$38.96		0.00	$0.00	$115.96	M-072-109
exc. & backfill for per./gutter	Clab	80	lf		0.00	0.937	$0.00	0.020	1.6	1.111	laborer	20.35	$36.17	shovel	0.00	$0.00	$36.17	M-022-258
lay per./gutter drain pipe	B-20	80	lf	4" diam. PVC	0.75	0.937	$56.22	0.040	3.2	1.111	laborer	21.50	$76.44		0.00	$0.00	$132.66	M-027-168-2000/est
install fill	B-37	638	sf	6" deep, compacted	0.15	0.937	$89.67	0.006	3.8	1.111	see B-37	21.84	$92.88	roller	3.10	$13.18	$195.74	M-022-262-0600
install moist. barrier/ins	Carp	800	sf	6 mil poly	0.04	0.937	$29.98	0.002	1.6	1.111	carpenter	27.50	$48.88		0.00	$0.00	$78.87	M-071-922-0901
																Subtotal	$1,646	
INSTALL FLOOR PANELS																		
unload and store panels	DM2*	1	time		0.00	1.000	$0.00	1.667	1.7	1.163	laborer, oper.	23.60	$45.75	forklift	10.98	$21.29	$67.04	DF-13
lay panels	F-2*	720	sf	panel cost below	0.00	1.000	$0.00	0.005	3.6	1.163	carp. & helper	24.27	$101.61		0.00	$0.00	$101.61	M-072-203-2420/est
floor panels		720	sf	comp. 5" EPS, 7/16" OSE	1.20	1.000	$864.00	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$864.00	M-072-203-2110
panel transportation costs (5)		0.33	ship.	assume local distrib.	600.00	1.000	$200.00	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$200.00	est.
install top subfloor	F-2*	720	sf	7/16" x 8 x 24' OSB	0.45	0.936	$303.26	0.008	5.9	1.163	carp. & helper	24.27	$167.66	power tools	1.27	$8.77	$479.70	est.
install flashing/prot/chase	Clab	112	lf	Insul-Guard assy		0.936	$323.25		6.0	1.163	laborer	20.35	$142.00	power tools	1.27	$8.86	$474.11	est
nails / staples		1	ea.		50.00	0.936	$46.80	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$46.80	est.
																Subtotal	$2,233	
INSTALL TIE DOWNS																		
install tie downs		4	ties	6" x 24" steel auger	15.00	0.936	$56.16	0.50	2	1.163	laborer	20.35	$47.33		0.00	$0.00	$103.49	est
CARRYING COSTS																		
Construction Loan Interest (9)		3.2	days	9.5% on $12,500	3.25												$10.41	
Insurance Expenses (10)		3.2	days	bldr risk & liability	3.30												$10.57	
Field Expenses (11)		3.2	days	toilet, site rentals	3.50												$11.21	
																Subtotal	$32	
TOTALS							$2,500		51.3				$1,285			$198	$4,015	

Table 4-4
On-grade Floor with
Trenched Footing
Foam Footer
(Figure 3-7)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q		
Component	S. C.	Material Quantity	Unit	Material Type	Cost per un. ($/un.)	Mat. L.M.	Material Cost (CxFxG)	Man-Hours per unit	Base Labor Hours (Cx1)	Inst. L.M.	Labor Type	Labor Rate ($/hr)	Labor Cost (1) (JxKxM)	Equipment Type	Equip. Rate ($/hr)	Equipment Cost (JxKxP)	Total Cost	Cost Source (2)
SITE WORK																		
clearing (brush w/ br. saw)	A-1	0.44	acre		0.00	0.937	$0.00	32.000	14.1	1.111	laborer	20.35	$318.33	power tool	8.03	$125.61	$443.94	M-021-108-0010
trench for footing	B11C	8.3	cy	112' trench 24" x 12"	0.00	0.937	$0.00	0.107	0.9	1.111	operator	23.60	$23.28	backhoe	13.72	$13.53	$36.81	M-022-254-0050
deliver/spread gravel fill	B-37	12.3	cy	6" bank run gravel	7.50	0.937	$86.54	0.400	4.9	1.111	laborer	21.84	$119.52		3.10	$16.97	$223.03	M-022-262-1100
moisture control barrier	Carp	800	sf	6 mil polyethylene	0.04	1.109	$35.49	0.002	1.6	1.054	carpenter	27.50	$46.38		0.00	$0.00	$81.86	M-071-922-0901
slab insulation, R-20	Carp	832	sf	5" EPS, deck lab.	0.62	1.109	$572.07	0.007	5.8	1.054	carpenter	26.40	$162.06		0.00	$0.00	$734.12	M-072-203-2130
found. perimeter drain	B-20	140	lf	4" perf. PVC	0.75	0.937	$98.39	0.064	9.0	1.111	laborer	21.50	$214.02		0.00	$0.00	$312.41	est
fill for perimeter drain	Clab	3	cy	6" drain rock	7.50	0.937	$21.08	0.600	1.8	1.111	laborer	20.35	$40.70	shovel	0.00	$0.00	$61.78	M-022-258
lay gutter drain pipe	B-20	80	lf	4" PVC	0.75	0.937	$56.22	0.064	5.1	1.111	laborer	21.50	$122.30		0.00	$0.00	$178.52	est
																Subtotal	$2,072	
FORM WORK																		
install/strip forms	C-1	112	lf	24" wood forms/ 4 us	0.67	1.233	$92.52	0.060	6.7	1.145	carpenter	27.50	$211.60	power tool	8.03	$61.79	$365.91	M-033-126-0150
footing reinf.	Rodm	155	lb	#4 rebar	0.24	1.233	$45.74	0.008	1.2	1.145	carpenter	32.30	$45.73		0.00	$0.00	$91.47	M-032-107-0502
install remesh	Rodm	7.2	csf	6" x 6" welded wire	7.00	1.233	$62.14	0.457	3.3	1.145	2 rodm	32.30	$121.69		0.00	$0.00	$183.83	M-032-207-0011
																Subtotal	$641	
POUR CONCRETE																		
deliver concrete		9.5	cy	3000 psi	50.00	1.233	$585.68	0.000	0.0	1.145		0.00	$0.00		0.00	$0.00	$585.68	M-033-126-0150
pour concrete (direct chute)	C-6*	9.5	cy	direct chute	0.00	1.233	$0.00	0.436	4.1	1.145	laborer, fore.	21.79	$103.34	vibrator	1.55	$7.35	$110.69	M-033-172-4300
finish concrete	C-9	720	sf	steel trowel finish	0.00	1.233	$0.00	0.013	9.4	1.145	finisher	25.55	$273.82	fin. machine	5.31	$56.91	$330.73	M-033-454-0200
install anchor bolts	Carp	22	times	1/2" x 10" anchor bol	0.65	1.233	$17.63	0.094	2.1	1.145	carpenter	27.50	$65.12		1.55	$3.67	$86.42	M-031-110-0060
																Subtotal	$1,114	
MISCELLANEOUS																		
install treated sub-plate	Carp	112	lf	ripped 2 x 10 PT	1.76	0.937	$184.70	0.040	4.5	1.111	carpenter	27.50	$136.88	power tool	1.27	$6.32	$327.90	
wing insulation	Carp	224	sf	4" EPS	0.50	1.109	$124.21	0.007	1.6	1.054	carpenter	26.40	$43.63		0.00	$0.00	$167.84	M-072-203-2120
install prot. board/ chase	Carp	112	lf	Insul-Guard assy		0.937	$207.01		6	1.111	carpenter	27.50	$183.32	power tool	1.27	$8.47	$398.79	
																Subtotal	$894.53	
CARRYING COSTS																		
Construction Loan Interest (9)		5.1	days	9.5% on $12,500	3.25												$16.67	
Insurance Expenses (10)		5.1	days	bldr risk & liability	3.30												$16.93	
Field Expenses (11)		5.1	days	toilet, site rentals	3.50												$17.95	
																Subtotal	$52	
TOTALS							$2,189		82.1				$2,232			$301	$4,773	

Table 4-5
Insulated Concrete Slab Floor
(Figure 3-8)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q		
Component	S. C.	Material Quantity	Unit	Material Type	Cost per un. ($/un.)	Mat. L.M.	Material Cost [CxFxG]	Man-Hours per unit	Base Labor Hours [CxI]	Inst. L.M.	Labor Type	Labor Rate ($/hr)	Labor Cost (1) [JxKxM]	Equipment Type	Equip. Rate ($/hr)	Equipment Cost [JxKxP]	Total Cost	Cost Source (2)
SITE WORK																		
clearing (brush w/ br. saw)	A-1	0.44	acre		0.00	0.937	$0.00	32.000	14.1	1.111	laborer	20.35	$318.33	power tool	8.03	$125.61	$443.94	M-021-108-0010
auger (corner holes)	DM1[4]	4	holes	24" diam., 8' deep	0.00	0.937	$0.00	0.375	1.5	1.111	laborer 2, oper.	22.52	$37.53	auger	19.64	$32.73	$70.26	DF-1
auger	DM1[4]	4	holes	30" diam., 8' deep	0.00	0.937	$0.00	0.375	1.5	1.111	laborer 2, oper.	22.52	$37.53	auger	19.64	$32.73	$70.26	DF-1
auger (interior posts)	DM1[4]	8	holes	18" diam., 8' deep	0.00	0.937	$0.00	0.375	3.0	1.111	laborer 2, oper.	22.52	$75.06	auger	19.64	$65.46	$140.52	DF-1
move & align auger	DM1[4]	16	holes		0.00	0.937	$0.00	0.125	2.0	1.111	laborer 2, oper.	22.52	$50.04	auger	19.64	$43.64	$93.68	DF-2
clean & change drill	DM1[4]	3	times		0.00	0.937	$0.00	0.250	0.8	1.111	laborer 2, oper.	22.52	$18.76	auger	19.64	$16.37	$35.13	DF-3
spread augered dirt on site	B10B	10.3	cy		0.00	0.937	$0.00	0.008	0.1	1.111	operator	26.85	$2.46	dozer	112.70	$10.32	$12.78	M-022-262-0010
rough grade	B-15	6.67	cy	3" gravel fill	3.75	0.937	$23.43	0.047	0.3	1.111	laborer	23.46	$8.17	dozer, trucks	63.52	$22.11	$53.70	M-022-212-0100
excavate & backfill for gutter	Clab	84	lf		0.00	0.937	$0.00	0.020	1.7	1.111	laborer	20.35	$37.98	shovel	0.00	$0.00	$37.98	M-022-258
lay gutter drain pipe	B-20	84	lf	4" diam. PVC	0.75	0.936	$58.97	0.064	5.4	1.163	laborer	21.50	$134.42		0.00	$0.00	$193.39	M--027-168-2000
																Subtotal	$1,152	
TRESTLE CONSTRUCTION																		
posts		80	lf	4x6 P.T. DF-L (3)	3.12	0.936	$233.63	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$233.63	M-061-127-0210
upper cord		184	lf	2x6 P.T. DF-L	0.84	0.936	$144.67	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$144.67	M-061-122-4222
layout and nailing	F-2*	4	pcs.		0.00	0.936	$0.00	0.667	2.7	1.163	carp. & helper	24.27	$75.31	power tools	1.27	$3.94	$79.25	DF-4
bracing outer bays		54	lf	4x4 P.T. DF-L(3)	3.12	0.936	$157.70	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$157.70	M-061-127-0200
bracing inner bays		54	lf	2x4 P.T. DF-L4.5'	0.56	0.936	$28.30	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$28.30	M-061-122-4202
square & brace post to beam	F-2*	24	pcs.	6 braces in a trestle	0.00	0.936	$0.00	0.200	4.8	1.163	carp. & helper	24.27	$135.48	power tools	1.27	$7.09	$142.57	DF-5
lower cord (bracing spacer)		36	lf	2x4 P.T. DF-L 4'-9"	0.56	0.936	$18.87	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$18.87	M-061-122-4202
install lower cord	F-2*	12	pcs.	3 cords in a trestle	0.00	0.936	$0.00	0.200	2.4	1.163	carp. & helper	24.27	$67.74	power tools	1.27	$3.54	$71.29	DF-6
build railing to move trestles	F-2*	1	ea.		0.00	0.936	$0.00	4.000	4.0	1.163	carp. & helper	24.27	$112.90	power tools	1.27	$5.91	$118.81	DF-7
moving trestles	F-2*	4	pcs.		0.00	0.936	$0.00	0.667	2.7	1.163	carp. & helper	24.27	$75.31	power tools	1.27	$3.94	$79.25	DF-8
align trestles after install.	F-2*	1			0.00	0.936	$0.00	3.000	3.0	1.163	carp. & helper	24.27	$84.68	power tools	1.27	$4.43	$89.11	DF-9
																Subtotal	$1,163	
SET TRESTLE IN CONCRETE																		
mix concrete		9.5	cy	3000 psi	50.00	1.233	$585.68	0.000	0.0	1.145		0.00	$0.00		0.00	$0.00	$585.68	M-033-126-0150
pour concrete (direct chute)	C-6*	16	holes	direct chute	0.00	1.233	$0.00	0.133	2.1	1.145	laborer, fore.	21.79	$53.09	vibrator	1.55	$3.78	$56.87	DF-10
moving and aligning truck	C-6*	16	times		0.00	1.233	$0.00	0.133	2.1	1.145	laborer, fore.	21.79	$53.09	vibrator	1.55	$3.78	$56.87	DF-11
shape foundation tops	C-6*	16	times		0.00	1.233	$0.00	0.133	2.1	1.145	laborer, fore.	21.79	$53.09	vibrator	1.55	$3.78	$56.87	DF-12
moisture control barrier	Carp	800	sf	6 mil polyethylene	0.04	1.109	$35.49	0.002	1.6	1.054	carpenter	27.50	$46.38		0.00	$0.00	$81.86	M-071-922-0901
perimeter lattice skirt	F-2*	138	sf	18" ced. latt. & mesh	2.14	1.000	$295.32	0.100	15.0	1.163	carp. & helper	24.27	$423.39	power tool	1.27	$22.16	$740.87	actual cost
																Subtotal	$1,579	
LAYOUT FLOOR PANELS																		
unload and store panels	DM2[4]	1	time		0.00	1.000	$0.00	1.667	1.7	1.163	laborer, oper.	23.60	$45.75	forklift	10.98	$21.29	$67.04	DF-13
glue & screw panels to trestle	F-2*	9	panels	panel cost below	0.00	1.000	$0.00	0.333	3.0	1.163	carp. & helper	24.27	$84.59	power tools	1.27	$4.43	$89.02	DF-14
put spline on panel	F-2*	320	lf	4" wide OSB strips	0.09	1.000	$29.87	0.008	2.7	1.163	carp. & helper	24.27	$74.97	power tools	1.27	$3.92	$108.76	DF-15

Table 4-6
Demonstration House Foundation/Floor
(Figure 3-9)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q		
Component	S. C.	Material Quantity	Unit	Material Type	Cost per un. ($/un.)	Mat. L.M.	Material Cost [CxFxG]	Man-Hours per unit	Base Labor Hours [CxI]	Inst. L.M.	Labor Type	Labor Rate ($/hr)	Labor Cost (1) [JxKxM]	Equipment Type	Equip. Rate ($/hr)	Equipment Cost [JxKxP]	Total Cost	Cost Source (2)
glue panel to panel joint	F-2*	400	lf	tube adhesive (UCP)	0.07	1.000	$28.00	0.003	1.2	1.163	carp. & helper	24.27	$33.87	power tools	1.27	$1.77	$63.64	DF-16
caulk panel to panel joint	F-2*	160	lf	acrylic latex clk	0.14	1.109	$24.84	0.003	0.5	1.163	carp. & helper	24.27	$13.55	power tools	1.27	$0.71	$39.10	DF-17
floor panels		9	panels	4' x 20' @ $2.65/sf	212.00	1.000	$1908.00	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$1908.00	cost survey
panel transportation costs (5)		0.33	ship.	assume local distrib.	600.00	1.000	$200.00	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$200.00	cost survey
align the floor & trim extra	F-2*	1	time		0.00	1.000	$0.00	1.500	1.5	1.163	carp. & helper	24.27	$42.34	power tools	1.27	$2.22	$44.55	DF-18
blocking at end of panels	F-2*	112	lf	2x6	0.55	0.936	$57.66	0.013	1.5	1.163	carp. & helper	24.27	$41.10	power tools	1.27	$2.15	$100.91	DF-19
rim joist	F-2*	112	lf	2x8	0.85	0.936	$89.11	0.013	1.5	1.163	carp. & helper	24.27	$41.10	power tools	1.27	$2.15	$132.35	DF-20
nails / staples		1	ea.		38.56	0.936	$36.09	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$36.09	R. Wilson est.
underlayment	F-2	736	sf	3/8" particle board	0.27	0.936	$186.00	0.011	8.1	1.163	carp. & helper	24.27	$228.52	power tools	1.27	$11.96	$426.48	M-061-168-0502
																Subtotal	$3,216	
CARRYING COSTS																		
Construction Loan Interest (9)		9.5	days	9.5% on $12,500	3.25												$30.88	
Insurance Expenses (10)		9.5	days	bldr risk & liability	3.30												$31.35	
Field Expenses (11)		9.5	days	toilet, site rentals	3.50												$33.25	
																Subtotal	$95	
TOTALS							$4,142		94.3				$2,507			$462	$7,206	

Table 4-6
Demonstration House Foundation/Floor
(Figure 3-9)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q		
Component	S.C.	Material Quantity	Unit	Material Type	Cost per un. ($/un.)	Mat. L.M.	Material Cost [CxFxG]	Man-Hours per unit	Base Labor Hours [CxI]	Inst. L.M.	Labor Type	Labor Rate ($/hr)	Labor Cost (1) [JxKxM]	Equipment Type	Equip. Rate ($/hr)	Equipment Cost [JxKxP]	Total Cost	Cost Source (2)
SITE WORK																		
clearing (brush w/br. saw)	A-1	0.44	acre		0	0.937	$0.00	32.000	14.1	1.111	laborer	20.35	$318.33	power tool	8.03	$125.61	$443.94	M-021-108-0010
excavate for crawl space	B11M	36	cy	22' x 38', 2-14" deep	0	0.937	$0.00	0.080	2.9	1.111	operator, laborer	23.60	$75.51	backhoe	18.81	$60.19	$135.70	M-022-238-0200
rough grade	Clab	6.7	cy	3" grav. fill, by hand	3.75	0.937	$23.43	0.667	4.4	1.111	laborer	20.35	$100.53		0.00	$0.00	$123.96	M-022-262-0100
fill at perimeter drain pipe	Clab	2.8	cy	gravel fill (022-212)	3.75	0.937	$9.72	0.667	1.8	1.111	laborer	20.35	$41.72		0.00	$0.00	$51.45	M-022-262-0100
site fill to raise grade (12)	B10B	36	cy		0	0.937	$0.00	0.008	0.3	1.111	operator	26.85	$8.59	dozer	112.70	$36.06	$44.65	M-022-262-0010
found. perimeter drain pipe	B-20	140	lf	4" perforated PVC	0.75	0.936	$98.28	0.064	9.0	1.163	laborer 2, fore.	21.50	$224.04		0.00	$0.00	$322.32	M-027-168-2000
lay gutter drain pipe	B-20	84	lf	4" diam. PVC	0.75	0.936	$58.97	0.064	5.4	1.163	laborer 2, fore.	21.50	$134.42		0.00	$0.00	$193.39	M-027-168-2000
																Subtotal	$1,315	
FOUNDATION																		
footing reinforcement	Rodm	450	lb	#4 rebar	0.24	1.233	$133.16	0.008	3.6	1.145	rodmen	32.30	$133.14		0.00	$0.00	$266.30	M-032-107-0502
dowels	Rodm	24	ea	2' lg 3/8" rebar	0.85	1.233	$25.15	0.114	2.7	1.145	rodmen	32.30	$101.19		0.00	$0.00	$126.34	M-032-107-2400
wall formwork	C-1	392	sfca	four use	0.38	0.936	$139.43	0.066	25.9	1.163	carp 2,help,lab	24.10	$725.15	power tools	0.95	$28.58	$893.16	M-031-158-0150
concrete mix and pour	C-6	8.5	cy	3000 psi, direct chut	50	1.233	$524.03	0.400	3.4	1.145	fore, lab 4,finish	21.79	$84.83	vibrator	1.55	$6.03	$614.89	& 033-172-1900
anchor bolts	Carp	24	ea	1' lg 1/2" diam.	0.75	1.233	$22.19	0.094	2.3	1.145	carpenter	27.50	$71.04		0.00	$0.00	$93.23	M-031-110-0100
sill plate	F-2	112	lf	2x6 P.T.	0.84	0.936	$88.06	0.032	3.6	1.163	carpenter	24.27	$101.16	power tool	1.27	$5.29	$194.51	M-061-122-4222
moisture control barrier	Carp	800	sf	6 mil polyethylene	0.04	1.109	$35.49	0.002	1.6	1.054	carpenter	27.50	$46.38		0.00	$0.00	$81.86	M-071-922-0901
foundation vents	Bric	8	ea	8"x16" galvanized	13.1	1.109	$116.22	0.267	2.1	1.054	laborer	27.95	$62.93		0.00	$0.00	$179.15	M-041-524-1200
sill sealer	Bric	112	lf	5 1/2" polyethylene	0.16	1.109	$19.87	0.016	1.8	1.054	laborer	27.95	$52.79		0.00	$0.00	$72.66	Jerry's (041-508)
																Subtotal	$2,522	
INTERMEDIATE POSTS AND GIRDER																		
concrete-footings & base	C-6	1.5	cy	3000 psi, direct chut	50	1.233	$92.48	0.873	1.3	1.145	fore, lab 4,finish	21.79	$32.67	vibrator	1.55	$2.32	$127.47	M-033-172-2400
formwork for base	C-1	17.5	sfca	21" x 21" x 6"	0.38	0.936	$6.22	0.066	1.2	1.163	carp 2,help,lab	24.10	$32.37	power tools	0.95	$1.28	$39.87	M-031-158-0150
wood posts	F-2	7.5	lf	4x4 P.T. DF-L (3)	3.12	0.936	$21.90	0.041	0.3	1.163	carp. & helper	24.27	$8.68	power tools	1.27	$0.45	$31.04	M-061-118-0101
girder	F-2(4	36	lf	4x8 P.T. DF-L (3)	3.12	0.936	$105.13	0.040	1.4	1.163	carp. & helper	24.27	$40.65	power tools	1.27	$2.13	$147.90	M-061-110-1182
bearing blocks in found. wall	F-2	2	lf	2x4 PT	0.56	0.936	$1.05	0.027	0.1	1.163	carp. & helper	24.27	$1.52	power tools	1.27	$0.08	$2.65	M-061-122-4002
																Subtotal	$349	
FLOOR FRAMING																		
joists (main floor only)	F-2	380	lf	2x10 joists, 24" o.c.	1.25	0.936	$444.60	0.018	6.8	1.163	carp. & helper	24.27	$193.07	power tools	1.27	$10.10	$647.77	M-061-114-2202
blocking	F-1	36	lf	2x10 at center span	1.14	0.936	$38.41	0.040	1.4	1.163	carpenter	27.50	$46.05	power tools	1.27	$2.13	$86.60	M-061-102-2150
rim joists	F-2	112	lf	2x10	1.25	0.936	$131.04	0.018	2.0	1.163	carp. & helper	24.27	$56.90	power tools	1.27	$2.98	$190.92	M-061-114-2202
subfloor	F-2	736	sf	3/4" plywood CDX	0.56	0.936	$385.78	0.013	9.6	1.163	carp. & helper	24.27	$270.07	power tools	1.27	$14.13	$669.98	M-061-164-0202
underlayment	F-2	736	sf	3/8" particle board	0.27	0.936	$186.00	0.011	8.1	1.163	carp. & helper	24.27	$228.52	power tools	1.27	$11.96	$426.48	M-061-168-0502
floor rim spacer for siding	Carp	112	sf	5/8" plywood CDX	0.43	0.936	$45.08	0.015	1.7	1.163	carpenter	27.50	$53.73		0.00	$0.00	$98.81	M-061-154-0702
insulation	Carp	706	sf	R30, 8 1/2" batt	0.54	1.109	$422.80	0.015	10.6	1.054	carpenter	27.50	$306.95		0.00	$0.00	$729.75	M-072-106-2200
air sealing at framing	Carp	224	lf	acrylic latex caulk	0.14	1.109	$34.78	0.035	7.8	1.054	carpenter	27.50	$227.24		0.00	$0.00	$262.02	M-079-204-2200
nails		1	ea.		38.53	0.936	$36.06	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$36.06	R. Wilson est.
																Subtotal	$3,148	

Table 4-7
Reference House Foundation/Floor
(Figure 3-10)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q		
Component	S. C.	Material Quantity	Unit	Material Type	Cost per un. ($/un.)	Mat. L.M.	Material Cost [CxFxG]	Man-Hours per unit	Base Labor Hours [CxI]	Inst. L.M.	Labor Type	Labor Rate ($/hr)	Labor Cost (1) [JxKxM]	Equipment Type	Equip. Rate ($/hr)	Equipment Cost [JxKxP]	Total Cost	Cost Source (2)
CARRYING COSTS																		
Construction Loan Interest (9)		13.0	days	9.5% on $12,500	3.25												$42.25	
Insurance Expenses (10)		13.0	days	bider risk & liability	3.30												$42.90	
Field Expenses (11)		13.0	days	toilet, site rentals	3.50												$45.50	
																Subtotal	$131	
TOTALS							$3,245		137.2				$3,780			$309	$7,465	

Table 4-7
Reference House Foundation/Floor
(Figure 3-10)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q		
Component	S. C.	Material Quantity	Unit	Material Type	Cost per un. ($/un.)	Mat. L.M.	Material Cost [CxFxG]	Man-Hours per unit	Base Labor Hours [CxI]	Inst. L.M.	Labor Type	Labor Rate ($/hr)	Labor Cost (1) [JxKxM]	Equipment Type	Equip. Rate ($/hr)	Equipment Cost [JxKxP]	Total Cost	Cost Source (2)
SITE WORK																		
clearing (brush w/ br. saw)	A-1	0.44	acre		0.00	0.937	$0.00	32.000	14.1	1.111	laborer	20.35	$318.33	power tool	8.03	$125.61	$443.94	M-021-108-0010
trench for footing	B-11(	3.1	cy		0.00	0.937	$0.00	0.107	0.3	1.111	operator,labore	23.60	$8.73	backhoe	13.72	$5.07	$13.80	M-022-254-0050
install 6" gravel footer fill	B-37	168	sf	compact under floor sla	0.15	0.937	$23.61	0.006	1.0	1.111	see B-37	21.84	$24.46	roller	3.10	$3.47	$51.54	M-022-262-0600
build footer beam	Clab	112	lf	1-3/4" x 7-1/4" pt assy	3.64	0.937	$382.00	0.020	2.2	1.111	Carp/lab	24.27	$60.40	power tool	1.27	$3.16	$445.56	note 12
install grade beam assy	clab	112	lf	assy+stakes	0.00	0.937	$0.00	0.016	1.8	1.111	Carp/lab	24.27	$48.32	power tool	1.27	$2.53	$50.85	note 12
install moist. barrier/ins	Clab	1520	sf	reflective bubble film	0.60	0.937	$854.54	0.002	3.0	1.111	laborer	20.35	$68.73		0.00	$0.00	$923.27	M-071-922-0901
exc. & backfill for per./gutter	Clab	120	lf		0.00	0.937	$0.00	0.020	2.4	1.111	laborer	20.35	$54.26	shovel	0.00	$0.00	$54.26	M-022-258
lay per./gutter drain pipe	Clab	168	lf	4" diam. PVC	0.75	0.936	$117.94	0.040	6.7	1.163	laborer	20.35	$159.04		0.00	$0.00	$276.98	M-027-168-2000/est
install bearer	1 carp	112	lf	2 x 4 PT	0.56	0.937	$58.77	0.015	1.7	1.111	carpenter	27.50	$51.33		0.00	$0.00	$110.10	est
bubble insulating film	Clab	336	sf	reflective, 2 layers	0.29	0.937	$91.30	0.005	1.7	1.111	carpenter	27.50	$51.33		0.00	$0.00	$142.63	PEC Prod./est.
install mortar pads	Clab	1	cy	quick set mortar	75.00	0.937	$47.08	3.014	2.0	1.111	carpenter	27.50	$61.70	shovel	0.00	$0.00	$108.78	est
install paver blocks		32	blocks	2" x 12" x 12" pavers	0.79	0.937	$23.69						$0.00			$0.00	$23.69	Jerry's bldg matls
																Subtotal	$2,645	
INSTALL FLOOR PANELS																		
unload and store panels	DM21	1	time		0.00	1.000	$0.00	1.667	1.7	1.163	laborer, oper.	23.60	$45.75	forklift	10.98	$21.29	$67.04	DF-13
lay panels	F-2*	9	panels	panel cost below	0.00	1.000	$0.00	0.250	2.3	1.163	carp. & helper	24.27	$63.51		0.00	$0.00	$63.51	DF-14
2 sided floor panels		720	sf	4' x 20' @ $3.55/sf	3.55	1.000	$2556.00	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$2556.00	cost survey/est
panel transportation costs (5)		0.33	ship.	assume local distrib.	600.00	1.000	$200.00	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$200.00	cost survey
install top subfloor	F-2*	270	sf	7/16" x 8 x 24' OSB	0.45	0.936	$113.72	0.013	3.5	1.163	carp. & helper	24.27	$99.07	power tools	1.27	$5.18	$217.93	est.
install ext. ins.	F-2*	240	sf	2-1/2" EPS	1.45	0.936	$325.73	0.013	3.1	1.163	laborer	20.35	$73.84	power tools	1.27	$4.61	$404.18	est.
install flashing/prot/chase	Clab	112	lf	Insul-Guard assy		0.936	$323.25		6.0	1.163	laborer	20.35	$142.00	power tools	1.27	$8.86	$474.11	est
nails / staples		1	ea.		50.00	0.936	$46.80	0.000	0.0	1.163		0.00	$0.00		0.00	$0.00	$46.80	est.
																Subtotal	$4,030	
INSTALL TIE DOWNS																		
install tie downs		4	ties	6" x 24" steel auger	15.00	0.936	$56.16	0.50	2	1.163	laborer	20.35	$47.33		0	$0.00	$103.49	est
CARRYING COSTS																		
Construction Loan Interest (9)		3.5	days	9.5% on $12,500	3.25												$11.28	
Insurance Expenses (10)		3.5	days	bldr risk & liability	3.30												$11.45	
Field Expenses (11)		3.5	days	toilet, site rentals	3.50												$12.15	
																Subtotal	$35	
TOTALS							$5,221		55.5				$1,378			$180	$6,813	

Table 4-8
Plenum Floor
(Figure 3-12)

5.0 ENERGY PERFORMANCE

To determine design F values for the on-grade panel systems, the heat flow Q of the Demonstration House floor is taken as the performance baseline; as a simple approximation the product UA for its insulated panel floor (UA= 23.1, R= 2.2, Brown and Laroque 1995) is set equal to the perimeter heat loss FP for a slab floor, where

Q = UA for the Demonstration House floor
Q = FP for slab floors
F = heat loss per foot of on-grade floor perimeter
P = length of perimeter in feet (taken as 114 ft. for the on-grade configured for the Demonstration House),and
A = area of floor
U = coefficient of heat transmission

Solving for F,

$$F = UA/P = 23.1/114 = .203$$

F values were not available from existing data below F = 0.3. In order to approximate the insulation levels required to achieve F = .203 we extrapolated from fully insulated slab data (Wattsun, 1991). Figure 5-1 shows the line developed to extrapolate from the F values listed in the Wattsun manual for slabs fully insulated with R = 5, R = 10 and R = 15. Using the line (Figure 5-1) and extrapolating to R = 20 gives an F value of 0.21:

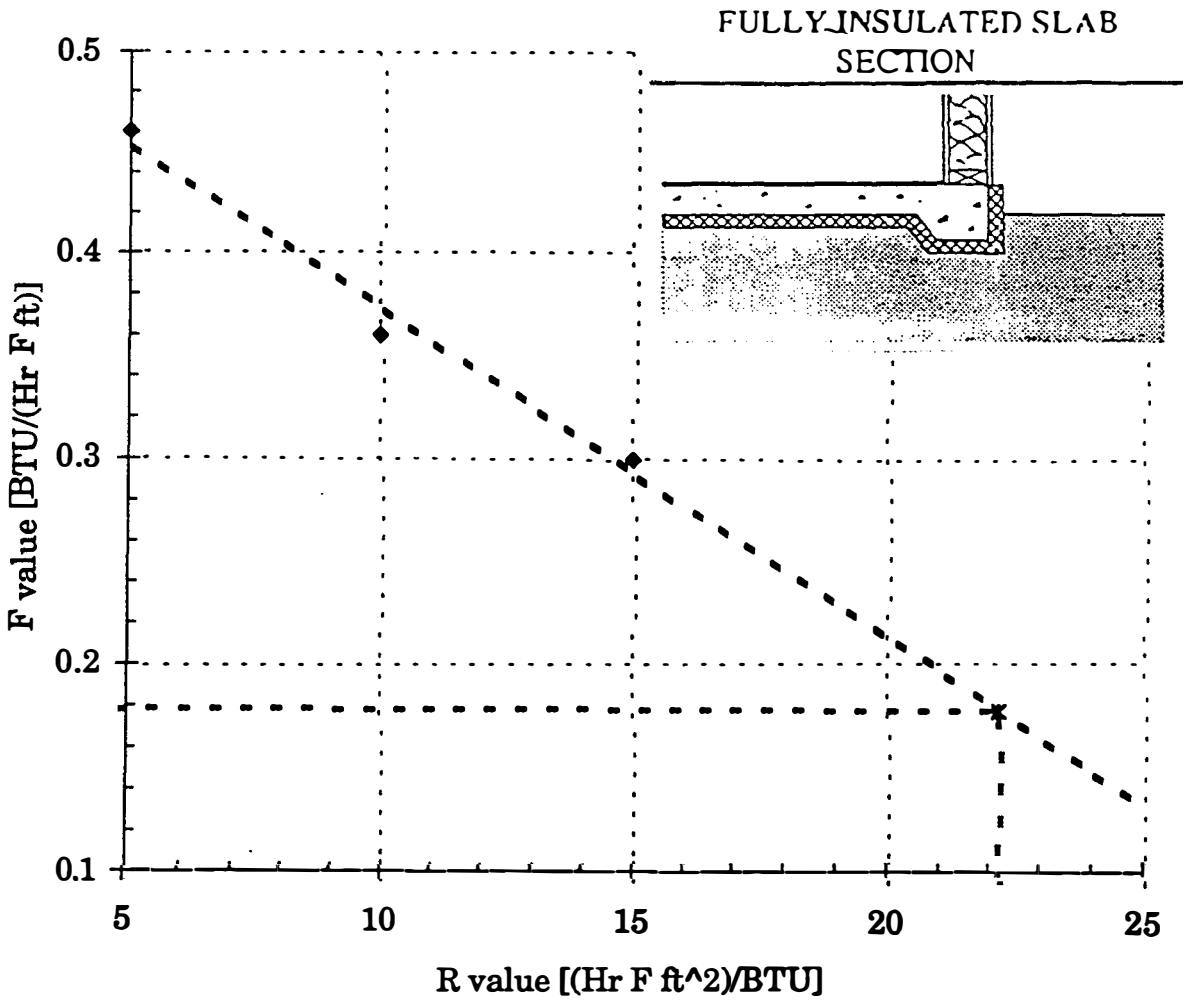

Figure 5-1
Extrapolated F Value for R-22.2 On-grade Floor

A further correction coefficient was employed to account for the effect of adding "wing" insulation to the fully insulated slab F values described in the Wattsun manual. Given the importance of edge effects on slab performance, this coefficient was assumed to be the ratio of the perimeter length of the wing insulation and the slab perimeter length, or 0.88. Multiplying F by 0.88 gives a corrected F of 0.187.

The theoretical heat loss for each of the basic floor systems compared is given below — for Demonstration and Reference Houses, the heat loss equals UA; for the slab systems it equals FP. In this projection only the Reference House employs traditional frame construction. All others are assumed to use SSIC panel envelope construction. Heat losses in table have been revised to include

framing effects.

System	R	UA	F_2	Perimeter		Heat Loss(Btu/Hr°F)	Floor	
Demonstration House	24	23.1				23.1		
Reference House	30.9	21.6				21.6		
On-grade with "wing"			22.2	.187	0.261	112		21.3
Concrete Slab`	20		0.261	112			24.3	

6.0 TESTING

A detailed testing program is being developed and will be described in a subsequent document. The testing program at this juncture is primarily intended to further develop the on grade floor/foundation system design – not to evaluate its performance as a finished design being proposed for adoption by the construction industry. In general the testing program will include an assessment of constructability (ease of construction), cost, structural performance, thermal performance, and durability.

The constructability testing of the system will address such issues as task sequence, materials staging, equipment needs, crew size and skill level. Structural performance testing will address resistance to uplift, long term creep, and deformation from loading. Thermal testing will evaluate heat flow through the floor edge and the interior of the floor with the goal of understanding its heat loss characteristics and their effect on house heat loads, floor temperature and freezing at the floor perimeter. Durability tests will assess moisture levels in the floor/foundation to determine the potential for rot and mildew. These tests will also evaluate the potential for freezing below the perimeter foundation. The time to construct the various components will be measured to determine the labor requirements for non conventional construction practices. These test results will be used to redesign the floor/foundation system and develop a final design.

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