ON-GRADE PANEL FLOOR SYSTEM
REPORT #2

ENERGY EFFICIENT INDUSTRIALIZED HOUSING
RESEARCH PROGRAM

ENERGY STUDIES IN BUILDINGS LABORATORY
CENTER FOR HOUSING INNOVATION
DEPARTMENT OF ARCHITECTURE
UNIVERSITY OF OREGON
EUGENE, OREGON 97403

U.S. Department of Energy
Contract No.DE-FC51-94R020277

September 1997

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FIGURES

1.0 EXECUTIVE SUMMARY

The on-grade insulated panel floor system is a combination floor/foundation system that uses one-sided structural insulated panels (SIPs). (See figure 2-1.) These panels normally consist of a foam insulating layer sandwiched between two layers of OSB (Oriented Strand Board). The purpose of the floor is to maximize energy performance while reducing cost and installation time. The flexible nature of the material will also improve the comfort of the floor compared to a concrete slab floor. In addition, utilizing panel and engineered wood components will increase the recyclability of the floor.

This report describes the testing phases of the floor research. In the first phase of testing, a floor was built to determine constructability, construction time, cost, and performance. In the second phase, field and laboratory tests are being conducted to determine the floor's structural capacity. The final phase entails constructing a second test floor that will be monitored for thermal and moisture performance.

The estimated total cost for the on-grade panel floor using 2 1/2"- 2 pcf foam panels is $3,952 including materials. This cost represents an $895 savings over a slab-on-grade foundation ($4,847), the least expensive floor and foundation system currently available. An even lower cost, $3,628, can be achieved using 1 1/2"- 1 pcf foam.

In field structural testing the floor behaved well and met or exceeded standards for concrete slab levelness and flatness and wood floor system deflection criteria. There was bounce apparent when jumping on the floor, but it was not noticed under normal walking conditions.

One problem discovered was the incompatibility of the the expanded polystyrene insulation and oil-borne solvent treated laminated veneer lumber (LVL) used for the perimeter beams. The best alternative to prevent the deformation of the polystyrene foam appears to be the use of Parallam for the floors. LVL could be used on the East Coast where it is available treated with CCA (a water-based solvent), but only for one-story applications. However, the cost and weight advantages of LVL over Parallam are not significant, so it would be simpler to use

Parallam for all applications throughout the country.

In January 1997, the floor was dismantled. The dismantling took approximately eight hours for an unskilled three-person crew. The process was extended due to difficulty locating screws in the upper OSB layer, additional screws remaining from the testing program, an inadequate number of power drills, and frozen ground covering the perimeter beam assembly. It is estimated that the floor could be dismantled in under four hours using an experienced crew and additional power tools.

Laboratory structural testing will include creep tests and structural load tests. The structural testing of the wall panel and floor assembly will be conducted this summer and fall. Figure 8-2 shows the number of tests required, with the critical set shown in the first column.

The thermal testing of the on-grade panel floor system will determine the temperature and moisture distribution in the floor system, which will provide a basis for verifying the thermal and moisture performance of the floor. The insulation capacity of the floor will also be measured, which will allow comparison with other floor systems. The second test floor is currently being constructed on Pine Mountain (elevation 6250') in Oregon and will be tested over the winter.

2.0 INTRODUCTION

The "on-grade insulated panel floor" is a combination floor/foundation system that uses one-sided structural insulated panels (SIPs). Normal panel construction consists of a foam layer sandwiched between two layers of OSB (Oriented Strand Board). The purpose of the floor is to maximize energy performance while reducing cost and installation time. The flexible nature of the material will also improve the comfort of the floor compared to a concrete slab floor. In addition, utilizing panel and engineered wood components will increase the recyclability of the floor. For a more detailed description of the design process, refer to the previous report "On-Grade Insulated Panel Floor System Preliminary Report."

Design

Figure 2-1 shows the current design for the on-grade insulated panel floor system.

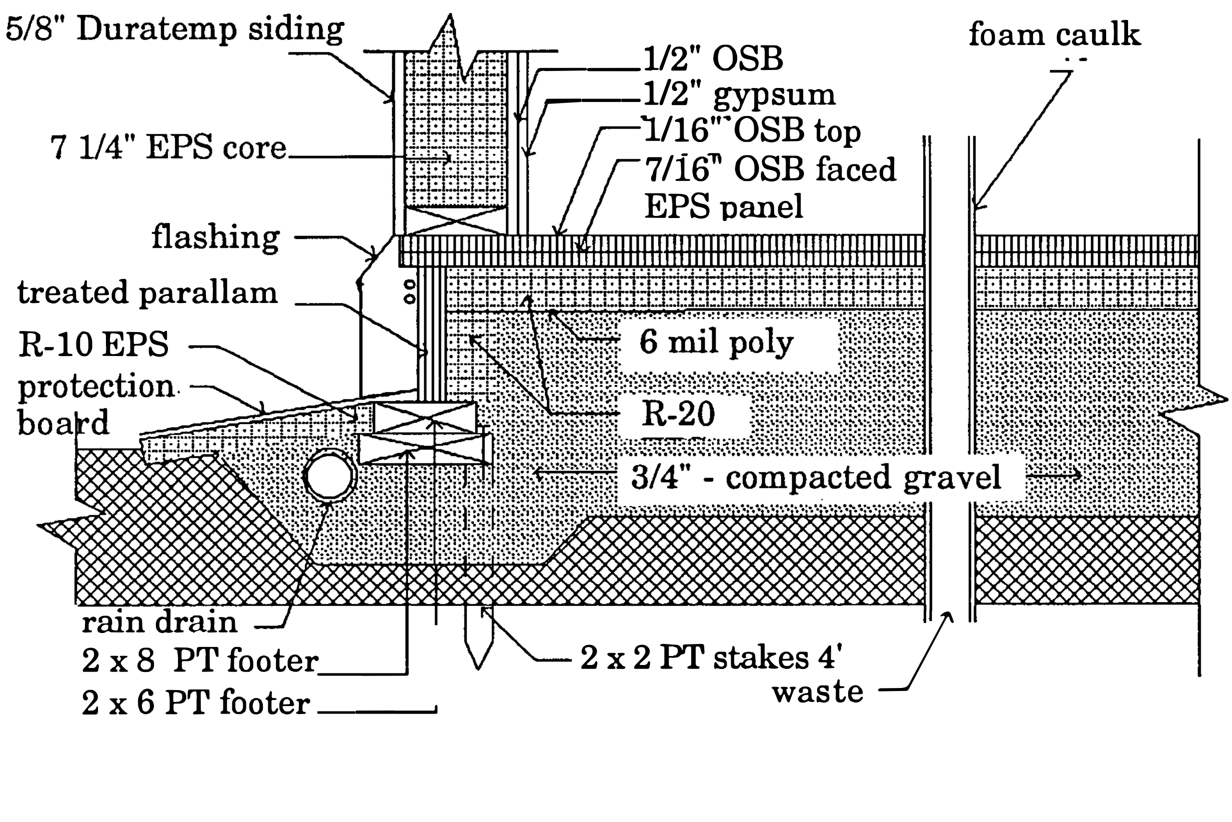

Figure 2-1, Floor Section Showing Footer Assembly

3.0 CONSTRUCTION

The on-grade panel floor design was modified for the test floor to simplify the construction and testing processes. Figures 3-1 and 3-2 show the panel layout, the upper OSB layer, and an as-built section of the floor.

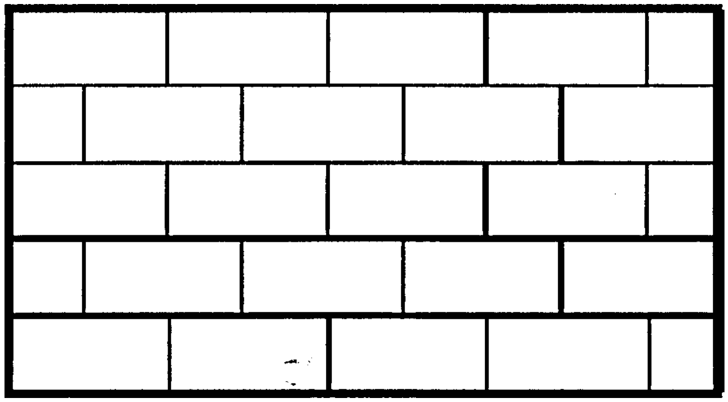

Figure 3-1, Panel Layout

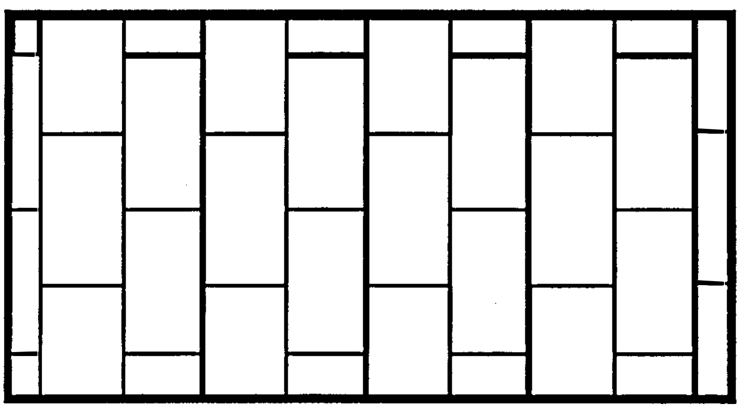

Figure 3-2, Upper Layer of Oriented-Strand Board (OSB)

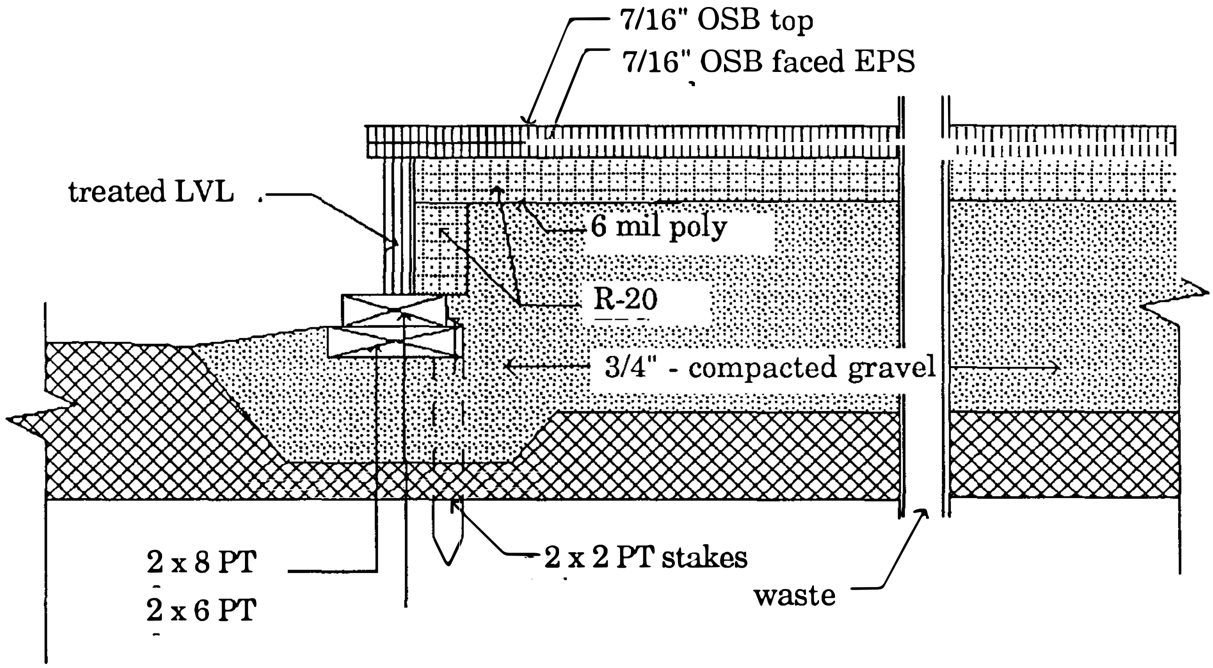

Figure 3-3, Floor Section as Tested

In August 1996 the on-grade insulated panel test floor was constructed on the north-west corner of the University of Oregon's Eugene campus. One day prior to the construction of the floor, the site was graded and the footer trench was dug 18" wide by 12" deep around the 20' x 36' perimeter of the floor site. The floor, was then constructed in a 10-hour workday by a full-time contracted crew of three including a carpenter, helper, and laborer, plus a part-time gravel sling operator.

Construction Log

The first task the contractors undertook in manufacturing the test floor was to install the gravel fill in the footer trenches. This was done with a truck used to "sling" the gravel, or place it in its final position, by shooting it from the truck with a controllable, high-speed conveyor belt. Once the gravel was placed it was compacted using a hand-pushed vibrating compactor. Then 2 x 4 anchor stakes 4 feet on center, were driven in by hand to a depth of approximately 18". Figures 3-4 and 3-5 show the excavated trench and the compaction process.

Figure 3-4, Excavation of the Footer Trench

Figure 3-5, Placing and Compacting the Gravel Footer

As the trench was being filled by the slinger and compacted by one of the construction crew, the two remaining members of the contractor team built the footer beams from 16 and 20 foot lengths of 1 3/4" x 7 1/4" treated laminated veneer lumber (Microlam or LVL) and treated 2 x 6s and 2 x 8s. R-20 insulation was nailed to the inside surfaces of the footer beams at this time.

When these tasks were completed, the footer beams were lifted and carried to their respective positions around the perimeter of the floor, shown in Figure 3-6. Here they were leveled and positioned by hand before they were nailed to each other and the anchor stakes previously driven into the gravel-filled footer trench. Once positioned and secured, the footer beams were braced by stakes driven into the ground approximately 24" outside the footers.

Figure 3-6, Installing the LVL Perimeter Beam

With the footer beams secure, gravel was then "slung" into the space inside the footer beams. The area was filled to half the height of the footer beams and compacted using the same hand-pushed vibrating compactor as was used on the footer trench. Once the entire lift of gravel was compacted, a second lift of gravel was used to bring the gravel level up to its final height. This gravel lift was graded using a long 2 x 4, notched at its ends to ensure the correct height of the gravel. After the grading, the gravel fill was compacted as before. A PVC pipe can be seen protruding from the gravel fill in the floor in Figure 3-7. The pipe was placed to test the constructability of plumbing and other services entering from under the floor.

Figure 3-7, Leveling and Compacting the Gravel Fill

On top of the graded, compacted gravel the contractors laid a moisture barrier of 6 mil polyethylene. Then the 7/16"OSB faced, R-20 insulated panels were laid on the moisture barrier in the pattern shown in Figure 3-1. Then on top of these insulated panels, 7/16" OSB was placed in the pattern shown in Figure 3-2 to prevent any seams in the second layer from resting directly over a seam in the first layer. This second layer of OSB was screwed to the OSB facing the R-20 insulation using 3/4" #6 screws placed 1' on center in all directions. Both layers of OSB were nailed to the footer beams using 16D galvanized nails 1' on center.

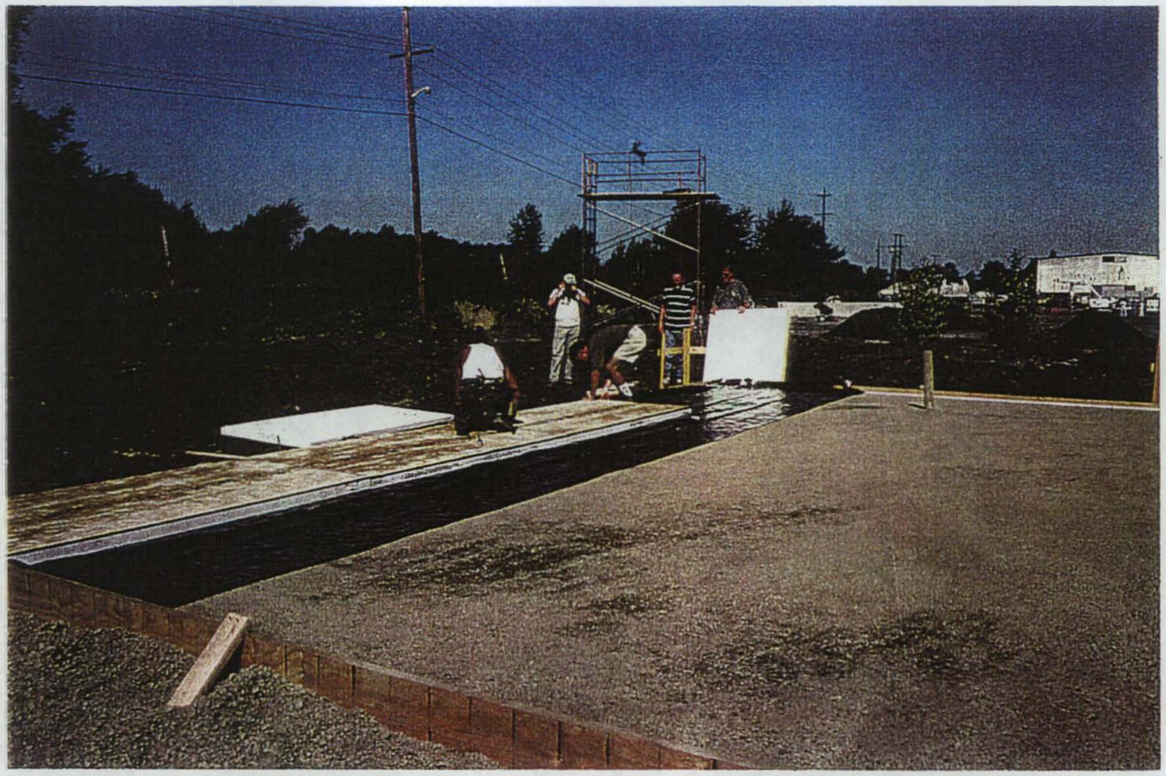

Figure 3-8, Installing the Moisture Barrier and OSB Panels

Figure 3-9, Completed On-Grade Insulated Panel Test Floor

Accuracy of Construction

After the floor was constructed, a visual accuracy test was performed. It was discovered that the footer beam joint at the south-east corner of the floor had separated approximately 1/8" at the top due to the pressure of the gravel during the slinging and compacting process. This could be remedied by supporting the corners of the footer beams with stakes or utilizing a more effective corner detail. It was also discovered that the floor had a "Bounce" of approximately 1/8" around some parts of the perimeter. One solution for this is to use a finer grade of gravel in the top lift, making the final leveling of the surface easier and more accurate. Finally since the perimeter insulation was installed with the perimeter beam and before the compaction process, the compactor was run over the insulation during the edge compaction resulting in an approximately 3/8" gap between the perimeter insulation and the floor panel insulation. To prevent this, an increase of 3/8" in the foam elevation should be built into the design.

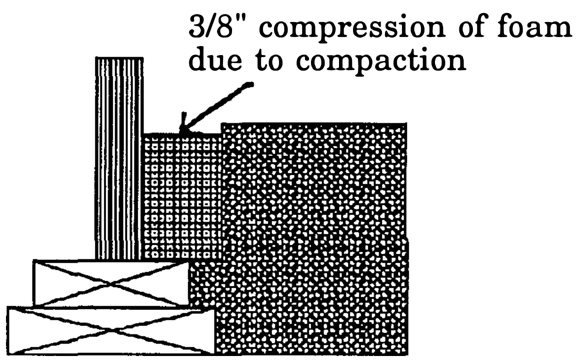

Figure 3-10, Compaction of the Perimeter Insulation

Besides these three correctable details in the construction of the floor, there were no other visible construction faults that might compromise the feasibility of its widespread use.

Improvements

In the process of constructing the test version of the on-grade insulated panel floor a number of possible improvements were discovered. First, it became apparent that the footer beams should be constructed in place or very near their final resting place in the floor. The 36' footer beams used in the test floor were fabricated approximately 30 feet from their final position in the floor and were just barely movable by the four people who were present at their hauling. It was obvious that a footer beam of any greater length would be impossible to move with the small-size crews usually responsible for light construction.

Another improvement in the construction process would be to eliminate the need to drive footer anchoring stakes every 4 feet in the footer trench. It would be easier to drive footer anchors at the corners of the floor and every 8 feet-12 feet and brace the footers with stakes driven outside the floor. Because the support stakes are required to keep the footer standing vertically during the gravel slinging process, there is no extra work involved with this system of bracing, yet it eliminates the material and labor of driving unneeded stakes.

The gravel compacting process could also be improved, as mentioned earlier. Much of the excessive bounce in the floor could have been avoided by modifying the gravel fill in two ways. First, the gravel should be compacted in 4"-6" lifts. This would ensure adequate compaction of the gravel. Second, a finer grade of gravel than 3/4" minus should be used for the top 4"-6" portion of the floor. Using smaller gravel on top would allow the crew to grade the top of the gravel to much finer tolerances than were afforded by the use of the large gravel. This material change would help to eliminate some of the bounce around the edges of the floor. Also as mentioned previously, the perimeter insulation should be raised approximately 3/8" to allow for its compression during the compaction.

Although there was no evidence that the moisture barrier of 6 mil polyethylene between the gravel fill and the foam panels inadequate, a possible improvement may be to increase the strength of the polyethylene layer to prevent perforations from the gravel fill.

Finally, improving the equipment used to screw the two layers of OSB together could have pared 1-2 hours off the time it took to complete the floor. In constructing the test floor the hired contractors used ordinary hand drills to drive the approximately 775 screws. Using this tool each worker could drive approximately 10 screws per minute. Using self-fed, standup screw guns, like those used by roofers, each worker could drive 30-40 screws per minute resulting in a time savings of 1-2 hours.

Applying these improvements will not only make the floors construction faster and less expensive, but also improve its quality.

Cost

The test floor was completed for $566.49 in labor. Materials were donated. With the floor system, as with any new project, there were a number of unfamiliar tasks. To accurately predict the time required to construct a floor, learning curve effects should be taken into account. The Energy Studies in Buildings Laboratory assumes a 20% reduction in the time required to complete new tasks. This percentage is based on cost analyses conducted for the stressed skin insulating core panel demonstration house. A more detailed description of the calculation can be found in the report titled "Cost Analysis: Stressed Skin Insulating Core Panel Demonstration House." If the time required for new tasks in the construction of the floor is reduced by 20%, it is estimated that the labor cost would be reduced to $496.77 for the components installed on the test floor.

The estimated total cost for the on-grade panel floor using 2 1/2"- 2pcf foam panels is then $3,952 including materials. The cost breakdown is shown in Figure 3-11 on the following page. This cost represents an $895 savings over a slab-on-grade foundation ($4,847). An even lower cost, $3,628, can be achieved using 1 1/2" 1pcf foam.

	Component	Material Quantity	Unit	Material Type	Cost /Unit	Cost Source	Material Cost Index	Material Cost	Man Hours/ Unit	Manhours/unit Source	Record-ed Hours	Base Labor Hours	Install. Cost Index	Labor Type/ Crew #	Labor Rate	Labor Cost	Equipment Type	Equip. Rate	Equipment Rate Cost Source	Equip. Cost	Total Cost
	Notes	1			2	3	4	5	6	7	8a	8b	9	10	11	12	13	14	15	16	17
SITE WORK																					
a	clear and grub	0.1	acre	w/ brush saw	$0.00	021-108-0010	1.06	$0.00	32.000	021-108-0010		3.20	1.06	A1	$21.65	$73.44	gas power tool	$8.35	021-108-0010	$28.32	$101.76
b	trench for footing	6.2	cy	112' trench 18" x 12"	$0.00	022-544-0050	1.06	$0.00	0.107	022-544-0050		0.66	1.06	B11C	$25.60	$18.00	backhoe	$14.80	022-254-0050	$10.41	$28.41
c	install 6" gravel footing	168	sf	compact under floor slab	$0.19	022-262-0600	1.06	$33.30		recorded	1.66	1.66	1.06	fore, 3 clab	$24.65	$43.37	vibroplate	$3.32	022-262-0600	$5.84	$82.52
d	build footer beam	112	lf	assembly	$3.05	Trus Joist McM	1.00	$341.60		recorded	2.35	[illegible]	1.06	carp, clab	$25.80	$51.41	power tool	$1.40	crew information	$2.79	$395.80
e	footer materials	118	lf	2 x 6 PT lumber	$0.83	061-127-0110	1.06	$103.19													$103.19
f	footer materials	118	lf	2 x 8 PT lumber	$1.14	061-127-0120	1.06	$143.09													$143.09
g	footer materials	5	lb	16d stainless steel nails	$5.50	060-504-0400	1.06	$29.15													$29.15
h	install footer	112	lf	assembly and stakes						recorded	3.33	2.66	1.06	carp, clab	$25.80	$72.86	power tool	$1.40	crew information	$3.95	$76.81
I	stake material	52	lf	2 x 4 PT lumber	$0.55	061-127-0100	1.06	$30.32													$30.32
j	perimeter insulation	75	sf	3" EPS	$0.39	072-116-2140	1.06	$30.61		recorded	0.50	0.40	1.06	clab	$21.65	$9.18				$0.00	$39.79
l	lay perimeter gutter drain pipe	120	lf	4" diam. PVC	$1.85	027-168-2000	1.06	$235.07	0.064	027-168-2000		7.68	1.06	clab	$21.65	$176.25				$0.00	$411.31
m	install fill	676	sf	6" deep, compacted	$0.19	022-262-0600	1.06	$134.00		recorded	6.88	6.88	1.06	fore, 3 clab	$24.65	$179.77	vibroplate	$3.32	022-254-0050	$24.21	$337.98
n	install moisture barrier	823	sf	6 mil poly	$0.03	071-922-0901	1.06	$28.79		recorded	0.35	0.28	1.06	carp	$29.95	$8.89				$0.00	$37.68
																				SITEWORK	$1,817.80
INSTALL FLOOR PANELS																					
o	unload panels	1	time				1.06	$0.00		recorded	1.67	1.33	1.06	clab, eqmd	$25.80	$36.47	forklift	$24.48	016-420-2020	$34.61	$71.08
p	lay panels	720	sf	panel cost below			1.06	$0.00		recorded	2.66	2.13	1.06	carp, clab	$25.80	$58.20				$0.00	$58.20
q	floor panels	720	sf	comp 5" EPS, 7/16" OSB	$1.65	Enercept	1.00	$1,188.00													$1,188.00
r	panel transporation costs	1	ship	assume local distribution	$300.00	Enercept	1.00	$300.00													$300.00
s	install top subfloor	736	sf	7/16" x 8" x 24' OSB	$0.45	061-164-1500	1.06	$351.85		recorded	3.75	3.00	1.06	carp, clab	$25.80	$82.04	power tool	$1.40	crew information	$4.45	$438.35
v	nails or staples	2	lb	8d galvanized nails	$0.99	060-504-0520	1.06	$2.10													$2.10
w	screws for subfloor	800	ea	1" long, #8 wood screws	$0.04	060-516-0010	1.06	$29.85													$29.85
																				INSTALL FLOOR PANELS	$2,087.57
INSTALL TIE DOWNS																					
x	install tie downs	4	ties	6" x 24" steel auger	$3.85	Bradley Enterpr	1.00	$15.40	0.167	estimate		0.00	1.06	clab	$21.65						$15.40
y	tie down framing	12	lf	2 x 6 PT	$0.83	061-0127-0110	1.00	$9.90	0.036	061-102-2050		0.00	1.06	carp	$29.95						$9.90
																				TIE DOWN	$25.30
																				CONSTRUCTION SUBTOTAL	$3,930.67
CARRYING COSTS																					
z	construction loan interest	1.3	days	9.5% on construction subtotal	$1.02	per day															$1.35
aa	insurance expenses	1.3	time	blder risk & liability, 1.96% on construction subtotal)	$0.21	per day															$0.28
bb	field expenses	1.3	days	toilet rental/day	$10.00	per day															$20.00
																		CARRYING COSTS			$21.63
TOTALS							MATERIAL COST	$3,006.21			HOURS	31.77			LABOR COST	$809.88		EQUIPMENT COST		$114.59	
																				TOTAL COST	$3,952.30

Figure 3-11, Comparison Cost Analysis - On-Grade Panel Floor

	Component	Material Quantity	Unit	Material Type	Cost /Unit	Cost Source	Material Cost Index	Material Cost	Man Hours/ Unit	Manhours/ unit Source	Base Labor Hours	Install. Cost Index	Labor Type/ Crew #	Labor Rate	Labor Cost	Equipment Type	Equip. Rate	Equipment Rate Cost Source	Equip. Cost	Total Cost
Notes		1			2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SITE WORK																				
A	clearing (brush w/ br. saw)	0.1	acre		$0.00		1.060	$0.00	32.000	021-108-0010	3.20	1.06	A1	$21.65	$73.44	power tool	$8.35	021-108-0010	$28.32	$101.76
B	trench for footing	8.3	cy	112' trench 24" x 12"	$0.00		1.060	$0.00	0.107	022-254-0050	0.89	1.06	B11C	$25.60	$24.10	backhoe	$14.80	022-254-0050	$13.93	$38.03
C	deliver/spread gravel fill	586	sf	8" bank run gravel	$0.26	022-262-0600/0700	1.060	$163.99	0.007	022-262-0600	4.10	1.06	3 clab,fore	$24.65	$107.18	vibroplate	$3.32	016-408-1300	$14.44	$285.61
D	moisture control barrier	1000	sf	6 mil polyethylene	$0.03	071-922-0901	1.060	$34.98	0.002	071-922-0901	2.00	1.06	carp	$29.95	$63.49		$0.00		$0.00	$98.47
E	perimeter insulation, R-15	224	sf	3" EXPS, deck lab.	$1.03	072-116-1960	1.060	$245.51	0.012	072-116-1960	2.69	1.06	carp	$29.95	$85.34		$0.00		$0.00	$330.85
F	foundation perimeter drain	120	lf	4" perf. PVC	$1.85	027-168-2000	1.060	$235.07	0.064	027-168-2000	7.68	1.06	clab	$21.65	$176.25		$0.00		$0.00	$411.31
G	fill for perimeter drain	3.1	cy	6" drain rock	$9.35	022-262-1100	1.060	$30.72	0.667	022-262-1100	2.07	1.06	clab	$21.65	$47.45		$0.00		$0.00	$78.18
H	lay gutter drain pipe	80	lf	4" PVC	$1.85	027-168-2000	1.060	$156.71	0.064	027-168-2000	5.12	1.06	B20	$22.82	$123.85		$0.00		$0.00	$280.56
																			SITE WORK	$1,624.78
FORMWORK																				
I	formwork	224	sfca	24" wood forms/ 4 use	$0.97	031-170-3050	1.060	$229.84	0.074	031-170-3050	16.58	1.06	C1	$25.91	$455.25	power tool	$1.04	031-170-3050	$18.27	$703.37
J	footing reinf.	165	lb	#4 rebar	$0.30	032-107-0502	1.060	$51.95	0.008	032-107-0502	1.32	1.06	rodman	$34.65	$48.48		$0.00		$0.00	$100.43
K	install remesh	792	sf	6" x 6" welded wire	$0.08	032-207-0011	1.060	$64.64	0.005	032-207-0011	3.96	1.06	2 rodmen	$34.65	$145.45		$0.00		$0.00	$210.09
																			FORMWORK	$1,013.89
POUR CONCRETE																				
L	deliver concrete	19.3	cy	3000 psi	$60.50	033-126-0150	1.060	$1,237.71	0.000		0.00	1.06			$0.00		$0.00		$0.00	$1,237.71
M	pour footer concrete	9.5	cy	direct chute	$0.00		1.060	$0.00	0.400	033-172-1900	3.80	1.06	C6	$23.16	$93.29	vibrator	$1.71	033-172-1900	$6.89	$100.18
N	pour slab concrete	9.8	cy	direct chute	$0.00		1.060	$0.00	0.436	033-172-4300	4.27	1.06	C6	$23.16	$104.90	vibrator	$1.71	033-172-4300	$7.74	$112.64
O	finish concrete	720	sf	steel trowel finish	$0.00		1.060	$0.00	0.013	033-454-0200	9.36	1.06	C9	$27.20	$269.87	fin. machine	$5.08	033-454-0200	$50.40	$320.27
P	install anchor bolts	22	time	1/2" x 10" anchor bolt	$0.79	031-110-0050	1.060	$18.47	0.094	031-110-0050	2.07	1.06	carp	$29.95	$65.65		$0.00		$0.00	$84.12
Q	curing concrete	720	sf	burlap, 4 uses, 7.5 oz	$0.03	033-134-0011	1.060	$22.90	0.003	033-134-0011	2.16	1.06	2 clab	$21.65	$49.57		$0.00			$72.47
																			POUR CONCRETE	$1,927.38
MISCELLANEOUS																				
R	install treated sub-plate	112	lf	2 x 10 pressure treated	$0.83	061-122-4222	1.060	$97.94	0.032	061-122-4222	3.58	1.06	F2	$26.03	$98.89	power tools	$1.38	061-122-4222	$5.24	$202.08
																			MISC	$202.08
																			CONSTRUCTION SUBTOTAL	$4,768.12
CARRYING COSTS																				
S	construction loan interest	6.1	days	9.5% on construction subtotal	$1.24	per day														$7.59
T	insurance expenses	6.1	days	blder risk & liability, 1.96% on construction subtotal)	$0.26	per day														$1.57
U	field expenses	6.1	days	toilet rental/day	$10.00	per day														$70.00
																			CARRYING COSTS	$79.15
TOTALS							MATERIAL COST	$2,590.43		HOURS	74.85			LABOR COST	$2,032.44	EQUIPMENT COST			$145.25	
																			TOTAL COST	$4,847.27

Figure 3-12, Comparison Cost Analysis - Slab on Grade Floor

4.0 STRUCTURAL ON-SITE TESTING

Test Layout

Seven tests were conducted on the floor to evaluate structural performance. Of particular importance was the deflection of the floor under different loading conditions. Following the test layout diagram is a description and the results of each test. Refer to Appendix B for a complete listing of the test results. X and Y coordinates have been assigned to each test location and measurement point, and in order to identify all the test locations an origin was placed in the south-west corner of the floor.

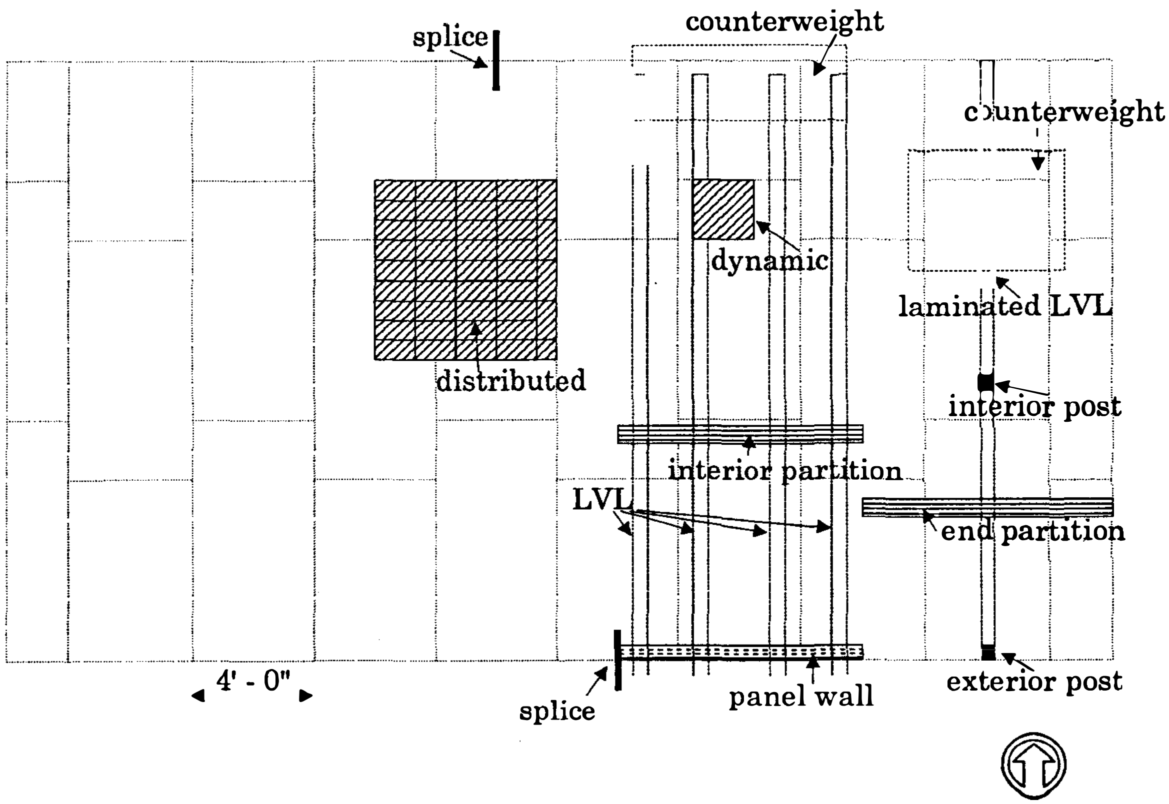

Figure 4-1, Testing Layout

Distributed load

Deflections were minimal, so it was feasible to have a person standing on the floor holding the measuring device without much of an impact on the deflections. Screws were placed in the top layer of OSB, and elevation measurements were taken through the hollow portion of the blocks after each layer was placed. Three layers of concrete blocks were placed in a 6' by 6' area, resulting in a final load of 125 lbs/ft^2. The maximum deflection was 0.40 inches in the center of the distributed load. The average deflection was 0.07 inches. with a floor design load of 40 lb/ft^2, the maximum deflection was 0.25 inches and the average was 0.05 inches.

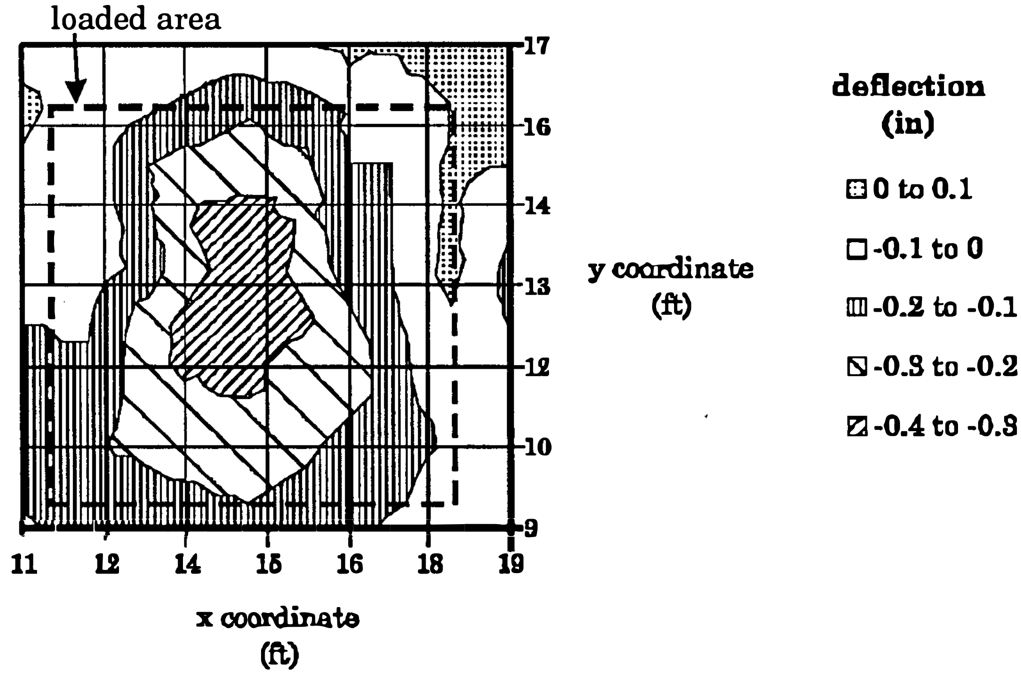

Figure 4-2, Distributed Load Deflection Results (125 lbs/ft^2)

Dynamic load

The purpose of the dynamic load test was to simulate residential equipment such as a washing machine, which may produce unique loading conditions. The test consisted of a vibrating compactor resting on the floor and vibrating for approximately one hour. Two-by-fours were secured around the base of the compactor to prevent lateral movement.

Total deflections of the floor within one foot of the compactor were measured. The maximum deflection after the compactor had been running for one hour was 0.08 inches and the average deflection was 0.01 inches. Soil compaction tests were done under both test areas and untested areas to identify possible results of running the compactor. There was no measurable difference in compaction between the tested and untested areas.

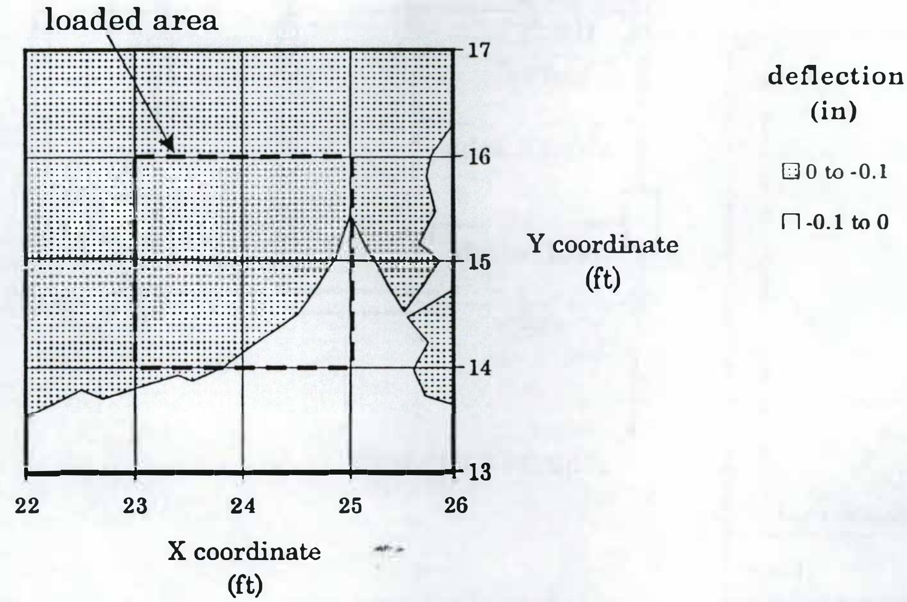

Figure 4-3, Dynamic Load Deflection Results (after 1 hour)

Floor at Exterior Bearing Wall (SSIC panel)

A unique testing apparatus, Figure 4-4, was constructed to test the floor under a bearing wall load. It was planned that an 8' x 8' SSIC panel wall would be tested with loads approximating three times the real loading conditions. A loaded dump truck was jacked up on the pulley system, Figure 4-4, providing the load on the LVLs. The anticipated load of 2200 lbs per foot was not reached due to the inadequate weight of the dump truck. The maximum load reached in the test was 1446 lbs per foot, at which point the truck was lifted off the ground.

At this load the maximum deflection was 0.65 inches at the location of the splice, and the average deflection was 0.19 inches. The test was conducted with one edge on the splice in the perimeter beam. Although this was not the optimal configuration, it proved the inadequacy of the perimeter beam as currently designed. Design modifications are discussed in Section 10.

There did not appear to be any rotation between the inner and outer panel. Rotation was expected because the outer panel was resting on the perimeter beam and the inner panel was resting only on the floor.

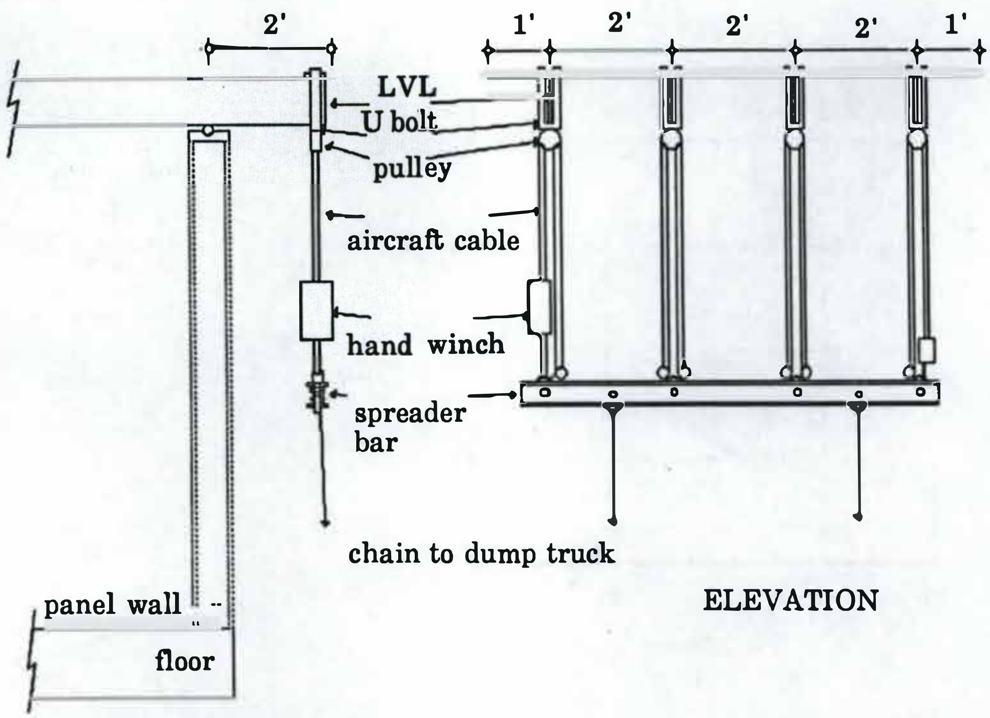

Figure 4-4, Testing Apparatus

Figure 4-5, Exterior Bearing Wall Load Test

Larger loads were planned, but it is unclear how large a load the testing device would have supported due to the splitting of the 2 x 8 used as a header supporting the pipe, which was used to ensure the equal distribution of the load over the top of the wall.

Aside

The wall skins were attached to a 2 x 6 top plate with 8D duplex nails about 4 1/2" on center with no adhesive. A 2 x 8 was supported on top of the two skins and carried the load from the joists through a horizontal pipe to the wall. The load caused the 2 x 8 to fail in bending between the two supporting skins; the failure allowed the load to be transferred to the 2 x 6 top plate, which in turn attempted to transfer the load to the skins. The nails were inadequate and the 2 x 6 was pushed down into the foam. Clearly heavy loads can not be transferred from the 2 x 6 top plate through its connections; some of it must be transferred directly to the skins. Normal nail spacing is 6"; our nail spacing was 4 1/2" on center.

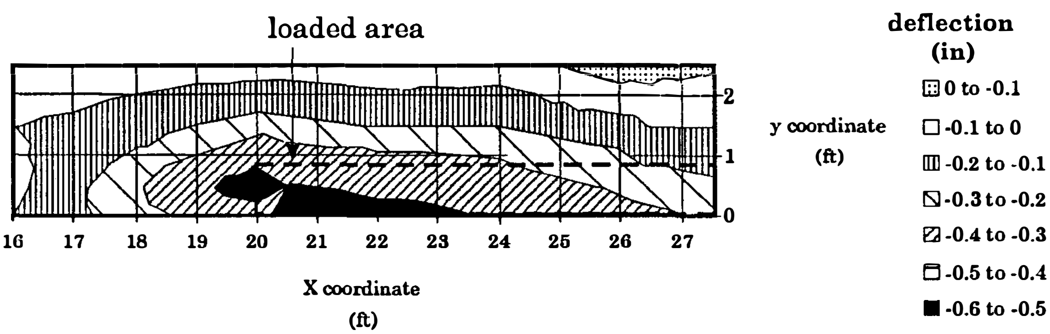

Figure 4-6, Floor at Exterior Bearing Wall
Deflection Results (1446 lbs/ft)

Floor at Interior Partition

A simulated partition wall, Figure 4-7, was constructed to represent the loading conditions of an 8-foot interior partition wall. The lower wall was easier to construct and test but provided the same loading conditions on the floor as a full-size wall with three studs.

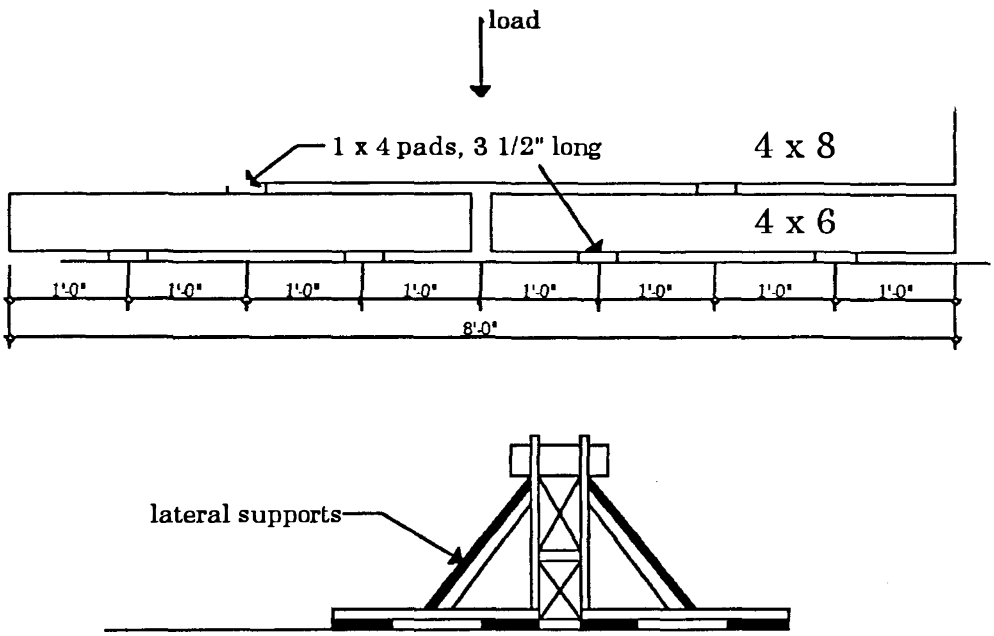

Figure 4-7, Simulated Interior Partition

The maximum deflection reached for the interior wall was 0.28 inches at a load of 3880 lbs (485 lbs per foot). The maximum occurred in two places, both of which were the middle of a panel in the upper layer of OSB. Recall that the middle of the upper layer of OSB corresponds to the seam in the insulated panels. The average deflection was 0.7 inches. At the design load of 380 lbs/ft the maximum deflection was 0.25 inches and the average was 0.05 inches.

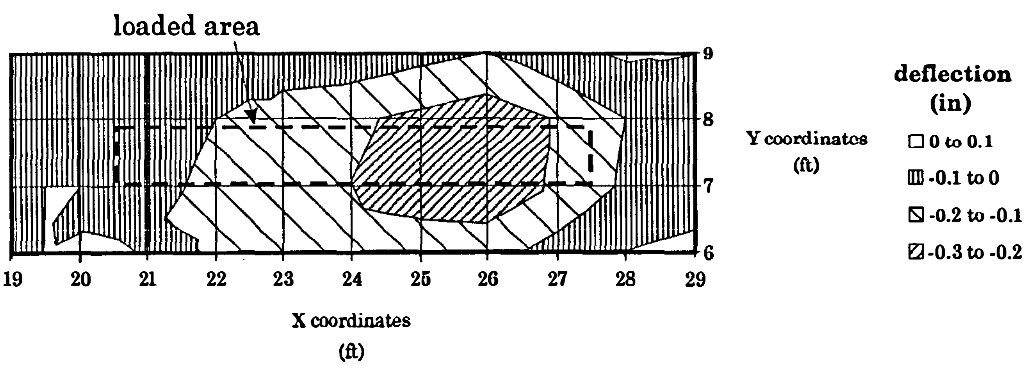

Figure 4-8, Floor at Interior Partition
Deflection Results (485 lbs/ft)

Floor at Interior Post

To test the deflection of floor under a smaller interior point load, a 4 x 4 post was loaded to 3700 pounds. The maximum deflection was 0.7 inches and the average was 0.13 inches.

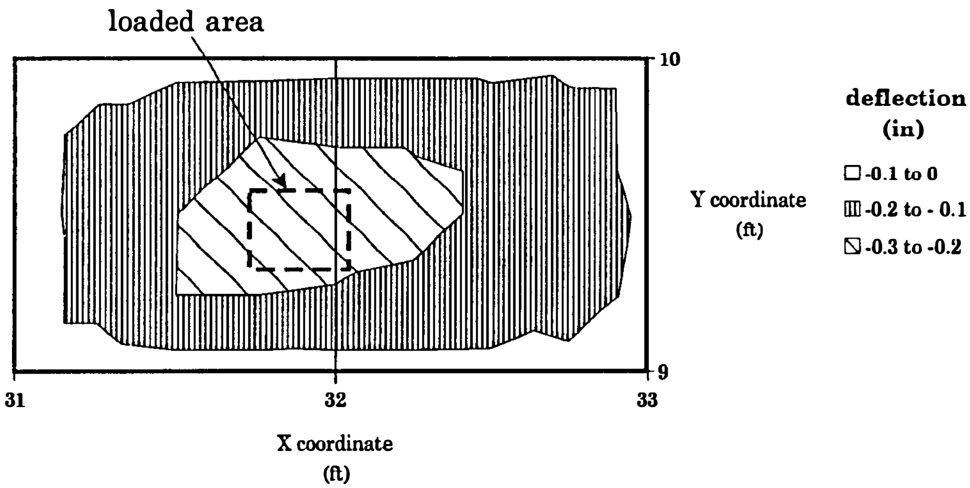

Figure 4-9, Floor at Interior Post
Deflection Results (3700 lbs)

Floor at Exterior Post

The deflection and performance of the perimeter beam under a structural post were tested using a 4 x 6 post. The post was loaded to 7700 pounds and the maximum deflection was 0.75 inches, the average deflection 0.19 inches. At the approximate design load, 2900 lbs, the maximum deflection was 0.18 inches and the average was 0.10 inches.

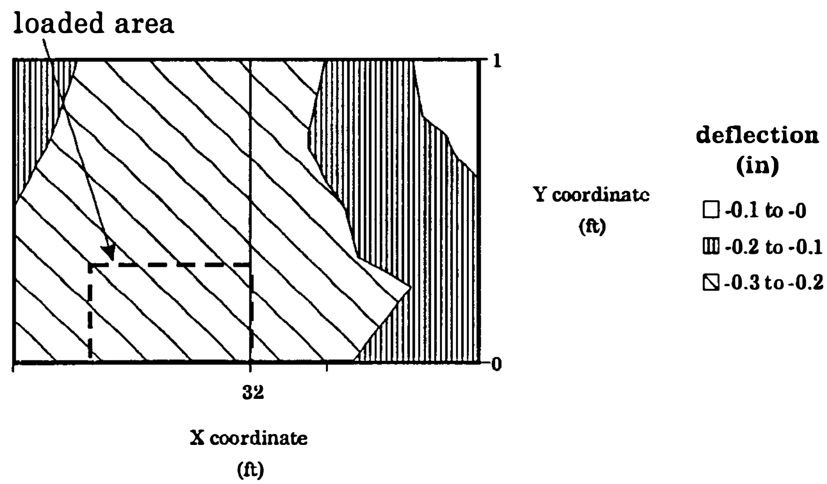

Figure 4-10, Floor at Exterior Post
Deflection Results (7700 lbs)

Floor at Interior Partition (Terminating in Exterior Wall)
To recreate the effect of an interior partition resting on the perimeter beam, the lower interior partition wall was used. The laminated LVLs were loaded to 750 pounds per foot. The maximum deflection was 0.7 inches and the average was 0.10 inches. At the design load of 380 lbs/ft, the maximum deflection was 0.15 inches and the average was 0.05 inches.

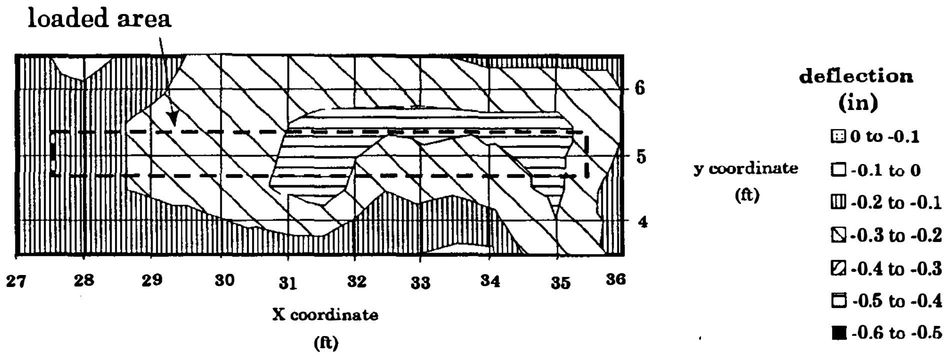

Figure 4-11, Floor at Interior Partition(Terminating in Exterior Wall) Deflection Results (750 lbs/ft)

One concern with the design was that a uniform load on a partition wall could possibly result in the buckling or rotation of the perimeter beam. This did not occur during the testing.

Loads and Deflections of All Tests
The following is a summary of the loads and resulting maximum deflections for six of the conducted tests. The dynamic load test is not included due to the different nature of the load. When comparing the total load and the deflection for the six tests, the relationship appeared to be linear once again. After linear regression analysis, the data points were all within 77% of a straight line. Based on this information, it is possible that the interior of the floor could also support bearing wall loads.

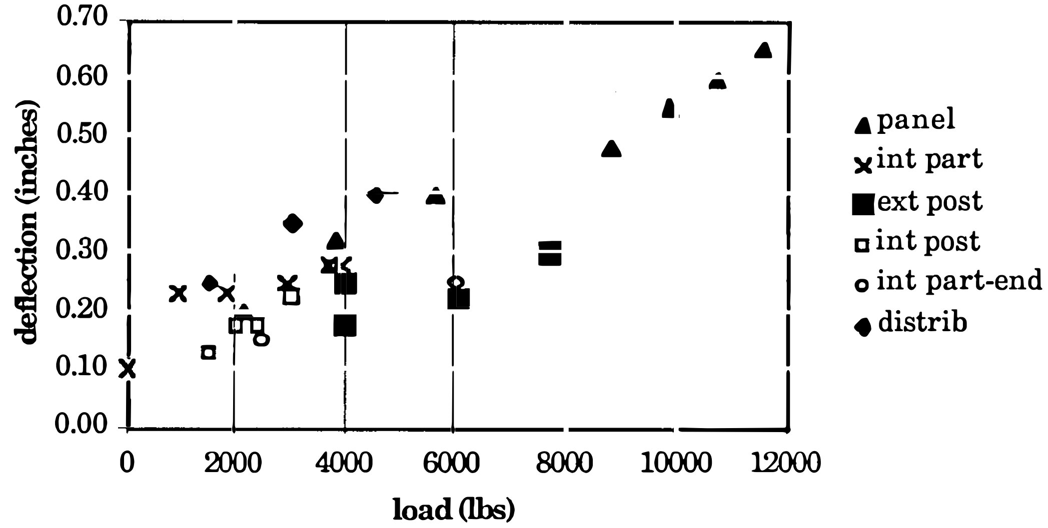

Figure 4-12, Total Load vs. Deflection for All Tests

By graphing only the wall tests, a correlation between load (lbs per linear foot) and deflection is evident. The relationship is nearly linear, especially when considering only the panel and interior partition tests.

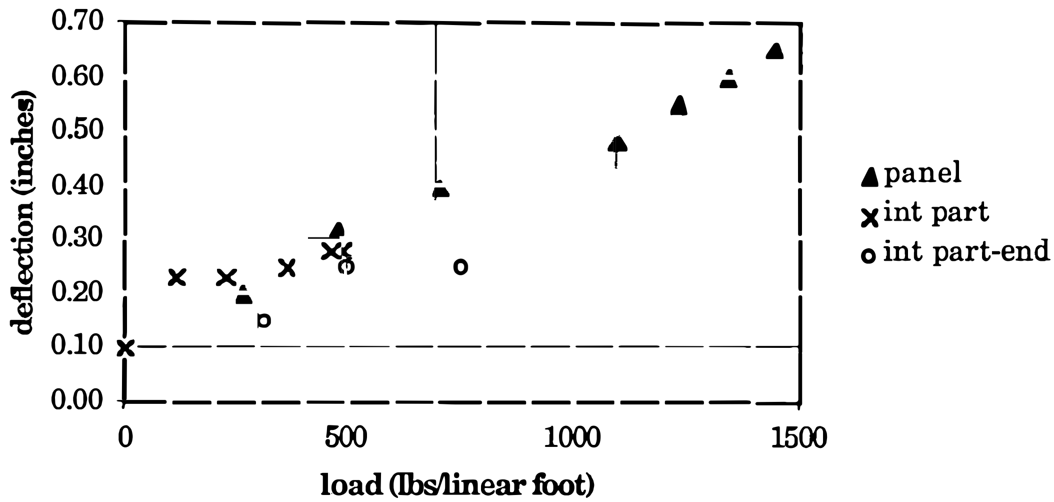

Figure 4-13, Load vs. Deflection for Wall Tests

5.0 FLOOR STANDARDS

Floor performance criteria are published in the "National Bureau of Standards Technical Notes" (900: Deflection Performance Criteria for Floors, and 904: Correlation of Floor Vibration to Human Response) dating back to 1976. This source lists the maximum deflections recommended based on the frequency of the floor. Since the frequency of the on-grade floor system is not known, this is not an applicable criterion.

The Canadian Wood Council recommends a maximum deflection of span/360. Earlier work also indicated a maximum of L/360 for a uniformly distributed live load of 40 psf (Building Science Series 47, 1973). If built as a joist system, a floor of the same size as the on-grade panel test floor would have a span of 20 feet. This corresponds to a maximum deflection of 0.67 inches.

In 1981 a conference was held to determine floor performance standards, and the results were published in the book, *Wall and Floor Systems: Design and Performance of Light-Frame Structures.* One of the main conclusions of the conference was that more research is needed for vibration assessment of floors.

For a comparison to concrete floors, the measurement of floor levelness and flatness used for random traffic floors (outlined in *Design and Construction of Concrete Floors*,) was calculated for the on-grade insulated floor. The F-number system is a measure of floor surface regularity; a value for both flatness and levelness can be determined. The method involves taking elevation readings at several points on the floor in a predetermined pattern. When the procedure was followed for determining the F-number for the on-grade panel floor under distributed load conditions, the result was a flatness value, FF = 24, and a levelness value, FL = 17. Since the standards for residential, random traffic floors allow for minimum values of FF = 15 and FL = 13, the on-grade panel floor is well within these standards. Details of the calculation procedure can be found in Appendix C.

6.0 DISMANTLING

In January 1997, the floor was dismantled. The dismantling took approximately eight hours for an unskilled three-person crew. The process was extended due to difficulty locating screws in the upper OSB layer, additional screws remaining from the testing program, an inadequate number of power drills, and frozen ground covering the perimeter beam assembly. The entire process was recorded using video and still cameras. It is estimated that the floor could be dismantled in under four hours using an experienced crew and additional power tools. Some important discoveries were made during the dismantling.

The most important finding was the chemical deformation of the perimeter foam as well as the panel foam in isolated locations as shown in Figure 6-1.

Figure 6-1, Chemical Deformation of Insulation and Panel Foam

The pressure-treated Microlam (or laminated veneer lumber, LVL) beams used in the footer were treated with an oil-borne solvent that dissolved the foam where it came in contact with it. The solvent probably came into greater contact with the foam because of the increase in water flow from rain due to the unprotected nature of the floor. A further discussion of this is included in Section 7: LVL Alternatives.

The floor possessed a considerable amount of bounce. This deflection is noticeable on camera and to observers but is less noticeable to the occupant walking or jumping on the floor. Measurements were not made of this action other than recording the response of the floor to a person jumping on it. It is also estimated, but not confirmed, that the dead weight of a structure on top of the floor would decrease the bounce in the floor. One cause of the bounce was the inaccurate leveling of the gravel fill. Gaps were noticeable during the dismantling between the foam panels and the poly layer covering the gravel. The largest observed gap was approximately 1/2".

Gravel indentations were expected and found on the underside of the foam panels. These indentations covered approximately 5% of the floor area and were evenly spread throughout the floor. Areas where tests were conducted did not appear to have different gravel indentation amounts or patterns. The maximum indentations were approximately 1/4" deep, but the majority were smaller.

Since the floor was exposed to large amounts of rain, it was expected that the two layers of OSB would swell considerably. Final measurements showed a difference of 7/8" between the high and low points on the floor. It can be concluded that the majority of the floor swelled about the same amount.

The perimeter beam was investigated for bowing (lateral deformation). It was observed that the south side of the floor was the only side with noticeable bowing. This deformation corresponded to the location of the splice where testing of the SSIC panel was conducted, 1/2" south of the SE and SW corners.

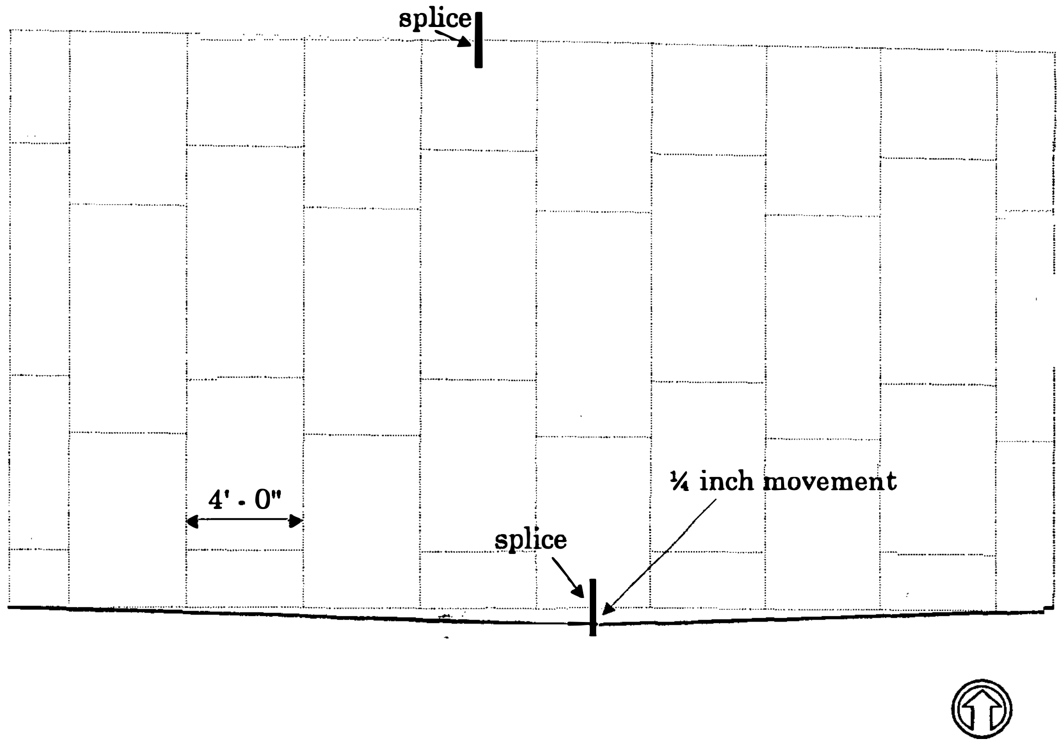

Figure 6-2, Lateral Deformation of the Perimeter Beam

The majority of the panels also appeared to be slightly convex to the OSB layer. Low spots in the middle of the top layer of OSB corresponded with the joints of the panels. Figure 6-3 shows the general deformation characteristic.

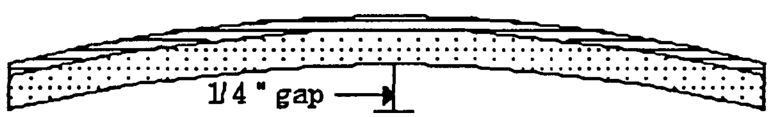

Figure 6-3, Panel Deformation

The gravel fill was tested for compaction by Braun Intertec Corporation, a local testing agency, using a nuclear densimeter. The results showed a range in compactions from 80.2% to 86.2%. This is low compared to similar fill conditions. Adequate compaction was not achieved due to the large lift size and lightweight vibrating compactor used. The compaction was relatively consistent throughout the floor and did not vary under the dynamic loading test area. Appendix D contains a testing layout including results.

A test pit was dug down to seven feet to explore the sub-grade material. As expected, wood chip debris was found beneath the gravel fill. The depth of this layer ranged from 16 inches to 3 feet. A non-native clay layer was found beneath the wood chip debris to the seven-foot depth.

7.0 LVL ALTERNATIVES

The deformation of the foam due to the oil-borne solvent used for the laminated veneer lumber means that an alternative is required. However, water-borne solvents are not used on the west coast to treat Microlam due to the unpredictable reduction in strength of the member. One alternative would be to change the foam from polystyrene to polyurethane since urethanes will not dissolve in an oil-based solvent. This would require changing both the perimeter insulation and the panel material. A simpler solution would be to use CCA treated Parallam (CCA is a water-borne solvent.) On the east coast, LVL can be used because controlled CCA treatment is available.

Since Parallam is more expensive per linear foot than LVL, cost is an important factor. However, while the required size would be larger, 1 3/4" x 9 1/2" Parallam compared to the 1 3/4" x 7 1/4" LVL, the materials cost would be less because the 2 x 6 in the footer assembly could be eliminated. The cost would therefore be approximately $3.05 / linear foot for the Parallam compared to the current cost for the LVL and the 2 x 6 of approximately $3.30 / linear foot ($2.30 LVL, $1.00 2 x 6).

Another concern with using Parallam is the increased weight of the footer assembly. LVL weighs 3.7 lbs/ft and Parallam weighs 5.2 lbs/ft. This results in a 54 lb weight increase for the longest section (36 feet), but the 2 x 6 would not be required. The weight of the 2 x 6 can vary dramatically depending on the type of lumber and the moisture content. A realistic range is 1.2 to 2.4 lbs/foot, which could negate the 54 lb difference.

Glulam beams were also considered. The smallest standard size available is 2 1/2" x 9" and the weight is 5.5 lbs/ft. Glulam, however, is not available treated with CCA or with an alternate water-borne solvent.

Currently there is controversy regarding the use of CCA-treated wood. In Environmental Building News, March 1997, a phase-out of CCA-treated wood was advised due to the environmental problems associated with disposal. CCA is not seen as a large problem if the treated wood can be kept out of the waste stream. For the on-grade insulated panel floor system, recycling of the wood is a viable option.

However, investigation is underway to determine if newer, more environmentally safe treatments are available for engineered wood products such as Parallam which could be used in the floor system.

8.0 STRUCTURAL LABORATORY TESTING

Structural testing will include both creep tests and structural load tests. It is feasible that ESBL could conduct indoor creep tests. If the deflections are small, however, it may be difficult to measure them with the appropriate accuracy using equipment available in the current lab facilities. The advantages of conducting the tests in house include minimal cost and availability of long-term monitoring.

The structural testing of the wall panel and floor assembly will be conducted at Oregon State University in the summer, 1997. The testing sequence is outlined in Figure 8-1. By following this testing sequence we are hoping to gain the most information from the least number of tests. The initial tests are based on the most important variables. Figure 8-2 shows the number of tests required with the critical set shown in the first column. Additional tests are strongly recommended in order to test other possible options and to gain as much information as possible, but these are limited due to funding. Once the testing apparatus is set up, the cost per test goes down dramatically. This suggests doing as many tests as possible.

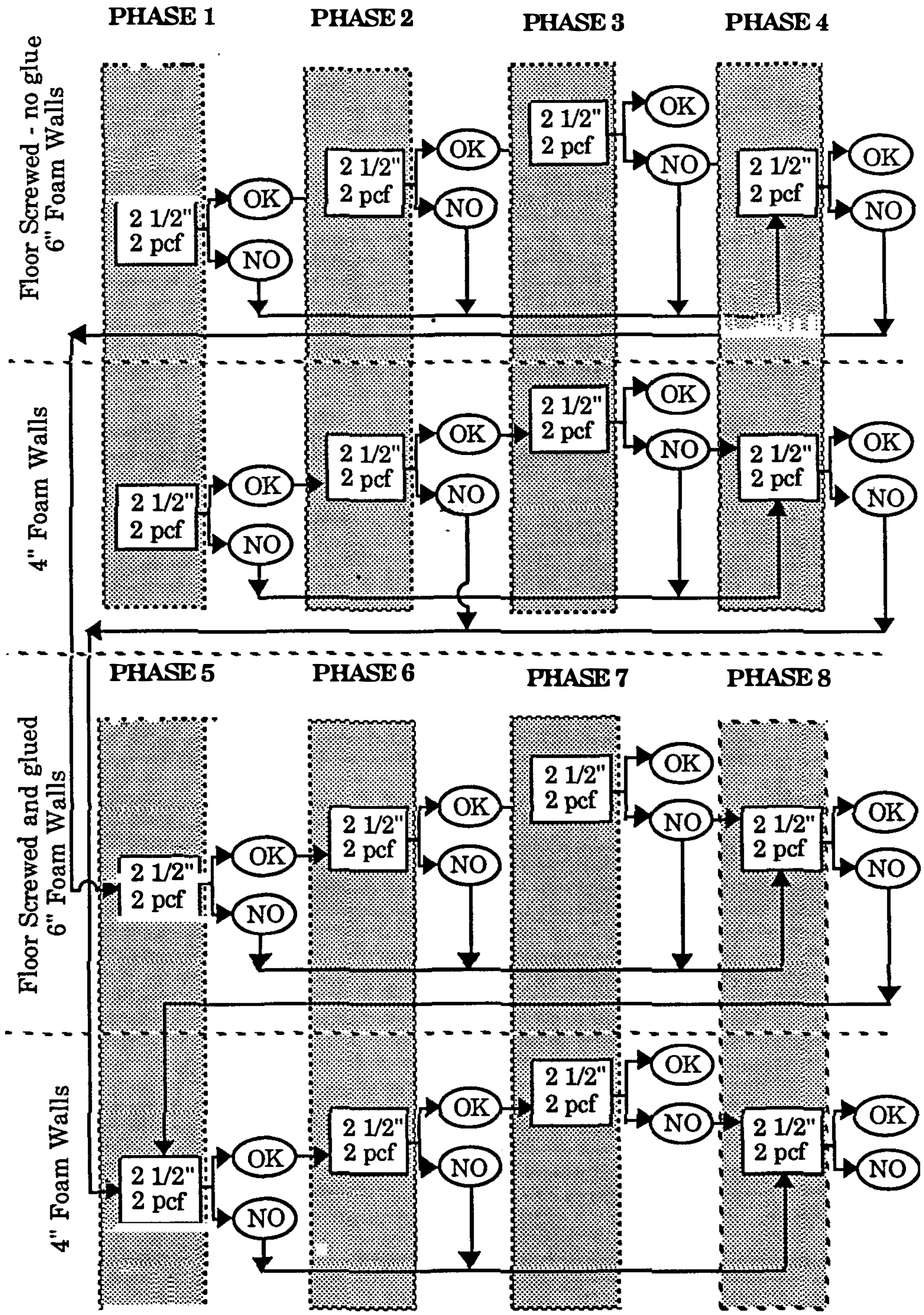

Figure 8-1, Structural Laboratory Testing Sequence

Foam Thickness	2 1/2"	2 1/2"	1 1/2"	1 1/2"	2 1/2"	2 1/2"	1 1/2"	1 1/2"
Foam Density	2 pcf	1 pcf	1 pcf	2 pcf	2 pcf	1 pcf	1 pcf	2 pcf
Floor Attachment	screw	screw	screw	screw	screw glue	screw glue	screw glue	screw glue
Loading Element								
Exterior 6" foam exterior wall	3	3	3	3	3	3	3	3
4" foam exterior wall	3	0	3	0	0	0	3	0
2x6 stud wall (ext)	3	0	0	0	0	0	0	0
Interior *								
interior partition	3	3	3	3	3	3	3	3
interior post	3	3	3	3	3	3	3	3
Creep Tests *								
interior partition	1		1		1		1	
interior post	1		1		1		1	
uniform load	1		1		1		1	
Phase	1	2	3	4	5	6	7	8
number of tests	15	9	15	9	12	9	15	9
total number of tests	15	24	39	48	60	69	84	93

* test only floors that performed satisfactorly for exterior foam wall panels

Figure 8-2, Structural Laboratory Tests to be Performed

9.0 THERMAL AND MOISTURE TESTING

Objectives

The purpose of the thermal testing of the on-grade panel floor system is to determine the temperature and moisture distribution in the floor system, which will provide a basis for verifying the thermal and moisture performance of the floor. The insulation capacity of the floor will also be measured, which will allow comparison with other floor systems.

Introduction

The temperature distribution of the on-grade floor system in winter reflects its thermal performance. Ideally, the temperature of the footing should remain above freezing to prevent frost heave. The temperature distribution of the on-grade panel floor system theoretically depends largely on the insulation capacity of the floor, the interior temperature of the room, the exterior temperature, and the ground temperature. Among these variables, the insulation of the floor is the most critical to a successful design for the on-grade panel floor system, since floor designers have less control over the others. The exterior temperature and the ground temperature are usually determined by the building's location, and the interior temperature varies over a limited range in winter.

Thermal testing of the on-grade panel floor system will focus primarily on the temperature and soil moisture contents at various critical points of the floor system. These points are usually the places most subject to damage from frost heave, such as at the footing, footers, and corner joints. By measuring the temperature and moisture content at these critical points, the frost heave damage can be monitored. Type-T thermocouples and soil moisture sensors will be used.

In addition to monitoring temperature and moisture, we will evaluate the insulation capacity of the on-grade floor system in order to compare the on-grade floor system with similar products. The major concerns of testing, compared to simulation, are accuracy, cost, and representativeness. Various precautions will be taken to address the accuracy and representativeness of the test. Moreover, multiple tests will be performed in various climate zones and soil types to improve the representativeness. A test chamber will be used for the test, which will consist of a test unit (forming the top and sides of the test chamber) and the floor system to be tested (forming the bottom of the test chamber). The insulation capacity test of the floor system includes two separate groups of tests: one to calibrate the insulation capacity of the test unit, the other to measure the conductive heat loss through the floor system. Co-heating tests will be performed to measure the total energy consumption of the test chamber. The conductive heat loss through the floor system can be obtained by excluding the heat loss of the test unit and the infiltration from the total energy consumption.

Temperature Testing

The temperature testing will monitor temperatures at points on the on-grade floor panel system that would likely be susceptible to frost heave damage. The temperature monitoring will use a data logger that will read thermocouples installed at these critical points at one-hour intervals. Type-T thermocouple wires will be used.

Moisture Testing

In order to monitor soil sensitivity to frost, the moisture content at the critical points of the on-grade floor panel system will be measured as well as the temperature. Moisture sensors could be installed together with the temperature sensors. We are planning to use Time Domain Reflectometry sensors manufactured by Campbell Scientific Inc.

Sensor Locations

Figure 9-1 shows the locations of the thermocouples and soil moisture sensors. The temperature and moisture sensors are located on the lower surface of the footer as well as between the gravel and soil under the footers. Some sensors are also located on the lower edge of the floor panels. Only the north and east sides of the test chamber need to be monitored, since they receive less solar insolation. Figure 9-2 gives the locations of sensors in plan view. In addition to monitoring the soil temperature and moisture, it is necessary to measure the internal air temperature as well as the floor surface temperature of the test chamber.

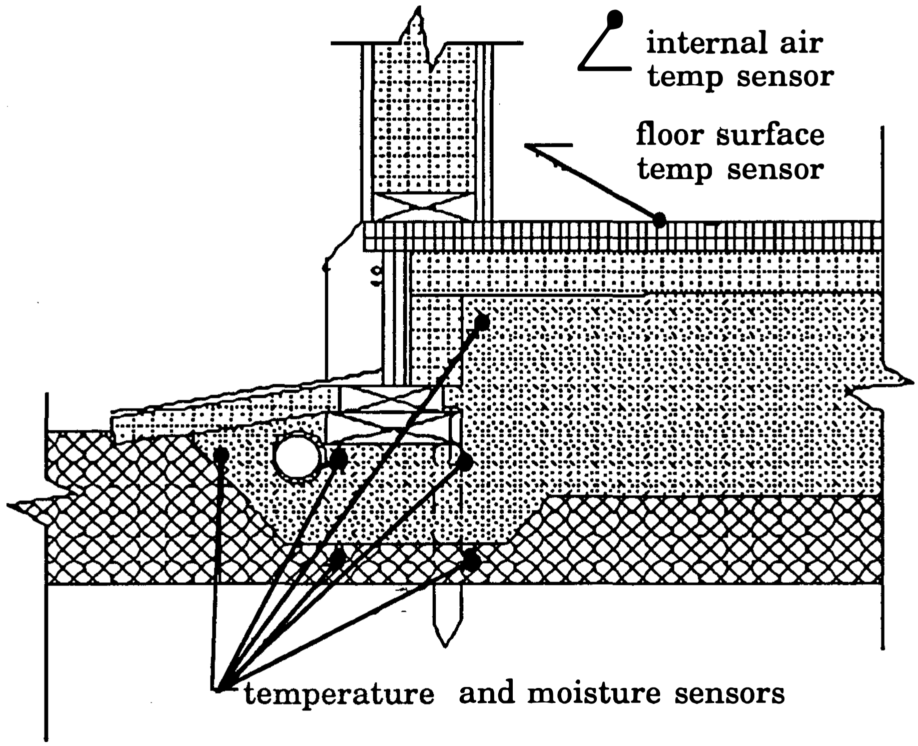

Figure 9-1, Location of Thermocouples and Soil Moisture Sensors

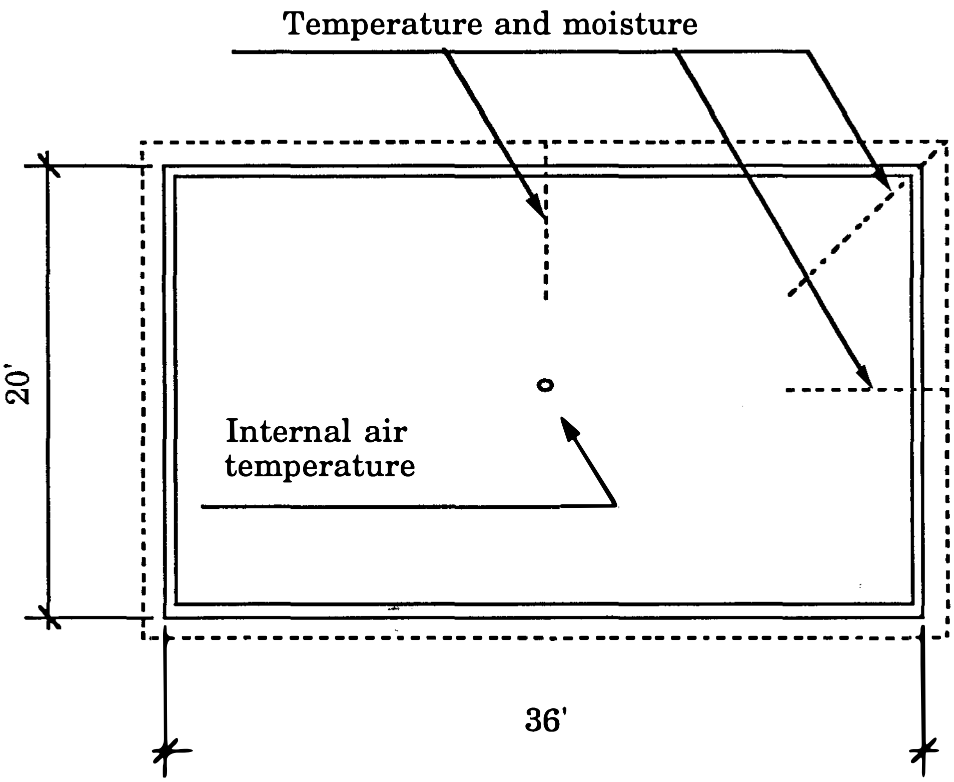

Figure 9-2, Plan Showing Sensor Locations

Measuring the Insulation Capacity of the Test Unit Floor System

The test scheme we propose for determining the insulation capacity of the floor system is to measure the steady state heat flux through the surface of the floor. A co-heating test of a test chamber will be performed in an approximately steady environment by maintaining a constant internal temperature. The test chamber consists of a test unit (forming the top and sides of the test chamber) and the floor system to be tested (forming the bottom of the test chamber). The energy consumption of the test chamber is monitored over a certain period of time. The measurements from nights that have small temperature swings will be used. The conductive heat loss through the floor system can be obtained by excluding the heat loss of the test unit and the infiltration from the total energy consumption. Figure 9-3 illustrates this test.

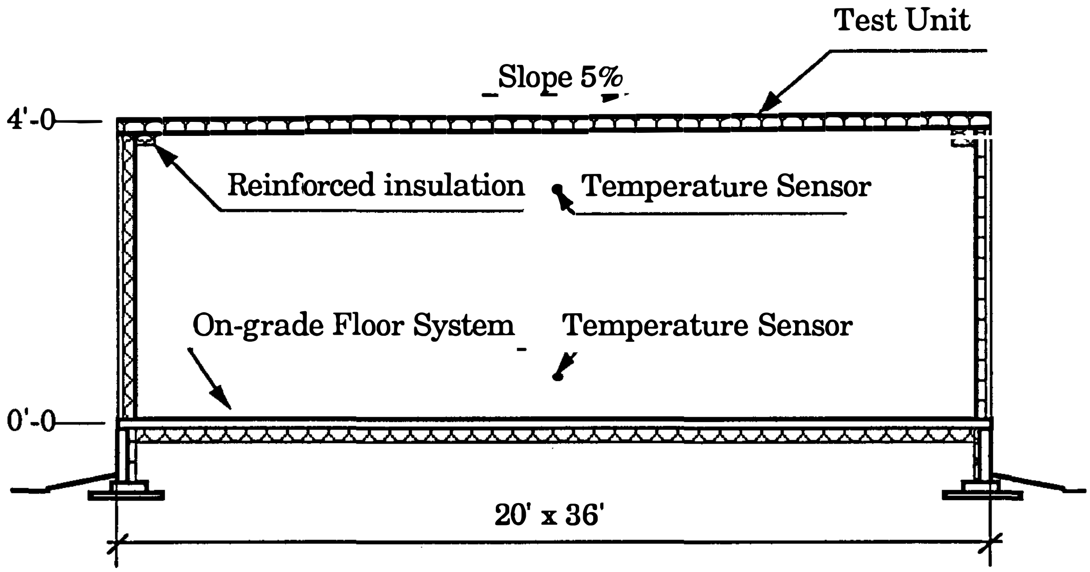

Figure 9-3, Test Chamber

A blower door or a tracer gas test will be performed to determine the infiltration of the test chamber. The insulation capacity of the test unit can be pretested in the lab. The overall accuracy can be maintained if the sufficient R-value of the test unit keeps the inaccuracy incurred by the conductive heat loss through the test unit relatively small. For instance, 12 1/4" R-Control panels can be used, which have an R-value of 48.31 at 40 F. The insulation at the edges of the test unit can also be reinforced to reduce the cold bridging of panels. Similarly, the test unit can be well sealed to reduce the infiltration and therefore minimize the error incurred by infiltration.

An indoor co-heating test can be performed to determine the heat loss conducted through the test unit, i.e. the top and sides of the test chamber as a whole. Figure 9-4 illustrates this test. A test bed placed underneath the test unit will serve as an absolute insulation such that the heat flow from the bottom of the test unit can be eliminated. (The test bed maintains the same inner temperature as the internal temperature of the test unit to eliminate the heat flow through the bottom of the test unit so that the heat flow through the test unit can be accurately measured.) A tracer gas or blower door test will be performed to measure the heat loss of the test unit with the test bed. The heat loss through the test unit can be obtained as the difference between total heat loss and the infiltration lost.

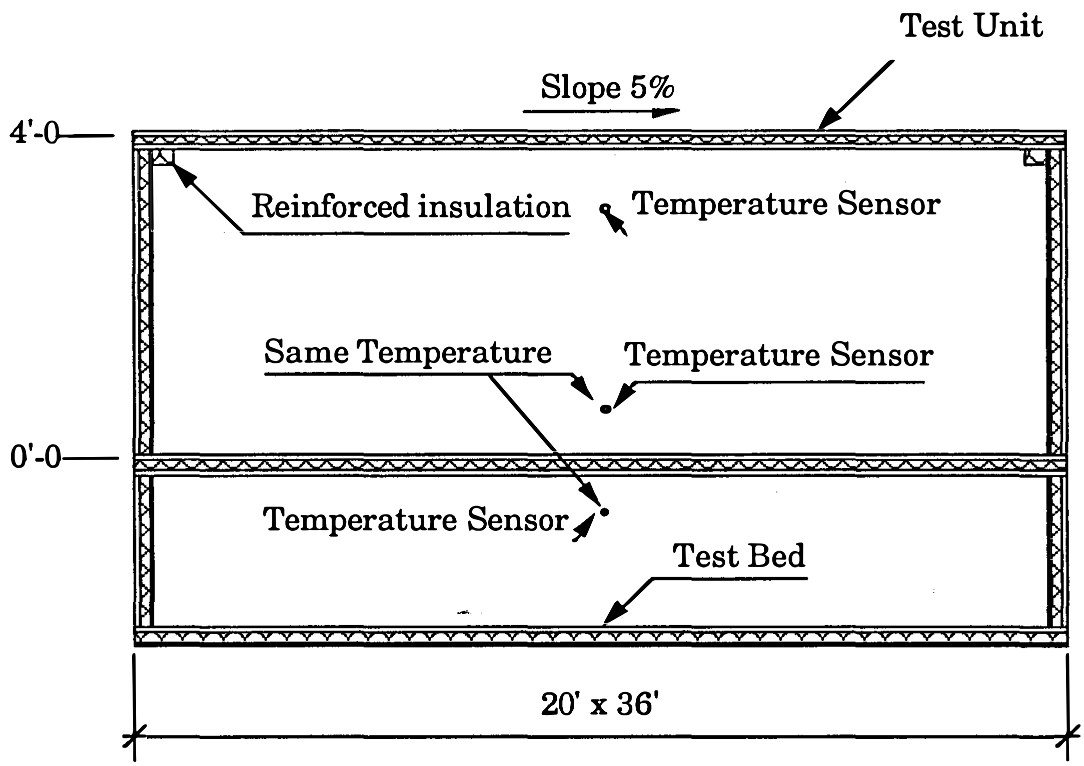

Figure 9-4, Indoor Co-Heating Test

The following equipment will be needed to test the insulation capacity of the floor system:

1. A Campbell Scientific CR-10 datalogger will be used to collect the data.
2. An AM416 may be needed to collect the weather data. The weather data includes exterior dry bulb air temperature, exterior relative humidity, solar insolation, wind speed, wind direction, and water precipitation.
3. Two Type-T thermocouples will be installed in the test unit to monitor the air temperature inside, one near the top, the other near the bottom. This will help to reduce the impact of the air temperature gradient.
4. Two Titan Milkhouse Heaters T771T at 1.3KW/each will be used.
5. Crydom Solid State Relays D2425 with Crydom 1 Series Heat Sinks HS-2 will be used to control the heaters. It is possible to program a two-step heater control to gain better constant temperature. This will require two relays.
6. One Single-Element Watthour Meter (2111202-T 2-in-1, single-element hookup) manufactured by Integrated Metering System Inc. will be used to measure the heater energy consumption.

Recording the Weather Data

Weather data for the test site will be collected by a weather station. The weather parameters include at least dry bulb temperature, relative humidity, wind speed, irradiance, and perhaps water precipitation, which is useful for monitoring the moisture content of the soil.

Accuracy Control

The accuracy of the tests determines their validity. The following precautions are required to improve the accuracy at every stage of the tests.

1. The insulation capacity of the test unit should be increased to reduce the inaccuracy incurred by conductive heat loss through the test unit. The test unit should be carefully detailed to eliminate cold bridges. The insulation at the corners of the test unit should be reinforced.
2. The R-value of the top panel of the test bed should be high enough to reduce the heat flow. The internal temperatures of the test bed and test unit should be as close as possible so that the test bed can serve as an absolute insulation.
3. The infiltration of the test unit should be reduced to decrease the inaccuracy incurred by infiltration. The test unit should be well sealed.
4. An effort should be made to approximate a steady state condition to the maximum degree. In order to stabilize the soil temperature, the test chamber will be preheated at a constant interior temperature for about one week before the co-heating test starts. The co-heating test will be performed over a number of days, and the measurements from nights that have small temperature swings will be used. The insulation capacity of the test unit can be calibrated indoors to improve accuracy.
5. A tracer gas test is preferable to a blower door test for determining the infiltration rate.
6. The manufacture and assembling of the test unit should have accuracy control in mind.

Detailing of the Test Unit and Test Bed

Figure 9-3, shown previously, is a diagram of the test unit and test bed, which are made of foam core panels and are the same size as the initial test floor. The height of the test unit is equal to the width of a panel to avoid joints. The joints should be carefully detailed to reduce cold bridging, and the insulation at the corners should be reinforced. The detailing of the test unit should consider the possible transportation and disassembling/ assembling.

Location for Building the Test Unit

The test chamber should cover a footprint similar to a typical residence. Considering the size, there will be concerns as to where to build the test unit and how to transport it to the floor site. To accurately calibrate the insulation capacity of the test unit, the test will need to be performed in a steady state condition. One approach would be to build the test unit and test bed indoors so that the test unit could be calibrated without being transported. The place could be a rented warehouse. After the test, the test unit would be disassembled and transported to the floor site. The reassembling process should be performed carefully to ensure the reproduction of the insulation capacity.

Another approach would be to build the test unit and the test bed at the floor site. A rented tent could be set up at the floor site for calibrating the test unit. This would eliminate the need for transportation.

Infiltration Test

The infiltration rate of the test unit needs to be determined accurately. A tracer gas test is preferable to a blower door test. A door will be needed for access to the interior of the test unit, which will require careful detailing in order to be able to seal the door.

10.0 RECOMMENDED DESIGN CHANGES AND CONCLUSIONS

Floor Performance

With regards to overall performance, the floor behaved well and meets standards for concrete slab levelness and flatness and wood floor system deflection criteria. The vibration criterion was not analyzed. There was significant bounce apparent when jumping on the floor, but it was not noticed under normal walking conditions. It is also unclear what percentage of the bounce would disappear under loaded conditions.

Footer Assembly

It is not feasible to get composite action between the three members (LVL, 2x6, and 2x8) with mechanical fasteners; the horizontal shear between the members is much too great. Composite action may be possible with some types of glues; not much is known about glue for such locations.

If we limit our building to one story, the 1 3/4" x 7 1/4" LVL will be adequate in most cases without developing full composite action provided we do not splice the LVL, or at least do not splice it near a critical location. The critical section is assumed to be under the end of a bearing wall next to an eight-foot window opening. The main problem with the LVL remains the incompatibility of the treated wood and the polyethylene insulation.

Buildings more than one story will require a 1 3/4" x 9 1/2" Parallam to be used in the footer assembly.

Material Selection

The best alternative to prevent the deformation of the polystyrene foam appears to be the use of Parallam for all floors. LVL could be used on the east coast where it is available treated with CCA, but only for one-story applications. The cost and weight advantages of Microlam are not significant, and it is simplest to use Parallam for all applications throughout the country. Glulam is not a viable option due to the treatment restriction.

11.0 ACKNOWLEDGEMENTS

Rudy Berg and Josh Powell worked on the initial research for the on-grade panel floor system.

12.0 REFERENCES

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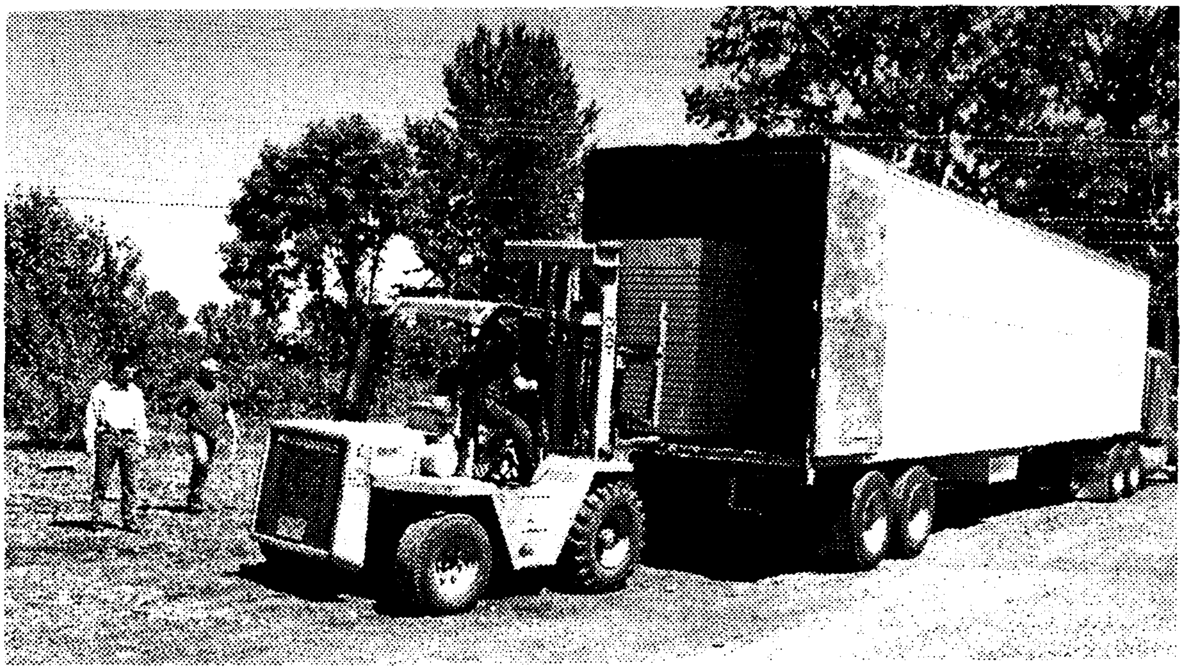
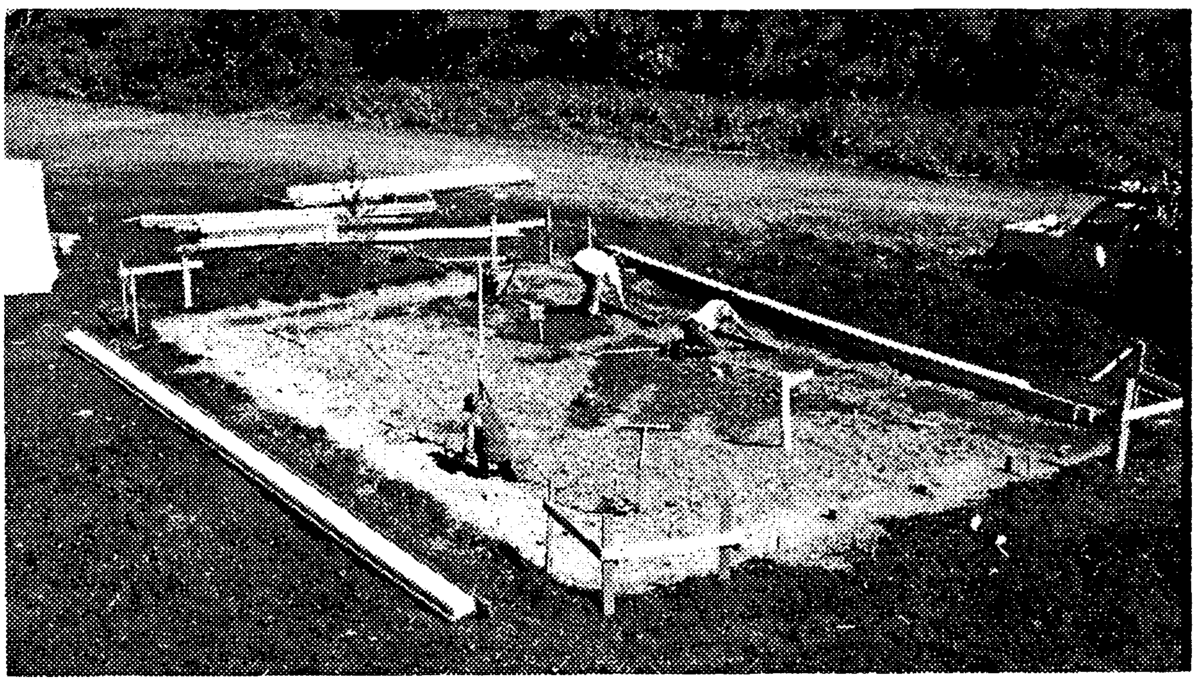
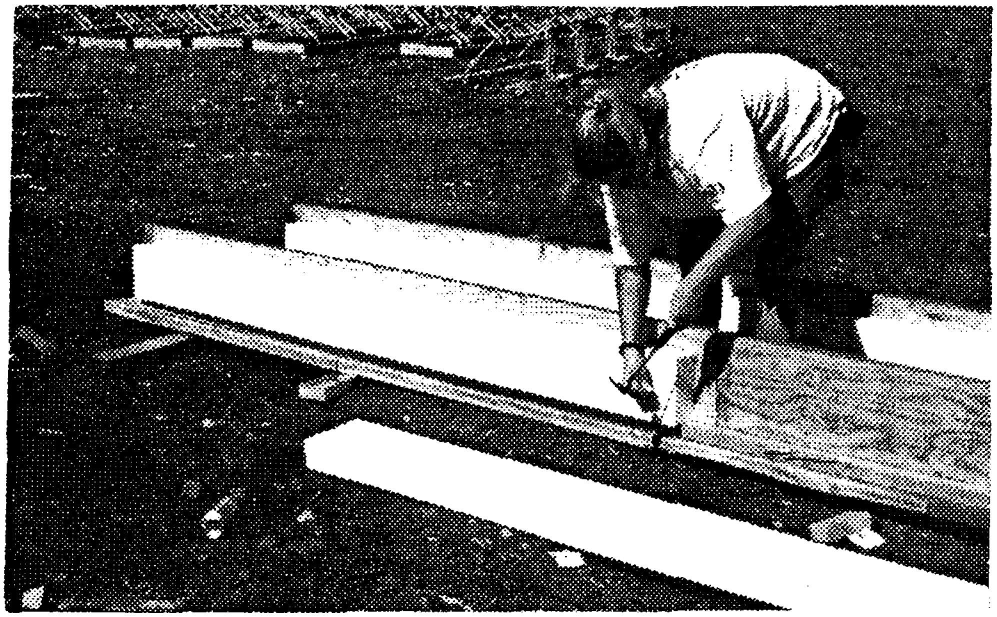
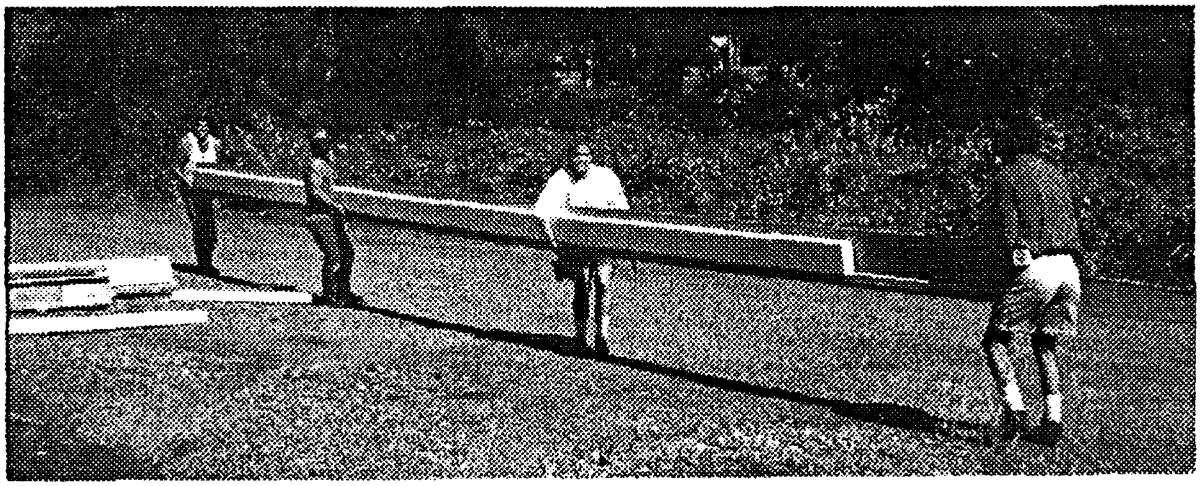
13.0 APPENDIX

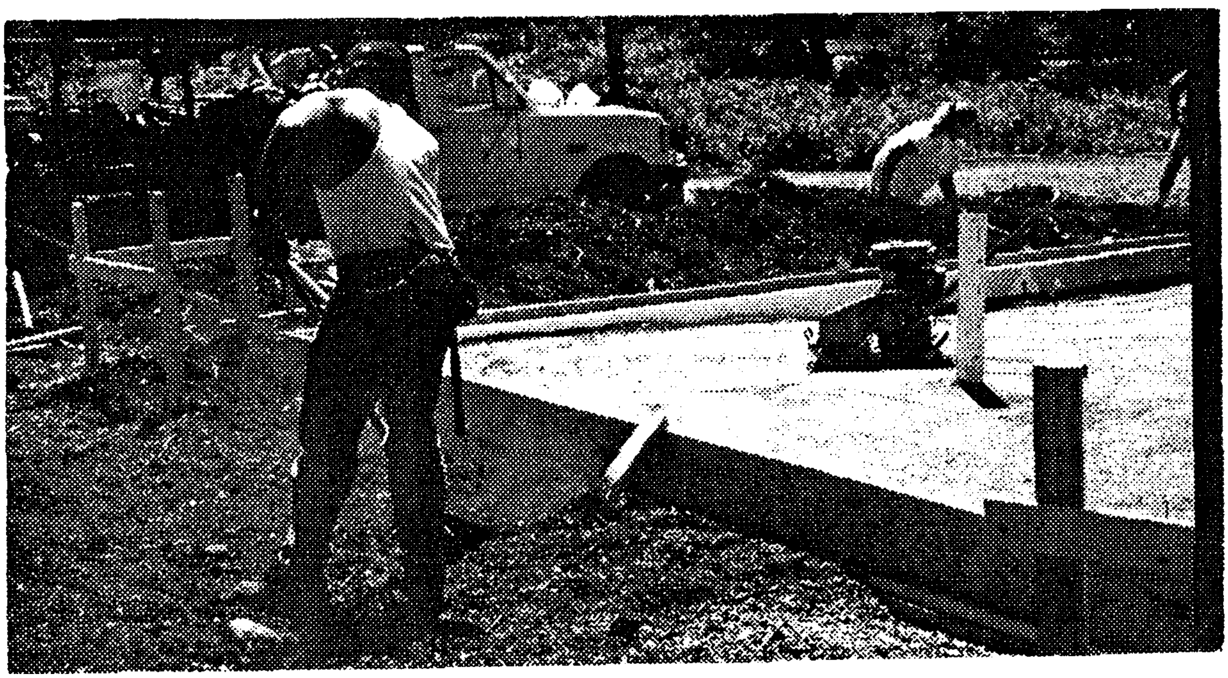
A: Additional Construction Photographs

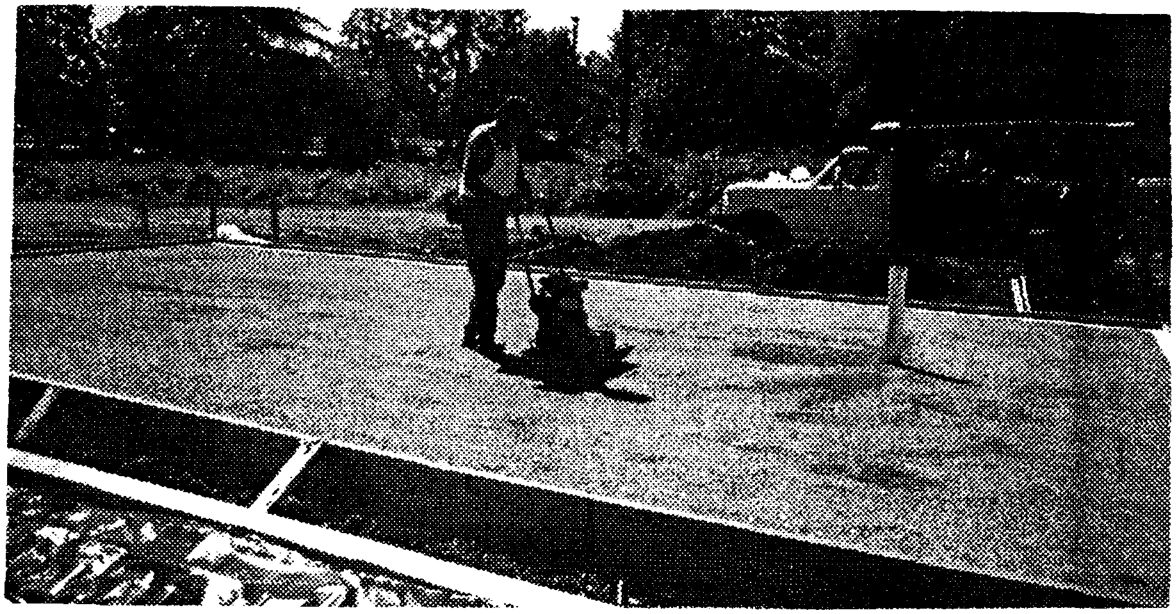


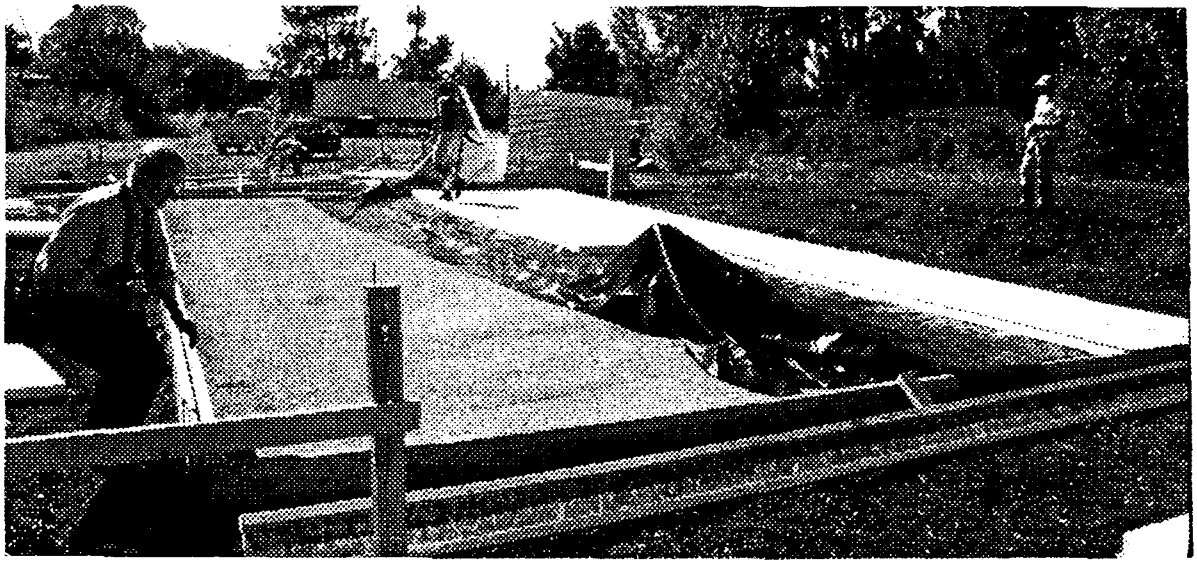


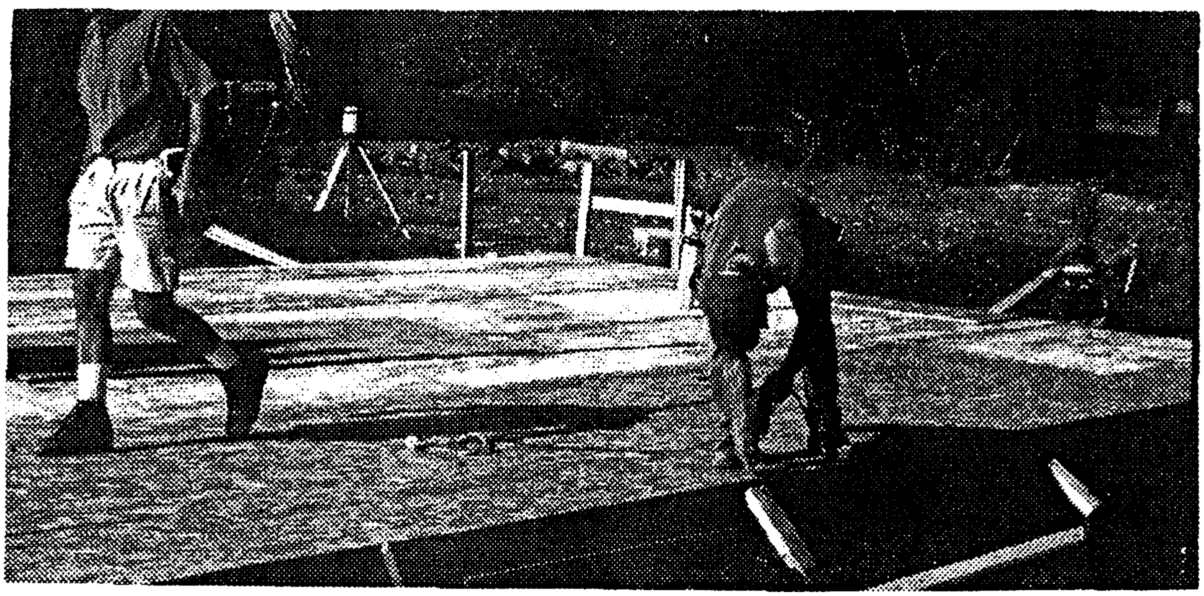












B: Cost Data

Additional note: Wing insulation is not required on either the slab or on-grade panel floor in the Eugene climate so it is not included in the cost estimate. The on-grade panel floor would be designed with wing insulation for alternate climates.

The following notes apply to the cost estimate spreadsheets included in Section 3.0; refer to the spreadsheet for number and letter references.

1. Quantities are based on material takeoffs.

2. Material cost/unit is either the bare material cost from Means plus 10% profit and overhead or the cost estimate from a local source.

3. Cost source identifies the Means reference or the local source.

4. Material cost index refers to the variation from the national average (Means data) for Eugene. 1.06 is the location factor for both installation and materials in Eugene, OR. 1.00 is used if the estimate is from a local source.

5. Material cost is calculated as follows:
   material cost = quantity x cost/unit x material cost index

6. Manhours/unit is based on Means data.

7. Manhours/unit source lists the Means reference.

8. Base labor hours are calculated as follows:
   base labor hours = quantity x manhours/unit

8a. Times are based on video tape analysis.

8b. Revised base labor hours are either calculated as in 8 if no recorded time is listed, noted as the recorded time, or noted as the recorded time reduced by 30% (shaded). The 20% reduction occurs for new tasks expected to require less time once the crew is familiar with them. 20% is based on the "Demo House Cost Estimate."

9. Installation cost index refers to the variation from the national average (Means data) for Eugene. 1.06 is the location factor for both installation and materials in Eugene, OR. An installation cost index of 1.000 was used when the recorded time was used.

10. Labor type refers to the personnel used. The following codes apply:

clab	common laborer
carp	carpenter
eqmd	equipment operator, medium

rodm	rodman
fore	foreman
finish	cement finisher
help	helper

11. Labor rates are based on Means data for crews or individual workers, including overhead and profit. When more than one worker is required for a task, the rate represents the average of the assigned workers. Rates for individual workers used:

clab	common laborer	$32.15
carp	carpenter	$41.00
eqmd	equipment operator, medium	$29.55
rodm	rodman	$34.65
fore	foreman	$33.65
cefi	cement finisher	$27.20
help	helper	$22.10

12. Labor cost is calculated as follows:
labor cost = base labor hours x installation cost index x labor rate

13. Equipment type represents the type of equipment required to do each individual task.

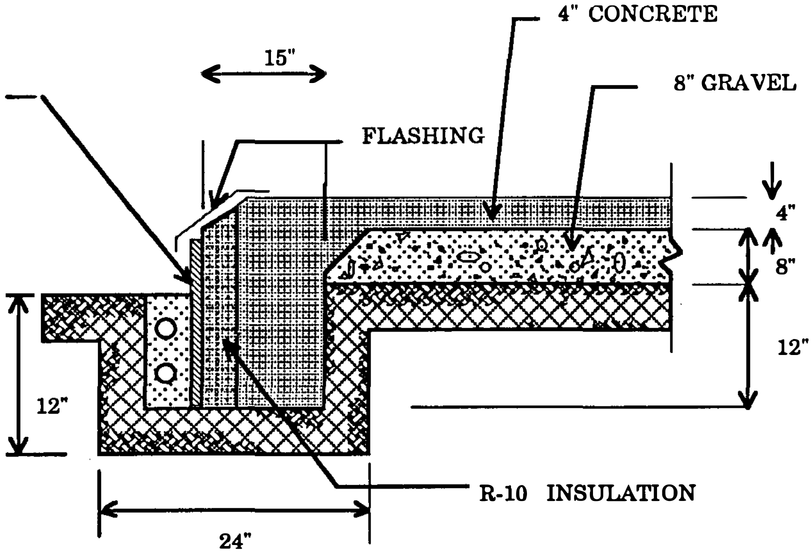
14. Equipment rates are based on Means data. If base costs are available, they are used first. If they are not available for the task, then weekly rental rates plus the hourly operating cost are used. 10% profit is added to these bare costs. Also, if the bare cost is used, it is first translated into an hourly rate since it is listed per unit.

15. Equipment rate source identifies the Means reference used.

16. Equipment cost is calculated as follows:
equipment cost = equipment rate x base labor hours

17. Total cost is calculated as follows:
total cost = materials cost + labor cost + equipment cost

SLAB COST ESTIMATE NOTES



A. Clear building footprint plus a 20' edge all around.
(36' + 40')(20' + 40') = 4560 sf = 0.1 acre

equipment rate = $243/acre
hourly rate = $243/acre x 1/32 acre/hr = $7.59/hr
hourly rate + 10% profit = $8.35/hr

B. trench is 112' x 12" deep x 24" wide = 224 cf = 8.3 cy

equipment rate = $1.44/cy
hourly rate = $1.44/cy x 1/.107 cy/hr = $13.46/hr
hourly rate + 10% profit = $14.80/hr

C. interpolate for material cost and output between 6" and 9" gravel fill

quantity based on interior area = (20-2.5)x(36-2.5) = 586 sf

Labor crew is estimated to be one foreman and three laborers, since crew B37 included five workers which seemed excessive for a 20' by 36' floor. Labor rate is the average rate of all the workers.

Equipment used was a vibratory plate compactor, rate based on weekly rental and hourly operating costs. ($100 wk/40 + $0.52/hr) + 10% = $3.32/hr.

D. moisture barrier quantity includes a 20" vertical leg around the perimeter, footprint, and 10% waste

E. insulation was assumed to be a 2' width around the perimeter, therefore cost was estimated from Means 072-116-1960, while manhours/unit was found from Means 072-109-0700

F. assume perimeter length plus 1' on each side to go around corner
length = (38 + 22)2 = 120'

used cost estimate and manhours/unit for non-perforated PVC as closest available

G. quantity = 112' x .75' x 1.0' = 84 cf =3.1 cy
assume 1 laborer speading gravel by hand

H. gutter drain for 2 long sides of house = (36' + 4')2' = 80 lf

I. 112' perimeter by 24" high

equipment rate is for 3 power tools for the crew of 4
equipment rate = $0.07/sfca
hourly rate = $0.07/sfca x 1/.074 sfca/hr = $0.95/hr
hourly rate + 10% profit = $1.04/hr

J. 2 -#4 bars around perimeter = 224 lf
weight = 0.668 lb/ft x 224 ft = 150 lbs
assume 10% wastage = 150 x 1.1 = 165 lbs

K. 20' x 36' = total area = 720 sf + 10% wastage = 792 sq ft
welded wire mesh, assume W1.4 x W1.4

L. slab + footings + 10% wastage
[(20'x36'x4") + (112'x15"x20")]x1.1 = 520 cf = 19.3 cy

M. footing concrete volume = 233 + 10% = 256.3 cf or 9.5 cy

equipment rate = $0.62/cy
hourly rate = $0.62/cy x 1/0.4 cy/hr = $1.55/hr
hourly rate + 10% profit = $1.71/hr

N. slab concrete volume = 240 cf + 10% = 264 cf or 9.78 cy

equipment rate = $0.68/cy
hourly rate = $0.68/cy x 1/0.436 cy/hr = $1.56/hr
hourly rate + 10% profit = $1.71/hr

O. 36' x 20' = 720 sf
steel trowel finish for resilient tile

equipment rate = $0.06/sf
hourly rate = $0.06/sf x 1/0.013 sf/hr = $4.62/hr
hourly rate + 10% profit = $5.08/hr

P. 22 anchor bolts required bases on report 1 estimates

Q. curing concrete on entire floor area using burlap, four uses, 7.5 oz

R. install 2x6 treated subplate

equipment rate = $0.04/lf
hourly rate = $0.04/lf x 1/0.032 sf/hr = $1.25/hr
hourly rate + 10% profit = $1.38/hr

S. construction loan interest is based on construction subtotal at current prime rate + 1% (9.5%)

time is based on hours to construct / 8 hours per day / 3 workers per day plus three days for curing

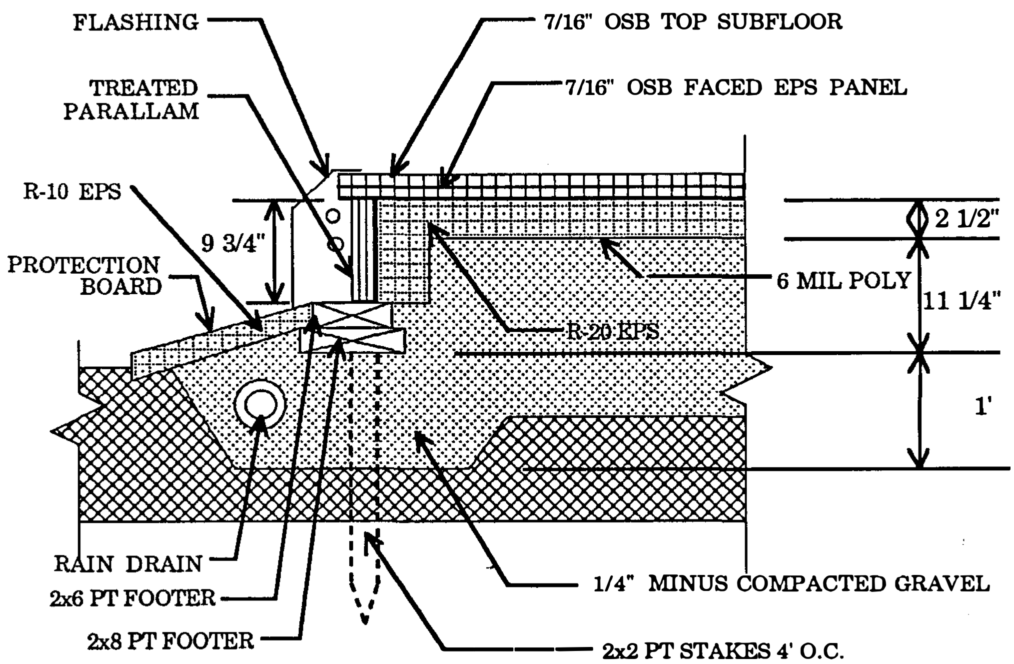
T. insurance rates are based on

M-010-040-0010/0050 average of builder's risk	= 0.41 %
M-010-040-0600 public liability	= 1.55 %
Total	= 1.96%

this percentage is applied to the construction subtotal

U. only field expenses are a site toilet, $10/day M016-420-6410

ON-GRADE PANEL FLOOR COST ESTIMATES NOTES



A. Clear building footprint plus a 20' edge all around.
(36' + 40')(20' + 40') = 4560 sf = 0.1 acre

equipment rate = $243/acre
hourly rate = $243/acre x 1/32 acre/hr = $7.59/hr
hourly rate + 10% profit = $8.35/hr

B. equipment rate = $1.44/cy
hourly rate = $1.44/cy x 1/.107 cy/hr = $13.46/hr
hourly rate + 10% profit = $14.80/hr

C. recorded hours used, no new task reduction

equipment used was a vibratory plate compactor, rate based on weekly rental and hourly operating cost. ($100 wk/40 + $0.52/hr) + 10% = $3.32/hr

D. includes the labor and Parallam material only
other materials are listed separately in the e-g

E-G. other components of the footer assembly

H. installing the footer includes the labor only to install the footer and stakes; they are not subdivided due to the lack of timed information

I. the stake material is assumed to be 4' stakes, 2x4s split into 2x2s a total of 26 stakes were used

J. perimeter insulation as shown in the diagram on the inside of the footer assembly, 112' x 8" = 75 sf

K. the perimeter drain used is similar to the one noted for the slab floor

120 ft allows for the perimeter plus one foot on the ends to turn the corner

L. fill installation refers to the fill directly under the floor, area = 676 sf

M. moisture barrier allows for 10% wastage, (20' + .5')(36' + .5')x1.1 =823 sf

N. unloading the panels could be done by hand to reduce the equipment cost; it would however increase the time required

O. time to lay panels was derived from recorded time

P. floor panel cost estimates were obtained from a local panel supplier

Q. panel transportation costs were also obtained from a local panel supplier based on the shipment cost to Eugene

R. installing top floor was estimated to be similar to installing waferboard with a pneumatic nailer

S-T. fastners

U. tiedowns are required to prevent uplift, the time is estimated based on local information and the assumption that one person would require 10 minutes to install one anchor

V. tiedown framing consists of a PT 2x6 nailed diagonally across the corner to the footer assembly

W. construction loan interest is based on construction subtotal at current prime rate + 1% (9.5%)

time is based on hours to construct / 8 hours per day / 3 workers per day plus three days for curing

X. insurance rates are based on

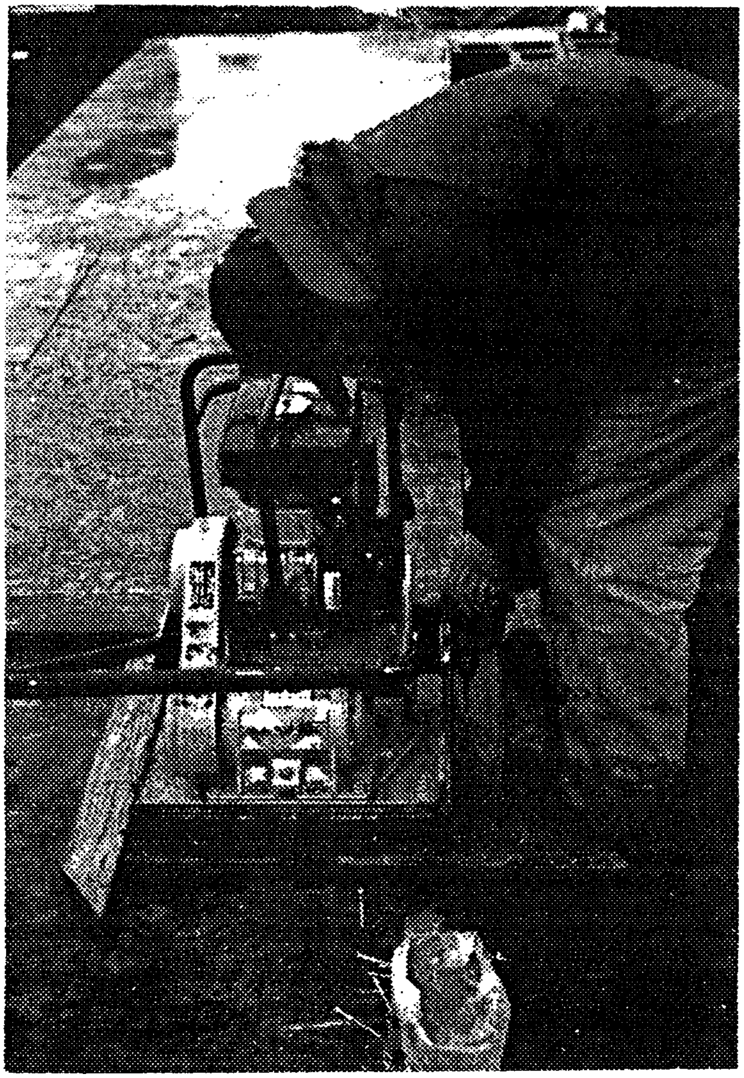
M-010-040-0010/0050 average of builder's risk	= 0.41 %
M-010-040-0600 public liability	= 1.55 %
Total	= 1.96%

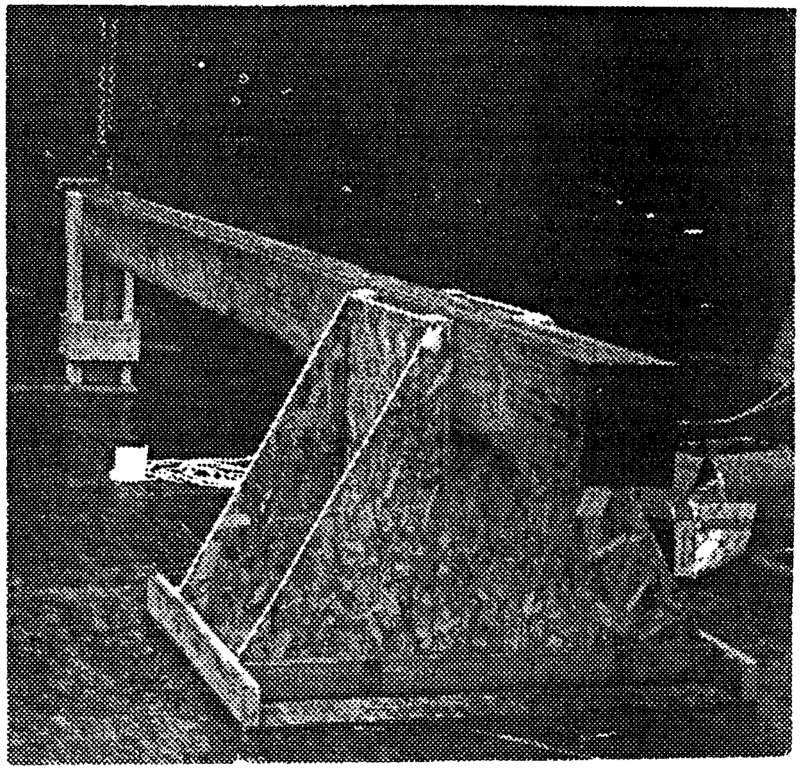
this percentage is applied to the construction subtotal

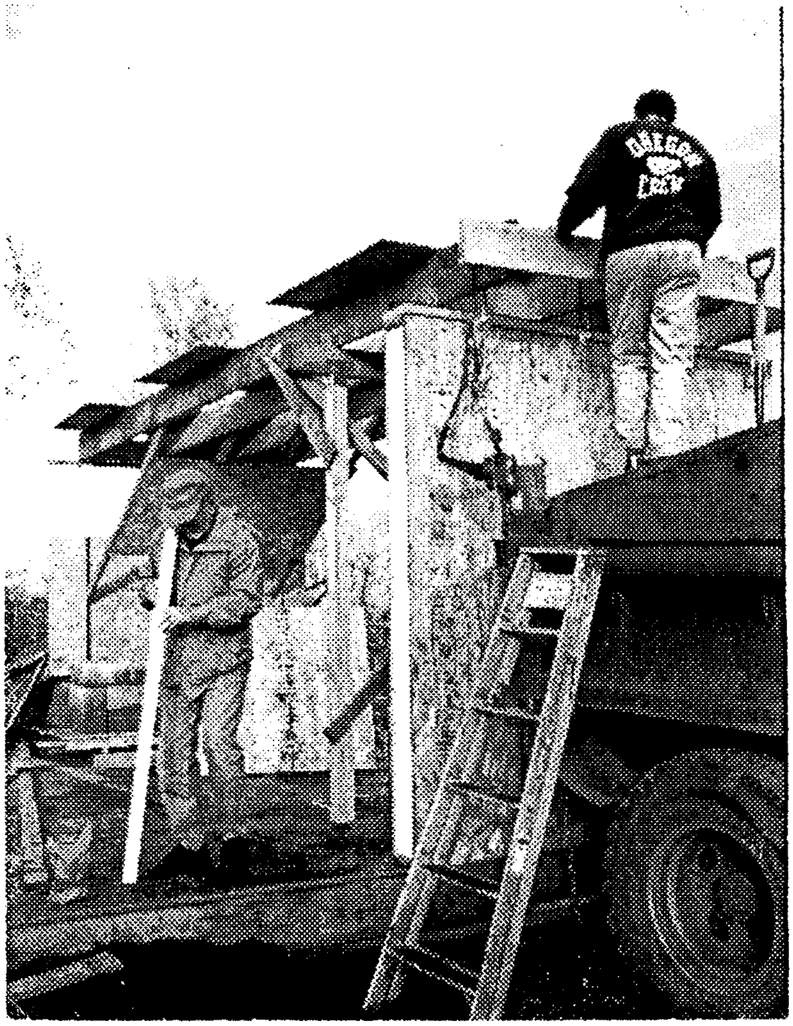
Y. only field expenses are a site toilet, $10/day M016-420-6410

C: Structural On-Site Testing

Testing Photographs







Test Results

ON-GRADE INSULATED PANEL FLOOR SYSTEM

TEST

INTERIOR PARTITION

DATE: 11/25/96
START TIME: 9:00
END TIME: 10:00
WEATHER: sun/sprinkles

COMMENTS

-no signification deflections

* readings in 40th of an inch
** deflections converted to inches (- means down)

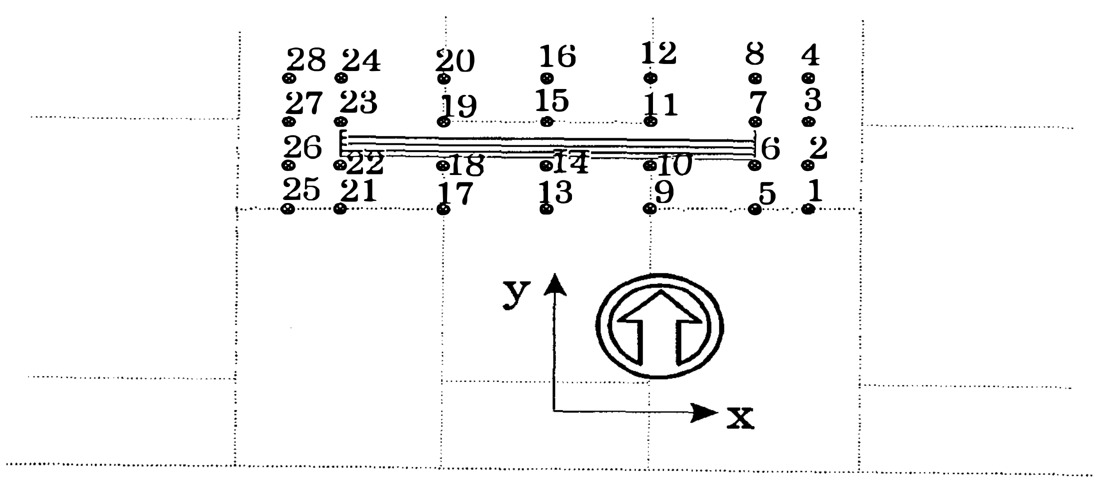
DATA

			loads (lbs) 0	beam		920		1605		2920		3880		3670		comments
	x	y		rod*	Δ**	rod	Δ	rod	Δ	rod	Δ	rod	Δ	rod	Δ	
1	29.0	6.0	8.7	8.6	-0.02	8.7	0.00	8.8	0.03	8.8	0.03	8.9	0.05	8.9	0.05	
2	29.0	7.0	9.0	8.9	-0.02	8.8	-0.05	8.8	-0.05	8.8	-0.05	8.7	-0.08	8.7	-0.08	
3	28.0	6.0	7.9	8.0	0.02	8.0	0.02	7.9	0.00	7.8	-0.03	7.9	0.00	7.9	0.00	
4	28.0	7.0	8.0	8.2	0.05	7.9	-0.02	7.9	-0.02	7.6	-0.05	7.7	-0.08	7.7	-0.08	
5	26.0	6.0	8.0	7.8	-0.05	7.5	-0.13	7.5	-0.13	7.3	-0.18	7.5	-0.13	7.5	-0.13	
6	26.0	7.0	8.0	7.8	-0.05	7.8	-0.05	7.6	-0.10	7.0	-0.25	6.9	-0.28	6.9	-0.28	
7	24.0	6.0	8.3	8.0	-0.08	7.5	-0.20	7.8	-0.13	7.8	-0.13	7.6	-0.18	7.6	-0.18	
8	24.0	7.0	8.4	8.1	-0.08	7.5	-0.23	7.8	-0.15	7.6	-0.20	7.6	-0.20	7.6	-0.20	
9	22.0	6.0	8.1	8.0	-0.02	7.6	-0.13	7.6	-0.13	7.8	-0.08	7.6	-0.13	7.6	-0.13	
10	22.0	7.0	8.1	7.9	-0.05	7.5	-0.15	7.7	-0.10	7.6	-0.13	7.6	-0.13	7.6	-0.13	
11	20.0	6.0	7.0	7.4	0.10	7.4	0.10	7.3	0.08	7.5	0.13	7.4	0.10	7.4	0.10	
12	20.0	7.0	6.9	7.3	0.10	7.0	0.02	7.0	0.02	7.1	0.05	6.9	0.00	6.9	0.00	
13	19.0	6.0	7.3	7.2	-0.02	7.1	-0.05	7.1	-0.05	7.1	-0.05	7.0	-0.08	7.0	-0.08	
14	19.0	7.0	6.9	6.7	-0.05	6.8	-0.03	6.9	0.00	6.8	-0.03	6.9	0.00	6.9	0.00	
15	19.0	8.0	6.9	6.7	-0.05	6.9	0.00	7.0	0.02	6.9	0.00	6.9	0.00	6.9	0.00	
16	19.0	9.0	6.7	6.7	0.00	6.6	-0.03	6.7	0.00	8.6	-0.03	6.7	0.00	6.7	0.00	
17	20.0	8.0	7.0	7.3	0.08	7.1	0.02	7.1	0.02	7.1	0.02	7.0	0.00	7.0	0.00	
18	20.0	9.0	6.9	7.2	0.08	7.0	0.02	7.1	0.05	7.0	0.02	6.8	-0.03	6.8	-0.03	
19	22.0	8.0	8.2	7.8	-0.10	7.9	-0.07	7.9	-0.07	8.0	-0.05	7.8	-0.10	7.8	-0.10	
20	22.0	9.0	8.1	8.1	0.00	8.1	0.00	8.1	0.00	7.8	-0.08	7.9	-0.05	7.9	-0.05	
21	24.0	8.0	7.9	7.8	-0.03	7.5	-0.10	7.5	-0.10	7.4	-0.13	7.2	-0.18	7.2	-0.18	
22	24.0	9.0	7.3	7.4	0.03	7.2	-0.02	7.3	0.00	7.3	0.00	7.2	-0.02	7.2	-0.02	
23	26.0	8.0	7.8	7.6	-0.05	7.2	-0.15	6.9	-0.23	6.9	-0.23	8.7	-0.28	6.7	-0.28	
24	26.0	9.0	8.0	7.8	-0.05	7.8	-0.05	7.8	-0.05	7.8	-0.05	7.6	-0.10	7.6	-0.10	
25	28.0	8.0	8.4	6.4	0.00	8.2	-0.05	8.1	-0.08	8.0	-0.10	8.0	-0.10	8.0	-0.10	
26	28.0	9.0	8.5	8.8	0.08	8.8	0.08	8.7	0.05	8.8	0.08	8.6	0.02	8.6	0.02	
27	29.0	8.0	9.0	9.0	0.00	8.9	-0.02	9.0	0.00	9.1	0.02	9.0	0.00	9.0	0.00	
28	29.0	9.0	9.0	9.2	0.05	9.1	0.02	9.0	0.00	9.0	0.00	9.0	0.00	9.0	0.00	

RESULTS

load	0.00	28.75	56.41	91.25	121.25	114.69	lbs / linear foot
maximum deflection	-0.10	-0.23	-0.23	-0.25	-0.28	-0.28	inches
average deflection	-0.01	-0.04	-0.04	-0.05	-0.07	-0.07	inches

DIAGRAM



ON-GRADE INSULATED PANEL FLOOR SYSTEM

TEST

EXTERIOR POST (4BY6)

DATE: 12/11/96
START TIME: 4:30
END TIME: 5:10
WEATHER: raining

COMMENTS

after intial loading post was not vertical, load cell repositioned over per. beam
* readings in 40th of an inch
** deflections converted to inches (- means down)

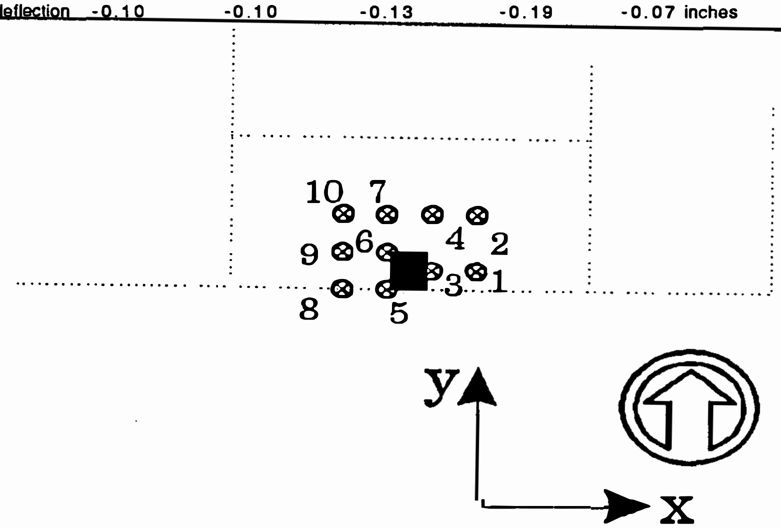
DATA

			loads (lbs) 0	4000		4000		6000		7700		0		comments
	x	y		rod*	Δ**	rod	Δ	rod	Δ	rod	Δ	rod	Δ	
1	32.8	0.3	7.0	6.5	-0.13	6.8	-0.05	6.7	-0.08	6.3	-0.18	6.9	-0.02	
~~2~~	~~32.8~~	~~1.0~~	~~6.0~~	~~6.0~~	0.00	6.0	0.00	6.0	0.00	5.9	-0.02	8.0	0.00	
3	32.3	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
~~4~~	~~32.3~~	~~1.0~~	~~6.0~~	~~5.8~~	-0.05	5.5	-0.13	5.5	-0.13	5.2	-0.20	5.8	-0.05	
5	31.8	0.0	6.5	6.1	-0.10	6.1	-0.10	5.8	-0.18	5.6	-0.23	6.3	-0.05	
~~6~~	~~31.8~~	~~0.5~~	~~6.2~~	~~5.5~~	-0.18	5.5	-0.18	5.3	-0.23	5.0	-0.30	5.9	-0.08	
7	31.8	1.0	6.3	6.1	-0.05	5.8	-0.13	5.5	-0.20	5.1	-0.30	5.9	-0.10	
8	31.3	0.0	6.8	5.8	-0.25	6.2	-0.15	6.2	-0.15	6.0	-0.20	6.3	-0.13	
~~9~~	~~31.3~~	~~0.5~~	~~6.8~~	~~8.2~~	-0.10	8.1	-0.13	6.0	-0.15	5.8	-0.20	6.1	-0.13	
~~10~~	~~31.3~~	~~1.0~~	6.4	6.2	-0.05	6.1	-0.08	6.0	-0.10	5.9	-0.13	6.1	-0.08	

RESULTS

	4000	4000	6000	7700	0	
load	166.67	166.67	250.00	320.83	0.00	psi
maximum deflection	-0.25	-0.18	-0.23	-0.30	-0.13	inches
average deflection	-0.10	-0.10	-0.13	-0.19	-0.07	inches

DIAGRAM



ON-GRADE INSULATED PANEL FLOOR SYSTEM

TEST

INTERIOR POST

DATE: 12/11/96
START TIME: 2:30
ENDTIME: 3:30
WEATHER: rain

COMMENTS

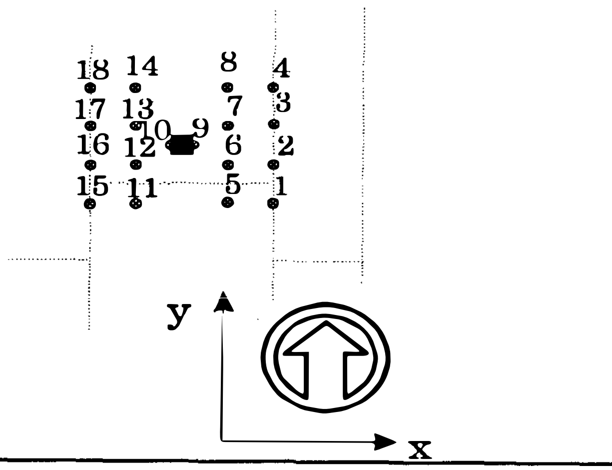
- tested until crack of the floor was heard

* readings in 40th of an inch
** deflections converted to inches (- means down)

DATA

			0	1500		2000		3000		2400		3700		0		comments
	x	y	rod	rod* (1500)	Δ**	rod	Δ	rod	Δ	rod	Δ	rod	Δ	rod (0)	Δ	
1			6.0	6.0	0.00											
2			6.5	6.2	-0.08											
3			7.0	6.6	-0.10											
4			7.3	7.0	-0.08											
5			6.1	6.1	0.00											
6	33.0	8.5	5.5	5.5	0.00	5.5	0.00	5.5	0.00			5.2	-0.08	5.5	0.00	
7	33.0	9.5	6.3	6.0	-0.08	6.0	-0.08	6.0	-0.08			6.0	-0.08	6.1	-0.05	
8			6.5	6.2	-0.08											
9	32.3	9.0	6.0	5.5	-0.13	5.5	-0.13	5.3	-0.18	5.3	-0.18	5.1	-0.23	5.8	-0.05	
10	31.8	9.0	6.0	5.5	-0.13	5.3	-0.18	5.1	-0.23			4.9	-0.28	5.5	-0.13	
11			5.3	5.3	0.00											
12	31.0	8.5	5.2	5.3	0.02	5.2	0.00	5.2	0.00			5.0	-0.05	5.4	0.05	
13	31.0	9.5	6.0	6.0	0.00	6.0	0.00	6.0	0.00			5.8	-0.05	6.0	0.00	
14			6.3	6.4	0.03											
15			5.7	5.8	0.02											
16			5.8	5.8	0.00											
17			6.2	6.1	-0.03											
18			6.8	6.8	0.00											
RESULTS																
				load	93.75		125.00		187.50		150.00		231.25		0.00 psi	
				maximum deflection	-0.13		-0.18		-0.23		-0.18		-0.28		-0.13 inches	
				average deflection	-0.03		-0.06		-0.08		-0.18		-0.13		-0.03 inches	

DIAGRAM



ON-GRADE INSULATED PANEL FLOOR SYSTEM

TEST

INTERIOR PARTITION ON END

DATE: 12/11/96
START TIME: 3:30
END TIME: 4:30
WEATHER: rain

COMMENTS

* readings in 40th of an inch
** deflections converted to inches (- means down)

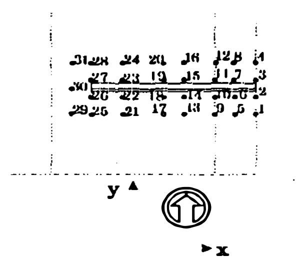
DATA

			loads (lbs)									comments
			10	2500		4000		6000		0		
	x	y		rod*	Δ**	rod	Δ	rod	Δ	rod	Δ	
1	36.0	3.5	6.5	6.3	-0.05	6.1	-0.10	6.2	-0.08	6.2	-0.08	
2	36.0	4.5	7.1	7.0	-0.02	7.0	-0.02	7.0	-0.02	7.2	0.03	
3	36.0	5.5	7.0	6.6	-0.10	6.4	-0.15	6.5	-0.13	6.9	-0.02	
4	36.0	6.5	6.5	6.2	-0.08	6.3	-0.05	6.2	-0.08	6.5	0.00	
5	35.0	3.5	5.8	5.5	-0.08	5.3	-0.13	5.1	-0.18	5.6	-0.05	
6	35.0	4.5	6.0	5.6	-0.10	5.3	-0.18	5.1	-0.23	5.9	-0.02	
7	35.0	5.5	6.0	5.7	-0.08	5.3	-0.18	5.1	-0.23	6.0	0.00	
8	35.0	6.5	6.2	6.0	-0.05	5.9	-0.08	5.9	-0.08	6.2	0.00	
9	34.0	3.5	5.1	5.1	0.00	5.2	0.03	5.2	0.03	5.5	0.10	
10	34.0	4.5	6.0	5.6	-0.10	5.5	-0.13	5.4	-0.15	5.9	-0.02	
11	34.0	5.5	6.0	5.5	-0.13	5.3	-0.18	5.1	-0.23	5.2	-0.20	
12	34.0	6.5	6.2	5.9	-0.08	5.9	-0.08	5.9	-0.08	6.0	-0.05	
13	32.5	3.5	5.0	5.0	0.00	5.0	0.00	5.0	0.00	5.0	0.00	
14	32.5	4.5	5.0	5.0	0.00	4.7	-0.08	4.6	-0.10	5.0	0.00	
15	32.5	5.5	5.9	5.5	-0.10	5.1	-0.20	5.0	-0.23	5.7	-0.05	
16	32.5	6.5	5.6	5.3	-0.08	5.1	-0.13	5.1	-0.13	5.4	-0.05	
17	31.5	3.5	4.7	4.5	-0.05	4.5	-0.05	4.5	-0.05	4.6	-0.03	
18	31.5	4.5	5.0	4.6	-0.10	4.1	-0.23	4.0	-0.25	4.6	-0.10	
19	31.5	5.5	5.6	5.0	-0.15	4.6	-0.25	4.7	-0.23	5.1	-0.13	
20	31.5	6.5	5.9	5.7	-0.05	5.6	-0.08	5.4	-0.13	5.9	0.00	
21	29.5	3.5	4.9	4.8	-0.03	4.8	-0.03	4.8	-0.03	4.9	0.00	
22	29.5	4.5	5.1	5.0	-0.02	5.0	-0.02	4.6	-0.13	5.0	-0.02	
23	29.5	5.5	5.5	5.3	-0.05	5.1	-0.10	5.0	-0.13	5.5	0.00	
24	29.5	6.5	5.9	5.8	-0.03	5.7	-0.05	5.5	-0.10	5.9	0.00	
25	28.0	3.5	4.2	4.1	-0.03	4.0	-0.05	4.1	-0.03	4.1	-0.03	
26	28.0	4.5	4.5	4.6	0.02	4.2	-0.08	4.2	-0.08	4.5	0.00	
27	28.0	5.5	4.8	4.7	-0.02	4.5	-0.08	4.5	-0.08	4.8	0.00	
28	28.0	6.5	5.1	5.2	0.03	5.2	0.03	5.3	0.05	5.2	0.03	
29	27.0	3.5	4.0	4.0	0.00	4.0	0.00	3.9	-0.03	4.0	0.00	
30	27.0	5.0	4.3	4.2	-0.02	4.1	-0.05	4.1	-0.05	4.2	-0.02	
31	27.0	3.5	4.7	4.5	-0.05	4.6	-0.03	4.5	-0.05	4.6	-0.03	

RESULTS

	2500	4000	6000	0	
load	78.13	125.00	187.50	0.00	lbs/linear foot
maximum deflection	-0.15	-0.25	-0.25	-0.20	inches
average deflection	-0.05	-0.09	-0.10	-0.02	inches

DIAGRAM



ON-GRADE INSULATED PANEL FLOOR SYSTEM

TEST		
SSIC PANEL	DATE:	11/24/
	START TIME:	12:3
	END TIME:	4:3
	WEATHER:	sun/sprinkles

COMMENTS

- -significant deflection on NW corner of floor
- -no noticable shifting between two panels
- -only loaded to 1/2 of desired load due to limits of the dump truck

* readings in 40th of an inch
** deflections converted to inches (- means dc

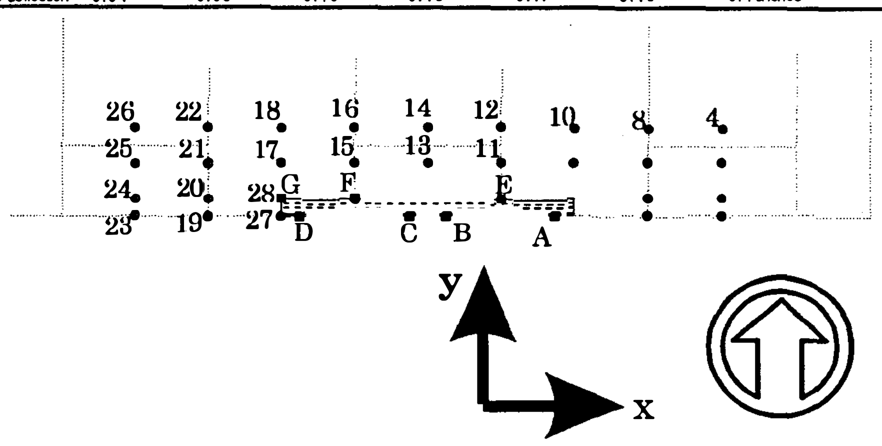
DATA

				loads cell reading (lbs)/revised load per foot														comments
			10	177/263		378/475		595/704		970/1099		1100/1236		1200/1341		1300/1446		
	x	y		rod*	Δ**	rod	Δ	rod	Δ	rod	Δ	rod	Δ	rod	Δ	rod	Δ	
4	32.0	2.5	44.0	43.9	-0.03	43.9	-0.03	44.0	0.00	44.1	0.03	44.0	0.00	43.9	-0.03	44.0	0.00	
8	30.0	2.5	43.9	44.0	0.03	44.0	0.03	43.9	0.00	43.8	-0.03	43.9	0.00	43.9	0.00	44.0	0.03	
10	38.0	2.5	42.9	43.0	0.03	43.0	0.03	43.0	0.03	42.8	-0.03	42.8	-0.03	42.9	0.00	42.9	0.00	
11	36.0	1.5	43.8	43.5	-0.07	43.5	-0.07	43.5	-0.07	43.4	-0.10	43.2	-0.15	43.2	-0.15	43.2	-0.15	
12	36.0	2.5	42.7	43.0	0.07	43.1	0.10	42.9	0.05	43.0	0.07	43.0	0.07	43.0	0.07	43.0	0.07	
13	34.0	1.5	43.0	42.7	-0.07	42.4	-0.15	42.4	-0.15	42.1	-0.23	42.2	-0.20	42.2	-0.20	42.2	-0.20	
14	24.0	2.5	43.1	43.0	-0.03	42.8	-0.08	42.9	-0.05	43.0	-0.03	43.0	-0.03	42.9	-0.05	42.9	-0.05	
15	22.0	1.5	43.3	42.9	-0.10	42.7	-0.15	42.7	-0.15	42.5	-0.20	42.4	-0.23	42.4	-0.23	42.5	-0.20	
16	22.0	2.5	43.0	42.9	-0.03	42.9	-0.03	42.9	-0.03	42.9	-0.03	42.9	-0.03	42.9	-0.03	42.9	-0.03	
17	20.0	1.5	42.9	42.5	-0.10	42.3	-0.15	42.2	-0.17	42.0	-0.23	41.9	-0.25	41.9	-0.25	41.9	-0.25	
18	20.0	2.5	43.1	43.0	-0.03	42.9	-0.05	42.9	-0.05	42.9	-0.05	42.8	-0.08	42.9	-0.05	42.9	-0.05	
19	18.0	0.0	43.4	43.1	-0.07	43.0	-0.10	42.9	-0.13	43.0	-0.10	42.7	-0.17	42.6	-0.20	42.4	-0.25	
20	18.0	0.5	43.7	43.5	-0.05	43.4	-0.08	43.4	-0.08	43.2	-0.13	43.0	-0.18	43.0	-0.18	42.6	-0.28	
21	18.0	1.5	43.8	43.7	-0.02	43.6	-0.05	43.6	-0.05	43.5	-0.07	43.3	-0.13	43.4	-0.10	43.2	-0.15	
22	18.0	2.5	43.9	43.9	0.00	43.8	-0.03	43.8	-0.03	43.9	0.00	43.7	-0.05	43.7	-0.05	43.7	-0.05	
23	16.0	0.0	44.3	44.3	0.00	44.3	0.00	44.3	0.00	44.1	-0.05	44.0	-0.07	43.9	-0.10	43.9	-0.10	
24	16.0	0.5	43.9	43.8	-0.03	43.8	-0.03	43.8	-0.03	43.6	-0.07	43.6	-0.07	43.6	-0.07	43.6	-0.07	
25	16.0	1.5	43.1	43.0	-0.03	42.8	-0.08	42.9	-0.05	42.8	-0.08	42.8	-0.08	42.7	-0.10	42.7	-0.10	
26	16.0	2.5	43.3	43.2	-0.02	43.1	-0.05	43.2	-0.02	43.1	-0.05	43.0	-0.07	43.1	-0.05	43.1	-0.05	
27	20.0	0.0	42.8	42.6	-0.05	42.2	-0.15	42.1	-0.17	41.8	-0.25	41.5	-0.32	41.4	-0.35	41.3	-0.38	
28	20.0	0.5	42.8	42.0	-0.20	41.5	-0.32	41.2	-0.40	40.9	-0.48	40.6	-0.55	40.5	-0.57	40.3	-0.63	
A	27.5	0.0	42.6	42.6	0.00	42.4	-0.05	42.2	-0.10	42.0	-0.15	41.7	-0.23	41.7	-0.23	41.5	-0.28	
B	24.5	0.0	3.6	3.5	-0.03	3.1	-0.13	2.7	-0.23	2.5	-0.28	2.1	-0.38	2.0	-0.40	1.9	-0.43	
C	23.5	0.0	30.7	30.4	-0.08	30.0	-0.18	29.7	-0.25	29.4	-0.33	29.0	-0.43	28.9	-0.45	28.6	-0.52	
D	20.5	0.0	17.6	17.2	-0.10	16.6	-0.25	16.3	-0.33	16.0	-0.40	15.4	-0.55	15.2	-0.60	15.0	-0.65	
E	NA	0.5	26.5	26.5	0.00	26.5	0.00	26.5	0.00	26.5	0.00	26.5	0.00	26.5	0.00	26.6	0.03	
F	NA	0.5	41.0	41.0	0.00	41.0	0.00	41.0	0.00	41.0	0.00	41.0	0.00	41.0	0.00	41.0	0.00	
G	NA	0.5	3.9	3.5	-0.10	2.8	-0.28	2.4	-0.38	2.1	-0.45	1.7	-0.55	1.6	-0.58	1.4	-0.63	

RESULTS

load	263	475	704	1099	1236	1341	1446	lbs
load	65.75	118.75	176.00	274.75	309.00	335.25	361.50	lb/linear foot
maximum deflection	-0.20	-0.32	-0.40	-0.48	-0.55	-0.60	-0.65	inches
average deflection	-0.04	-0.08	-0.10	-0.13	-0.17	-0.18	-0.19	inches

DIAGRAM



ON-GRADE INSULATED PANEL FLOOR SYSTEM

TEST

DATE: 12/11/96
START TIME: 10:30
END TIME: 11:30
WEATHER: sun/sprinkles

DISTRIBUTED

COMMENTS

* readings in 40th of an inch
** deflections converted to inches (- means down)

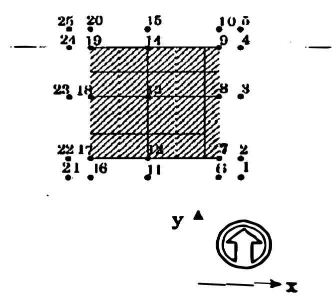
DATA

			0	1 layer 1500 lbs		2 layers 3000 lbs		3 layers 4500 lbs		comments
	x	y	rod*	rod*	Δ**	rod	Δ	rod	Δ	
1	11.0	9.0	4.6	4.4	-0.05	4.3	-0.08	4.3	-0.08	
2	11.0	10.0	5.3	4.9	-0.10	4.8	-0.13	4.7	-0.15	
3	11.0	13.3	5.4	5.1	-0.08	5.0	-0.10	5.1	-0.08	
4	11.0	16.0	5.5	5.5	0.00	5.5	0.00	5.6	0.02	
5	11.0	17.0	5.4	5.3	-0.03	5.3	-0.03	5.2	-0.05	
6	12.0	9.0	4.8	4.5	-0.08	4.4	-0.10	4.3	-0.13	
7	12.0	10.0	5.0	4.5	-0.13	4.3	-0.18	4.3	-0.18	
8	12.0	13.3	5.2	4.9	-0.08	5.0	-0.05	5.1	-0.03	
9	12.0	16.0	5.1	5.1	0.00	5.1	0.00	5.0	-0.02	
10	12.0	17.0	5.1	5.1	0.00	5.1	0.00	5.0	-0.02	
11	14.7	9.0	5.2	4.9	-0.08	4.4	-0.20	4.5	-0.18	
12	14.7	10.0	5.5	5.0	-0.13	4.6	-0.23	4.5	-0.25	
13	14.7	13.3	5.6	4.6	-0.25	4.2	-0.35	4.0	-0.40	
14	14.7	16.0	4.7	4.3	-0.10	4.0	-0.18	4.0	-0.18	
15	14.7	17.0	5.0	4.9	-0.02	4.8	-0.05	4.9	-0.02	
16	18.0	9.0	5.1	5.0	-0.02	4.9	-0.05	4.9	-0.05	
17	18.0	10.0	4.9	4.7	-0.05	4.6	-0.08	4.6	-0.08	
18	18.0	13.3	5.0	5.2	0.05	5.2	0.05	5.1	0.02	
19	18.0	16.0	5.4	5.4	0.00	5.3	-0.03	5.4	0.00	
20	18.0	17.0	5.1	5.1	0.00	5.4	0.08	5.3	0.05	
21	19.0	9.0	5.0	5.0	0.00	5.0	0.00	5.0	0.00	
22	19.0	10.0	5.2	5.2	0.00	5.0	-0.05	5.0	-0.05	
23	19.0	13.3	5.5	5.1	-0.10	5.0	-0.13	5.0	-0.13	
24	19.0	16.0	4.7	4.9	0.05	4.8	0.02	5.0	0.08	
25	19.0	17.0	4.8	4.8	0.00	4.9	0.03	4.9	0.03	

RESULTS

	1 layer	2 layers	3 layers	
load	42.00	83.00	125.00	psf
maximum deflection	-0.25	-0.35	-0.40	inches
average deflection	-0.05	-0.07	-0.07	inches

DIAGRAM



ON-GRADE INSULATED PANEL FLOOR SYSTEM

TEST

DYNAMIC

DATE: 12/11/96
START TIME: 12:00
END TIME: 1:00
WEATHER: rain

COMMENTS

* readings in 40th of an inch
** deflections converted to inches (- means down)
- both readings with compactor in place

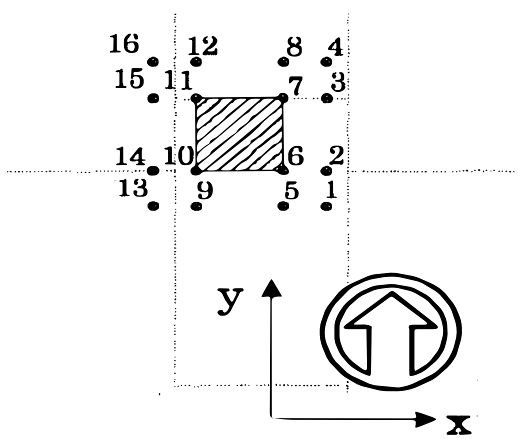
DATA

	x	y	0	after 1 hour rod*	Δ**	comments
1	25.5	13.0	5.7	5.6	-0.03	
2	25.5	14.0	5.5	5.6	0.02	lifting occured at most locations
3	25.5	16.0	5.2	5.1	-0.03	
4	25.5	17.0	5.7	5.9	0.05	
5	24.5	13.0	5.0	5.0	0.00	
6	24.5	14.0	5.7	5.6	-0.03	
7	24.5	16.0	5.1	5.5	0.10	
8	24.5	17.0	5.5	5.6	0.02	
9	22.5	13.0	5.8	5.5	-0.08	
10	22.5	14.0	5.7	5.8	0.02	
11	22.5	16.0	6.0	6.1	0.02	
12	22.5	17.0	6.0	6.0	0.00	
13	21.5	13.0	5.9	5.9	0.00	
14	21.5	14.0	5.8	5.8	0.00	
15	21.5	16.0	5.8	5.9	0.03	
16	21.5	17.0	5.9	6.0	0.02	

RESULTS

maximum deflection -0.08 inches
average deflection 0.01 inches

DIAGRAM



D: F-Number Calculations

Using the procedure outlined in *Design and Construction of Concrete Floors* and ASTM E1155, a value for both flatness and levelness was calculated for the floor as follows:

Flatness

$FF = 4.57 \ (3Sq + \ q \ )$

FF = flatness number
Sq = standard deviation of q
q = 24 inch curvature
q = mean of q

Sq = 0.04
q = 0.07

$FF = 4.57/(3Sq + \ q \ ) = 4.57/(3 \times 0.04 + 0.07) = 24.0$

FF = 24

Levelness

$FL = 12.5 \ (3Sz + \ z \ )$

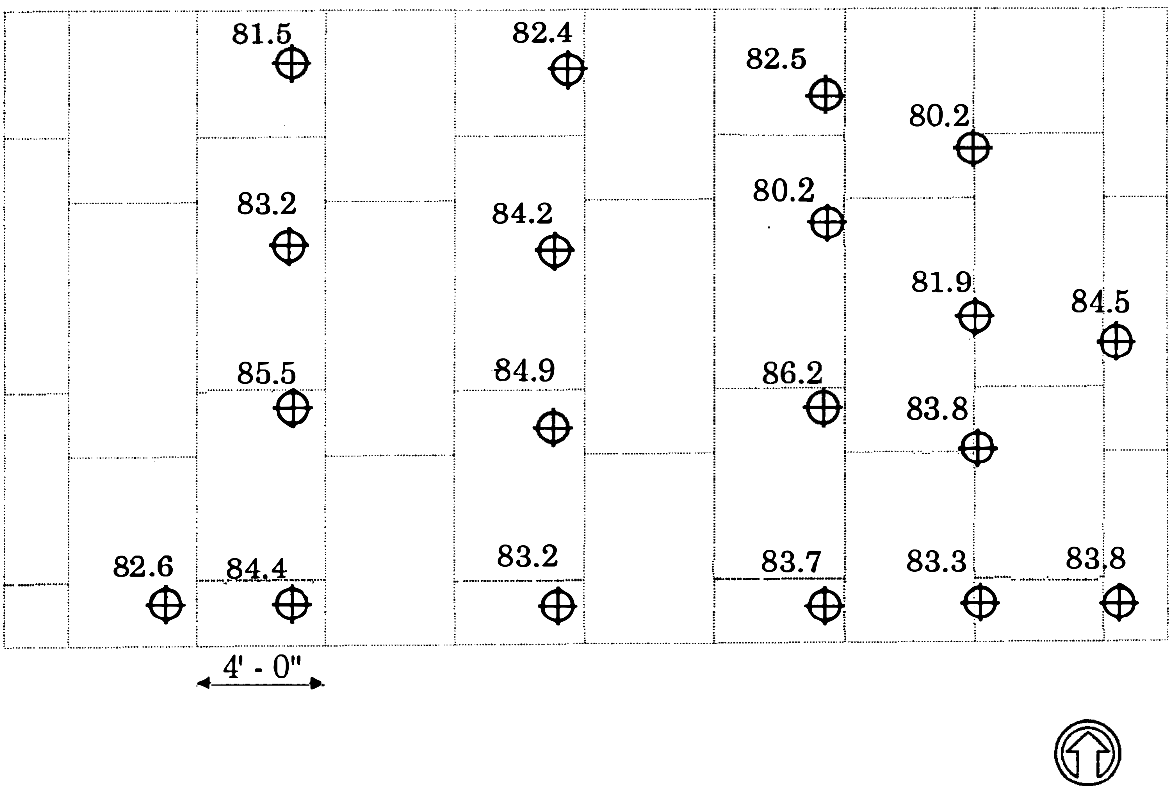
FL = levelness number
Sz = standard deviation of z
z = 10 ft slope
z = mean of z

Sz = 0.11
z = 0.41

$FL = 12.5/(3Sq + \ q \ ) = 12.5/(3 \times 0.11 + 0.41) = 16.9$
FL = 17

E: Dismantling

Compaction Results



Values represent modified proctor compaction test results at test location as a percentage. 10" depths were used for most tests. The two east tests represent an average of the 6" and 12" test results. Tests were conducted by Braun Intertec from Eugene, OR.