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Reducing The Cost of Floor Systems in Modular Homes

NAHB RESEARCH CENTER

Reducing the Cost of Floor Systems in Modular Homes

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EXECUTIVE SUMMARY

Modular construction techniques have the potential to reduce construction time in all areas of the housing market, from entry level through high-end. Although modular homes are generally set on crawlspace or basement foundations, there exists an opportunity in many areas of the United States to use slab-on-grade construction. Combining the modular and slab-on-grade technologies can offer many benefits to consumers, including low-cost quality housing. In fact, the potential cost savings from using a slab-on-grade foundation is nearly $5,200 when compared to a crawlspace foundation on a 28-foot-by-44-foot site-built home.

Based on a thorough examination of the issues, it appears that a removable floor system offers a feasible approach to delivering floorless modular homes that are compatible with a slab-on-grade foundation. It can also be applied to upper floor boxes, thus eliminating the redundant floor-ceiling assembly found on modular homes with multiple stories. The removable floor concept is a proven methodology that has been used by a manufacturer in northern Maryland.

In examining the potential market for modular slab-on-grade homes, six states were found to have nearly 5 percent slab-on-grade foundation and at least 5 percent modular construction, both as a percentage of all residential starts. These six states are Florida, Georgia, Virginia, New Jersey, New York, and Ohio. There may also be significant market opportunity for modular housing in those areas with a high percentage of slab-on-grade construction and low modular starts. An example is in Texas, where 91 percent of single family homes are built on a slab-on-grade while only 0.4 percent are modular.

Despite the findings in this report that confirm the technical feasibility and the potential cost-savings of a floorless modular unit, there remain serious questions about the costs that will be added elsewhere in the process. For example, added site work and production changes in the plant will no doubt decrease some of the potential cost savings. Many of these issues can be addressed through a demonstration of the process.

Since the construction of a demonstration home was not complete at the time of this report, these plant and site-related issues could not be studied. Although preliminary planning did not indicate any serious problems, further work should be undertaken to examine the actual impact on final construction costs.

INTRODUCTION

Modular housing accounts for nearly four percent of the annual new housing starts in the United States. One major advantage of modular construction over site-built construction is its industrialized nature. Since most of the home is built in a factory, weather-related problems are minimized. Modular construction techniques also have the potential to reduce construction time at the site. Both reduced time and greater control over the process provide potential opportunities to reduce housing costs.

Despite its potential, there are many limitations to the use of modular construction. For example, modular homes are typically set on either a crawlspace or basement foundation, even though slab-on-grade construction is the predominate type of foundation in many areas of the United States. The major factor limiting modular building in these areas is that modular homes are already built with a wood floor in place, essentially making them incompatible with a slab-on-grade foundation. This has effectively resulted in the absence of modular building in several large regional markets.

The NAHB Research Center completed an initial evaluation of modular construction methods and slab-on-grade foundations to assess the potential benefits of combining these two technologies. Initially, this study focused on various approaches to building modular homes on a slab-on-grade foundation, but the scope was later expanded to cover methods that could eliminate the redundant floor-ceiling assemblies that occur on multiple-story modular homes. A description of the tasks, results, recommendations for further work, and conclusions are presented in this report.

TASKS

The project consisted of the tasks summarized below.

Task 1: Technical Feasibility Study - This task included a literature review, the identification of options to reduce the costs of modular floor and foundation systems, and site visits to manufacturers to discuss these options.

Task 2: Economic Feasibility Study - This task consisted of an analysis showing the potential cost difference between a crawl space foundation and a slab-on-grade foundation, and the added cost of the redundant floor/ceiling assembly in multiple-story modular homes.

Task 3: Potential Market Evaluation - This task included characterizing modular home production in the United States and identifying states with a high percentage of both slab-on-grade and modular production.

Task 4: Demonstration Home - This task included recruiting a builder and manufacturer to design and construct a demonstration home. The initial design of the demonstration home was completed, although the actual plant construction and field installation were not finished in time to be included in this report.

RESULTS

Technical Feasibility Study

The original focus of this task was to evaluate the technical feasibility of producing a modular unit suitable for a slab-on-grade foundation. Subsequently, it became apparent that methods identified for a slab foundation may also be applicable to the top box of a two-story unit. This is because two-story modular homes are built with a ceiling for the first story and a separate floor for the second story (see Figure 1), creating a redundant floor/ceiling assembly.

From this initial study, two areas where cost-savings may be possible were identified as project objectives.

Objective No. 1. - The top and bottom boxes of modular homes each are typically built with a floor and a ceiling. This results in a redundant floor/ceiling system between the top and bottom boxes of multiple-story homes. Removing this redundancy will reduce the cost of the units by an amount approximately equal to the cost of the floor or ceiling system that is eliminated. A cost-effective method of delivering units without the redundant floor/ceiling system should be developed.

Objective No. 2. - In many locations, a slab-on-grade is the most cost-effective foundation. Yet few, if any, modular homes are set on slab-on-grade foundations because modular boxes are built with a wood floor already in place. The wood floor would need to be removed prior to setting the boxes on a slab foundation if any significant cost savings are to be achieved. A cost-effective method should be developed to allow for modular construction on a slab-on-grade foundation.

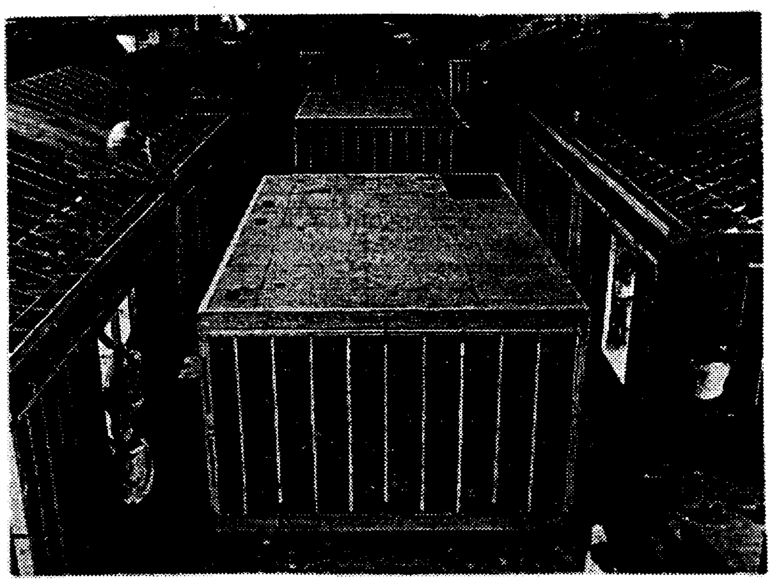

Figure 1. Modular Units Showing Floor and Ceiling on Each Box.

Although achieving these objectives would likely reduce the costs of modular housing, a number of barriers to their implementation exist. Several possible solutions to the obvious obstacles were identified and are presented in the following sections. These options were discussed with modular manufacturers to obtain their input.

Options for eliminating the redundant floor/ceiling

In multiple-story homes, eliminating the redundant floor/ceiling will result in significant cost savings. Options include removing either the floor or ceiling.

The floor on the top box may be removed and replaced with a removable and reusable floor system as shown in Figure 2. The temporary floor system would facilitate construction and transportation of the box. The floor system could be removed prior to on-site installation and returned to the plant for re-use. In fact, one of the manufacturers visited during this project has been using this technique for several years.

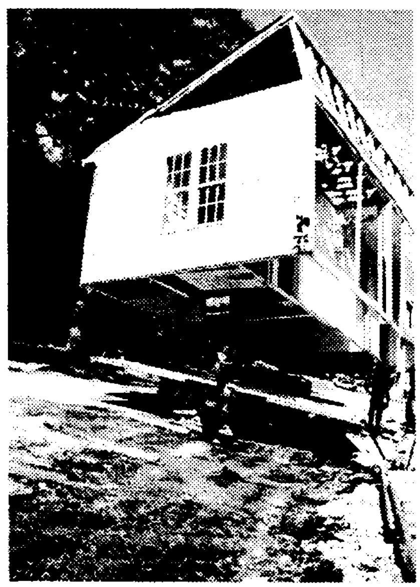

Figure 2. Modular Box Being Lifted from Removable Floor System.

A second approach would be to eliminate the floor of the top box and replace it with a series of structural beams. These beams would secure the box during construction, transportation, and installation. An example of this is shown in Figure 3.

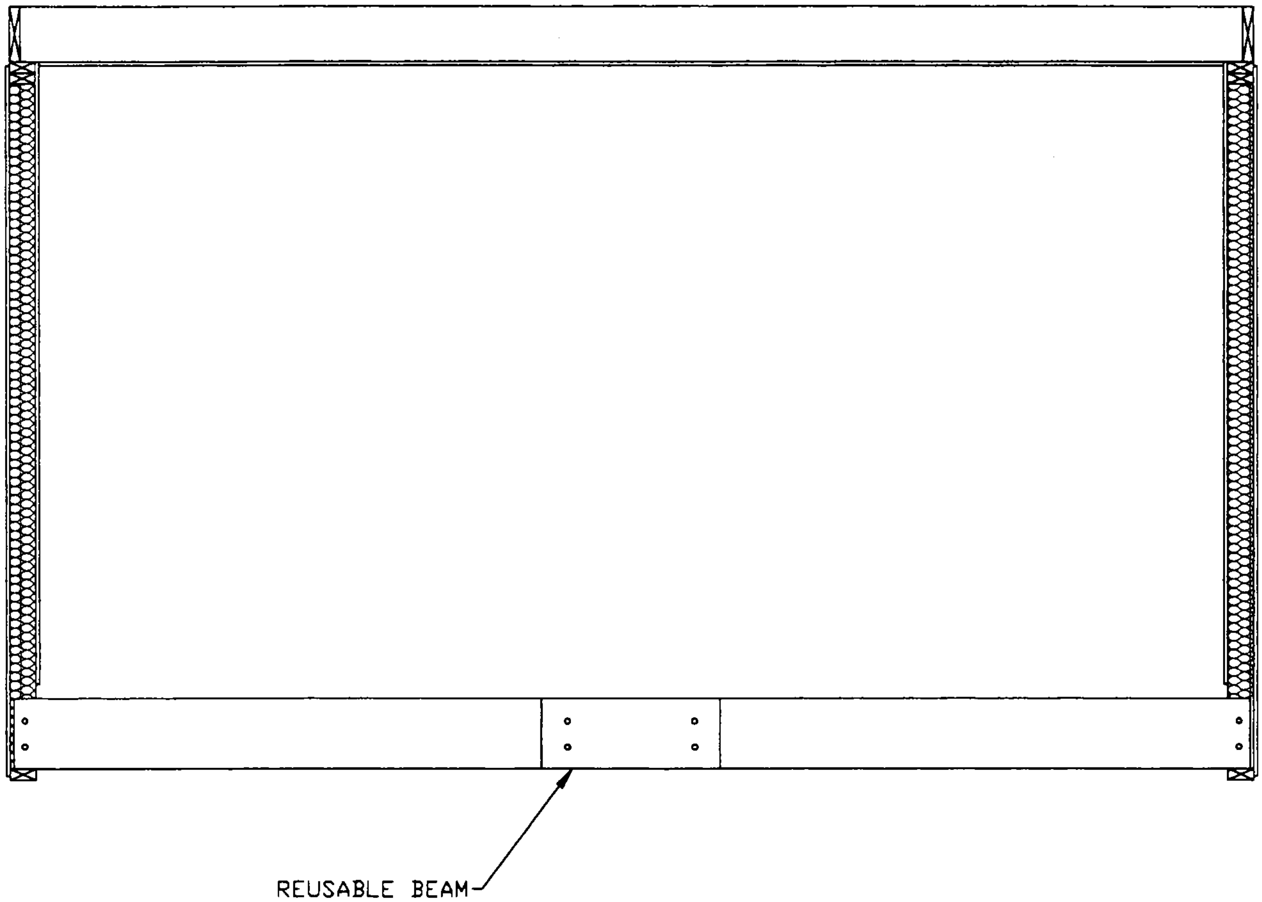

Figure 3. Structural Beam Floor System.

A third approach would be to eliminate the ceiling system of the bottom box using alternative ceiling supports. For example, removable beams similar to those shown in Figure 3 could be used to strengthen the box during construction and transportation.

Options for setting modular units on a slab-on-grade foundation

With slab-on-grade construction, two approaches were identified that could allow the unit to be set without a permanent wood floor on the bottom box. These are the same as the first two approaches used for the redundant floor/ceiling on the two story modular home: the removable floor deck shown in Figure 2 and the beam system shown in Figure 3.

Discussion of options with modular manufacturers

Initially, phone interviews were conducted to assess likely candidates for plant visits. Based on these interviews, eight modular manufacturers were selected. The general objectives of removing the floor/ceiling redundancy and delivering a unit for a slab-on-grade foundation were discussed. Problem areas, suggestions, and new ideas were recorded.

The following manufacturers were visited as part of this task.

1. Regional Building Systems (Northeast, Maryland)
2. All American Homes (Decatur, Indiana)
3. Schult Homes (Middlebury, Indiana)
4. Whitley Manufacturing (South Whitley, Indiana)
5. North American Housing (Boones Mill, Virginia)
6. Mod-U-Kraf Homes Inc. (Rocky Mount, Virginia)
7. Homes of Merit (Bartow, Florida)
8. Nationwide Homes (Martinsville, Virginia)

Impact on the modular process

Results of the site visits and discussions with manufacturers indicate that four areas would be affected by modifying the current methods for constructing floors of modular homes: Construction, Transportation, Setting, and Finishing.

Construction - The floor of a modular box is used during assembly to provide support for plumbing fixtures, appliances and cabinets. With the removable floor or structural floor beam approach, appliances and cabinets would need to be secured to the walls (Figure 4). Provisions to permit adequate wall support may require strengthening of portions of the walls.

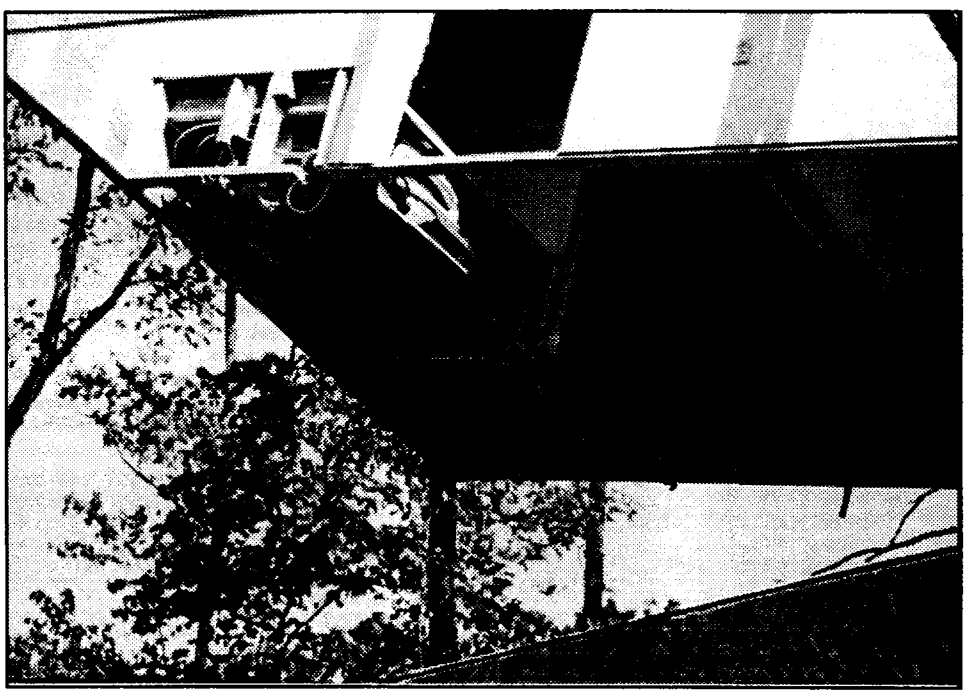

Figure 4. Cabinet Attachment - Wall Supported.

Depending on the type of manufacturing facility, the crews working on modular boxes rely on the floor to provide a level, obstruction-free surface on which to work. For example, at one plant the units are moved along the line on rollers that elevate the boxes approximately 18 inches above the plant floor. If the floors on individual units are absent, then crews must negotiate the additional height and possible hazards introduced by exposed floor rollers.

On multiple-story units, the ceiling beam option would require changes in plant operations. For example, the ceiling drywall could no longer be installed in the plant. This is viewed as a major barrier to this approach.

Transportation - Problems surrounding transportation are mostly related to the type of trailer, size of the boxes, and the storage of accessory items. With the beam system, flat bed trailers (Figure 5) with a solid base should not pose a problem unless the box extends significantly over the edges of the trailer. A more common type of trailer is made of an open beam deck or rollerbed, which could present problems in supporting the boxes and protecting their contents. In this case a removable or permanent floor would be necessary.

With the ceiling beam option on two-story homes, it would also be necessary to provide some form of protection on the top of the open boxes.

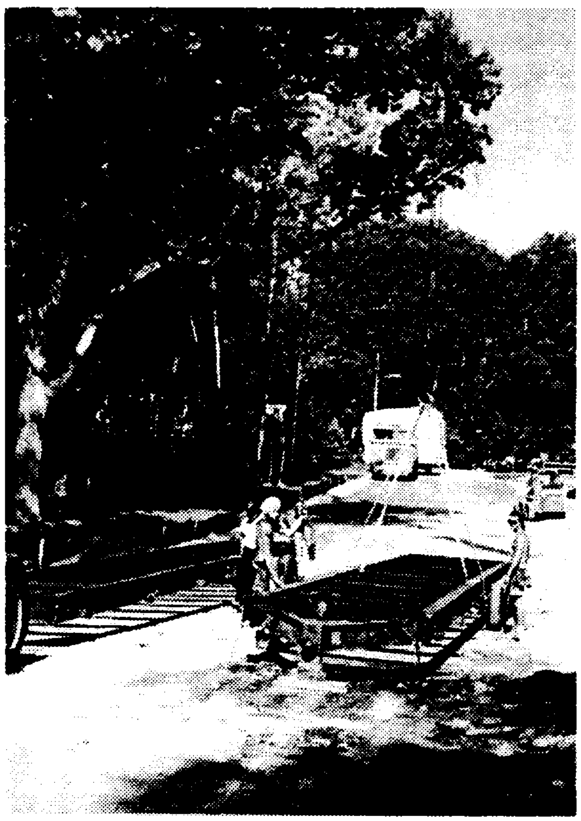

Figure 5. Typical Trailer.

Setting - Problems in this area are related to the stiffness of the boxes and the method of lifting them in place. Typically, boxes are lifted by straps that run through the floor system as shown in Figure 6. This approach could be used with a floor or ceiling beam system, but another method of lifting the boxes will be required if a removable floor deck is used. Roll off trailers, commonly used in the industry, would not be compatible with the removable floor deck or floor beam system.

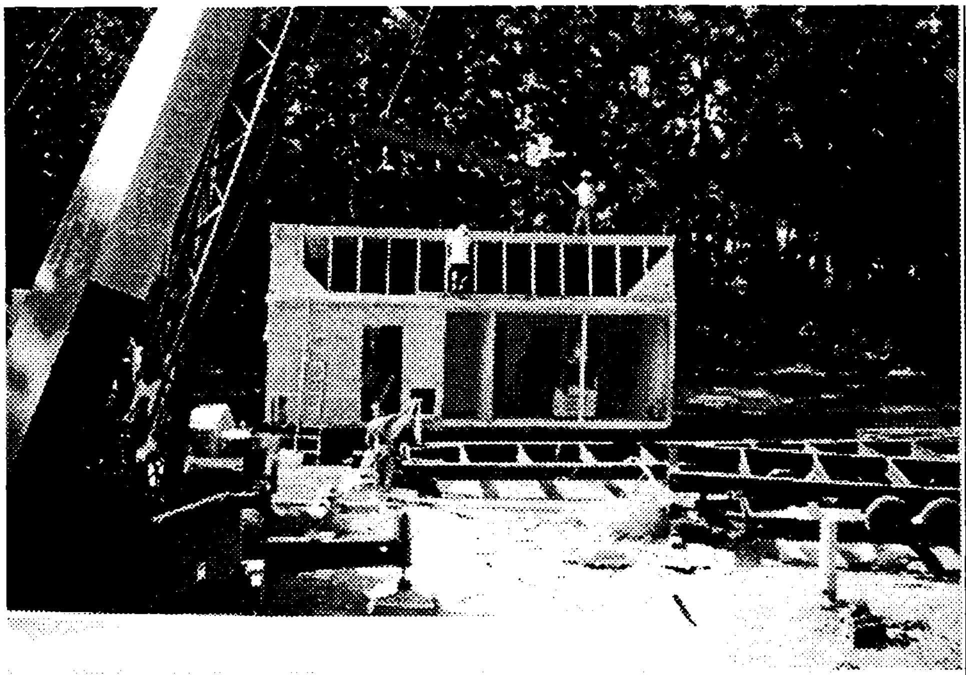

Figure 6. Lifting of Box

Finishing - As mentioned previously, installation of the ceiling drywall at the site would be required with the ceiling beam approach. The impact of the floor beam or removable floor deck system would vary, since some manufacturers provide finished floors while others do not. Tubs, showers, water closets, cabinets, and other fixtures are frequently installed in the plant. The lack of a permanent floor system would affect these practices. In addition, plumbing lines and ductwork may be more difficult to align with a slab-on-grade than with a basement or crawlspace. A greater amount of site finishing work would also be required. For example, the base trim could not be plant-installed, although it could be pre-cut for field installation.

Analysis of options

Since the barriers to use of the ceiling beam approach would be difficult to overcome, the floor beam system and the removable deck are more feasible. Generally, the response from manufacturers was mixed, with some seeing the benefits and others resistant to the ideas presented to them.

Several of the manufacturers, particularly those in Virginia, believed that floorless systems were feasible but they did see a market in their service area due to buyer preferences for basements.

A pragmatic view of the feasibility of removing the floor system was represented by a plant production manager. In answer to the question, "Is it feasible? He responded "Absolutely." When asked, " Do I want to do it"? the response was, "Absolutely not!" This manager could see the benefit and the potential market, but was obviously aware of the plant and field changes required to remove the floor and still retain the savings associated with eliminating the permanent floor deck.

A listing of the advantages and disadvantages of the three options identified by the Research Center is provided in Table 1. Underlined portions apply to all three options.

Table 1: Options for reducing floor costs.

OPTION	APPLICATION	ADVANTAGES	DISADVANTAGES
Removable floor deck	Slab-on-grade, multiple-story units	1. deck is reusable, lowering long run costs 2. provides floor for construction in plant and storage during transport 3. walls have play, allowing for alignment in setting 4. requires less wood for each unit than traditional permanent floor approach 5. compatible with slab-on-grade foundation	1. requires initial investment in floors 2. roof beam must be added to support the boxes during setting 3. floors must be shipped back to plant 4. retraining of crews required, plant operational changes required 5. increased site work 6. crane must be used for site construction
Beam system on floor	Slab-on-grade, multiple-story units	1. low initial cost compared to removable floor system. 2. walls have play, allowing for alignment in setting 3. requires less wood for each unit than traditional permanent floor approach 4. compatible with slab-on-grade foundation	1. lack of floor during construction 2. requires small initial investment in beams 3. retraining of crews required, plant operational changes required 4. increased site work 5. No storage during transport for shipping loose materials 6. design and location of internal walls affected by beam location

Table 1 (Continued)

OPTION	APPLICATION	ADVANTAGES	DISADVANTAGES
Beam system in ceiling	Multiple-story units	1. less initial investment than for false deck 2. supports could be disposable or reused 3. requires less wood for each unit than traditional permanent ceiling approach 4. beams could be incorporated in the home design in some cases	1. drywall for ceiling would have to go on the bottom of the top box or be installed in the field 2. requires small initial investment in beams 3. retraining of crews required, plant operational changes required 4. increased site work 5. additional cost of false work to protect the unit from the elements

The advantages and disadvantages uncovered in this investigation indicate that the removable floor system offers the best opportunity of the options presented to the manufacturers. This approach can be applied to both slab-on-grade and multiple-story boxes. It is also a proven methodology that has been used by a manufacturer in northern Maryland for two-story homes.

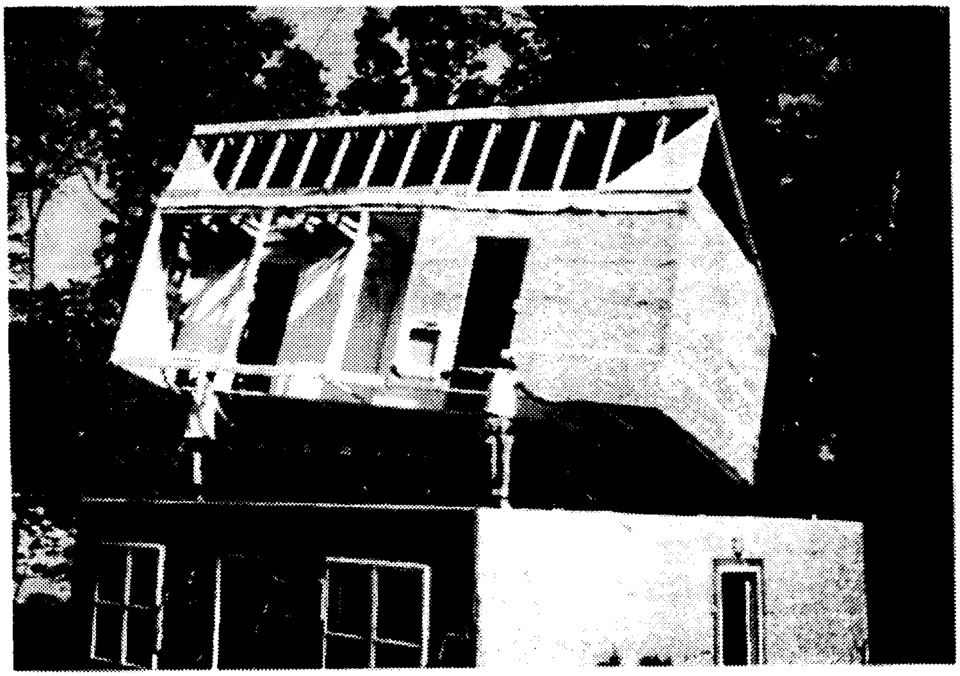

Figure 7. Floorless Second Floor Box.

Figure 8. Removable Floor on Trailer.

Figure 9. Removable Floor Folded for Shipment.

The research team observed the setting of a two-story modular home in Maryland that included second story boxes without floor diaphragms (Figure 7). Prior to the delivery and setting of the home, the plant was visited to observe the construction methodology. In this plant boxes were assembled on three parallel lines, with removable deck boxes and traditional boxes intermixed depending on the jobs. The cabinets for the kitchen and vanities had full horizontal blocking along the upper and lower edges, enabling the cabinets to be hung to the walls rather than rest on the floor. Tub units were also installed in the plant by nailing blocks to the face of the studs to serve as support for the tub. Plumbing supply lines were polybutelene, which allowed for flexible connections. The bottom plate was made so that it could be knocked out at the floor for waste line connections prior to setting the unit.

The floorless boxes were nailed to the removeable deck with form nails, permitting easy removal at the site prior to setting. Boxes were lifted by crane using a permanent lift beam in the roof truss. This beam is accessed through holes left in the roof with two to four lifting points, dependent on the size of the unit.

The removeable deck is made in sections 14 feet by 4, 6, or 8 feet wide and bolted together to provide the necessary length. Sections of the deck are framed with steel tubing and decked with 1⅛ inch OSB (Figure 8). The deck can be broken down into sections and turned sideways for the return trip to the plant, eliminating the need for wide-load permitting (Figure 9).

The lack of a floor allowed for ease in alignment of walls and final positioning of boxes as the house was assembled on site. Although the system was only used for second-story homes, it could be easily adapted for slab-on-grade construction. However, a greater amount of site work will be required for aligning plumbing, securing walls to the slab, and applying finish materials.

Economic Feasibility Study

Under this task, the research team conducted a preliminary economic comparison of floorless modular construction versus conventional modular construction.

Table 2 illustrates the potential cost savings with a slab-on-grade foundation compared to a crawl space foundation. This shows a potential savings of approximately $5,200 for the slab-on-grade for a 28-foot-by-44-foot site-built building. A number of factors will ultimately determine how much of this savings will actually be realized, including local customary practice, labor rates, and material costs. In addition, when setting a modular unit on a slab-on-grade foundation, increased site work will be required for slab preparation, drywall and other finish work, and setting of fixtures. A demonstration home, as proposed in this project, would provide more detailed information on the cost impact of these additional items. However, it seems likely that significant savings will occur due to the large cost differential between crawlspace and slab construction.

Table 2: Costs of Slab-on-Grade and Crawlspace Foundations

SLAB-ON-GRADE				
		Quantity	Unit Price	Cost
Forms in Place	12"H, one use	144 sfca	$5.10	$734.40
Spread Footings	3000 psi concrete	23 cy	$53.00/cy	$1,219.00
Placing Footing	138'L x 18"W x 36"D	23 cy	$10.15/cy	$233.45
Floor Slab System	44'W x 28'L x 4"D	1,232 sf	$1.88/sf	$2,316.16
Perimeter Insulation	Polystyrene, R8	304 sf	$0.66/sf	$200.64
			TOTAL	$4,703.65
WOODEN FLOOR DECK ON CRAWL SPACE				
		Quantity	Unit Price	Cost
Footing System	8"H x 18"W	144 lf	$7.61/lf	$ 1,095.84
Block Wall System	144'L x 40"H, uninsulated	480 sf	$7.66/sf	$3,676.80
Wood Joists	2"x10", 16" o.c.	1,232 sf	$1.43/sf	$1,761.76
Box Sills (Band Joist)	2"x10"	1,232 sf	$0.21/sf	$258.72
Girder	3 - 2"x12" incl. columns	1,232 sf	$0.92/sf	$1,133.44
Sheathing	3/4" CDX plywood	1,232 sf	$0.91/sf	$1,121.12
Insulation	Fiberglass batts, R19	1,232 sf	$0.76/sf	$936.32
			Total	$9,984.00

Table 2 also illustrates that there is considerable incentive to eliminate the costs associated with the redundant floor/ceiling system in multiple-story construction. The cost of the floor joists, the bands, and the sheathing amount to approximately $3,100. As with the slab-on-grade, additional site work would lower this potential savings.

Potential Market Evaluation

Under this task, the research team characterized modular housing produced by region of the United States and identified geographic regions with a high concentration of modular housing and slab-on-grade housing. Data was obtained as follows:

Housing starts - Using building permit data obtained from the U.S. Bureau of the Census, F.W. Dodge annually estimates the number of residential starts by state. Research Center analysts summed these estimates for 1987 through 1991.

Foundation types - In cooperation with the Research Center, F.W. Dodge conducts a comprehensive annual survey of home builders, asking questions on the types of homes they build and the methods they use. This *Annual Builder Practices Survey (ABPS)* includes questions on the types of foundations used in new home construction. Responses fall into the broad categories of basement, crawlspace, and slab.

Research Center analysts summed *ABPS* results of detached single-family home foundations for 1987 through 1991, calculating percentages by state for homes on each type of foundation. These percentages were then applied to the estimates of state housing starts to obtain the number of foundations by type from 1987 to 1991.

Modular home production - In 1991, Research Center analysts made national and state estimates of modular homes as a proportion of total residential starts, which includes single-family detached homes, townhomes, and multifamily apartments and condominiums. Single-family detached homes account for the overwhelming majority of all modular production. The estimates were developed through synthesis of several in-depth reports of the modular home market.

Percentages of modular construction and slab-on-grade foundations were compared by state. Results are summarized in Table 3. Six states were found to have nearly 5 percent slab-on-grade foundation and at least 5 percent modular construction, both as a percentage of all residential starts. These six states, Florida, Georgia, Virginia, New Jersey, New York, and Ohio, are shaded in Table 3.

Table 3: Modular and Slab-on-grade Production by State

State	1987-91 SFD Starts (total)	1987-91 SFD on Slab (total)	SFD on Slab (% starts)	1987 Modular (% starts)	1987-91 Est Modular Starts
Florida	**492,397**	**481,867**	**97.9%**	**4.8%**	**23,635**
Arizona	115,806	110,191	95.2%	0.0	0
New Mexico	34,145	32,482	95.1%	0.3%	102
Nevada	53,169	49,978	94.0%	0.4%	213
Texas	243,345	221,478	91.0%	0.4%	973
Oklahoma	38,331	34,669	90.4%	0.3%	115
Mississippi	38,704	33,846	87.4%	0.2%	77
Louisiana	44,621	36,535	81.9%	0.2%	89
California	658,141	498,173	75.7%	0.5%	3,291
Arkansas	40,546	26,289	64.8%	0.3%	122
Alabama	70,181	38,661	55.1%	1.2%	842
Tennessee	110,796	49,492	44.7%	0.8%	886
Georgia	**204,183**	**85,517**	**41.9%**	**6.8%**	**13,884**
South Carolina	86,420	30,679	35.5%	0.8%	691
Indiana	101,046	35,591	35.2%	3.2%	3,233
New Jersey	**106,350**	**33,372**	**31.4%**	**10.3%**	**10,954**
North Carolina	187,000	53,207	28.5%	2.1%	3,927
Virginia	**189,854**	**35,840**	**18.9%**	**5.6%**	**10,632**
Kentucky	67,761	9,909	14.6%	0.3%	203
Washington	120,216	11,613	9.7%	1.1%	1,322
New York	**154,121**	**12,722**	**8.3%**	**11.8%**	**18,186**
Illinois	150,667	11,665	7.7%	1.3%	1,959
Colorado	57,802	4,321	7.5%	0.7%	405
Ohio	**146,988**	**8,363**	**5.7%**	**5.6%**	**8,231**
Idaho	22,380	1,081	4.8%	0.1%	22
Iowa	27,722	1,184	4.3%	0.3%	83
Rhode Island	15,226	582	3.8%	0.7%	107
Utah	34,303	1,273	3.7%	0.3%	103
Delaware	22,130	803	3.6%	1.3%	288
Michigan	132,842	4,620	3.5%	5.2%	6,908
Minnesota	93,041	2,942	3.2%	1.2%	1,116
Oregon	49,903	1,491	3.0%	0.1%	50
Maine	26,028	693	2.7%	1.5%	390
Pennsylvania	180,911	4,075	2.3%	6.8%	12,302
West Virginia	11,879	276	2.3%	0.3%	36
Kansas	40,607	807	2.0%	0.9%	365
Maryland	133,786	2,379	1.8%	8.4%	11,238
Vermont	14,525	262	1.8%	0.7%	102
Connecticut	44,691	690	1.5%	2.4%	1,073
North Dakota	10,965	153	1.4%	0.2%	22
Massachusetts	80,790	970	1.2%	5.4%	4,363
Missouri	87,617	667	0.8%	0.3%	263
Montana	11,809	51	0.4%	0.1%	12

Table 3 (Continued)

State	1987-91 SFD Starts (total)	1987-91 SFD on Slab (total)	SFD on Slab (% starts)	1987 Modular (% starts)	1987-91 Est Modular Starts
Wisconsin	77,992	223	0.3%	1.5%	1,170
New Hampshire	31,251	34	0.1%	2.5%	781
Nebraska	17,676	0	0.0%	0.3%	53
South Dakota	8,989	0	0.0%	0.2%	18
Wyoming	7,853	0	0.0%	0.1%	8

Discussion of market evaluation results

The Research Center's initial approach was to identify areas with both a significant percentage of modular starts and slab-on-grade foundations for single-family homes. Although this is a fundamentally sound approach, there may also be significant market opportunity for modular housing in those areas with a high percentage of slab-on-grade construction and low modular starts. This is partially borne out by the interest of Schult Homes to develop a slab-on-grade modular product for Texas, where 91 percent of single family homes are slab-on-grade while only 0.4 percent are modular.

It is reasonable to assume that if the modular slab-on-grade construction proves to be a viable form of more affordable housing, there will be movement into states with high percentage of slab-on-grade starts. Table 4 below includes the states with the highest percentage of starts (over 90 percent) built on slab-on-grade foundations.

Table 4: States with Highest Percentage of Slab-on-Grade Starts

State	1987-91 SFD Starts (total)	1987-91 SFD on Slab (total)	SFD on Slab (% starts)	1987 Modular (% starts)	1987-91 Est Modular Starts
Florida	492,397	481,867	97.9%	4.8%	23,635
Arizona	115,806	110,191	95.2%	0.0%	0
New Mexico	34,145	32,482	95.1%	0.3%	102
Nevada	53,169	49,978	94.0%	0.4%	213
Texas	243,345	221,478	91.0%	0.4%	973
Oklahoma	38,331	34,669	90.4%	0.3%	115

A final point regarding markets should be addressed. Many of the manufacturers visited during this project market the value of the redundant floor/ceiling quite aggressively. They claim that it results in stronger homes with better noise reduction between floors. These claims may discourage the construction of modular homes without the redundant floor/ceiling assembly, even through the redundant assembly is not common practice for stick-built homes.

Demonstration Home Construction

The objective of this task was to evaluate the feasibility of building, transporting, setting, and finishing floorless modular boxes through the construction of a prototype demonstration home. Subtasks included recruiting candidate builders to construct a demonstration home; evaluating options with potential candidates; working with the selected builder to develop final construction recommendations; and construction and monitoring of the demonstration home.

Builder candidates

Through our earlier visits to modular plants, a builder in Maryland was initially selected to build the demonstration home. The plans called for construction of a single-story slab-on-grade home in the Annapolis, Maryland area. However, due to issues unrelated to this project, the builder withdrew from participation in the demonstration.

A second builder, Schult Homes of Indiana, was selected to fill the role created by the withdrawal of the Maryland builder. In order to develop recommendations for construction of the demonstration home, a planning conference was held with the manufacturer and other interested parties.

Modular housing conference

The planning conference was held at Texas A&M University on February 22 and 23, 1994. The purpose was to bring interested parties together to discuss the issues related to floorless modular units and to identify specific solutions to obstacles.

The participants at the conference included representatives from the following organizations:

- Texas A&M University
- University of Oregon
- Schult Homes Corporation
- H&H Steel Erectors
- Neatherlin Homes Inc.
- NAHB Research Center

The initial discussion focused on the characteristics of a typical home in the Texas market. Considering that over 90 percent of the homes in Texas are built on a slab-on-grade foundation, Schult Homes believed that they would have to look at ways to adapt modular methods to a slab-on-grade home to be truly competitive.

Participants identified the following potential benefits of slab-on-grade modular construction: increased market potential, reduced foundation schedule, reduced excavation, design configuration freedom, lower cost compared to crawl space foundations, and ease of design for accessibility.

During the conference Schult Homes made a commitment to build a prototype slab-on-grade building. The demonstration building would be used as an office for Schult Homes personnel (see Figure 10). An initial list of design responsibilities was developed so that Schult Homes could move forward with the project. Their first step was to obtain a Texas State certification to allow them to build manufactured housing and modular housing in the same facility.

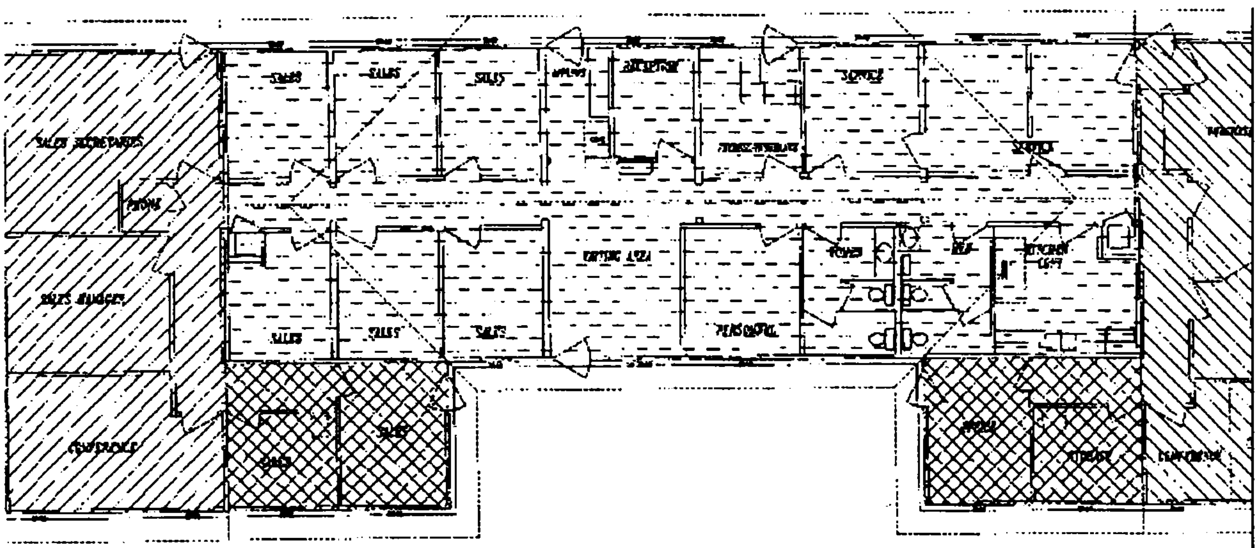

Figure 10. Floor Plan of Proposed Demonstration Building

Options discussed for setting modular homes on a slab-on-grade foundation included a metal wrapped floor, a precast concrete floor, a 2 x 4 pressure treated lumber sleeper floor deck, a system of removable interior and exterior beams, and a removable temporary floor deck. Participants agreed that the use of a removable floor deck was the most logical choice since there was a low initial investment, the concept had been proven in two-story construction, and the approach was compatible with many existing manufacturing facilities.

Several other technical issues were addressed at the conference including lifting details, wall anchorage, and plumbing and mechanical systems. Recommendations that resulted from these discussions are presented on the following pages.

Demonstration home recommendations

The preliminary recommendations for lifting details, wall anchorage, plumbing, and mechanical issues are as follows:

Lifting Details

A lifting beam was proposed that would sit inside the roof trusses and remain in place. An example of the proposed beam is shown in Figure 6. Schult Homes preferred to design the interior lifting beam such that it could be reusable. Small holes would be left in the roof so that a cable could be attached to lift the unit.

Wall Anchorage

As with all buildings, the exterior walls of the demonstration building must be anchored to the foundation. One possible approach is to use a metal angle in the slab placed at a four-to six-foot spacing. This method would not require exact location of sill bolts or the need for access into the wall cavity. Figure 11 shows the proposed angle detail near the bottom plate of the wall. The angles should be of sufficient length and number so that tension perpendicular to the grain does not cause the bottom plate to split where it is connected to the angle.

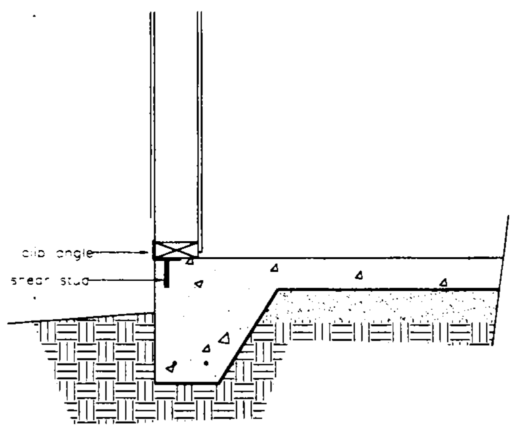

Figure 11. Lag Bolt Wall Anchorage.

Another method (Figure 12) would be to attach hold down straps to the studs underneath the exterior sheathing and use hydraulic shot nails to attach them into the face of the slab. Traditional powder-actuated nails may not provide sufficient withdrawal strength in this application.

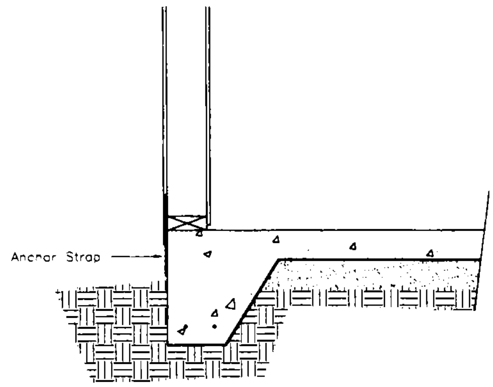

Figure 12. Hydraulic Shot-Nail Wall Anchorage.

Non-load bearing interior walls need only to be anchored to prevent lateral movement of the wall. It was proposed to use a urethane adhesive along the length of the wall (Figure 13) to provide this anchorage. The adhesive force and dead weight of wall would be used to prevent out-of-plane movement of the wall. Base trim could then be used to cover the joint at the bottom of the wall. The base trim for interior walls would have to be shipped loose, although it could be precut to length.

Another method to provide interior wall anchorage would be to install straps to the studs in the factory and then to shot nail the straps to the slab. This method would be acceptable for areas with carpeted floors, but would cause problems with vinyl sheet floors

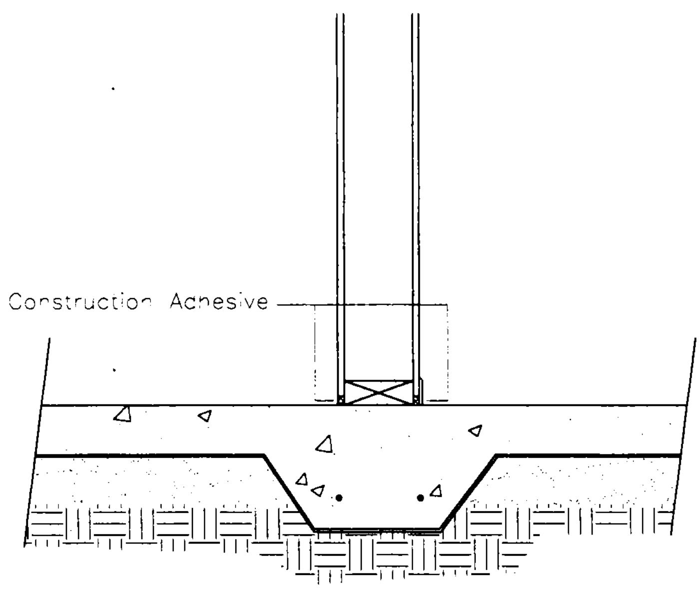

Figure 13. .Construction Adhesive Securing Partition Walls

Plumbing

Plumbing waste and supply lines must be aligned to allow for field connections. However, it is difficult to set a modular unit and have perfect alignment between plumbing lines in the unit and those in the concrete slab. One suggested approach would be to offset the alignment of the waste lines so that elbows can be used to make the connection alignment less critical. An example of an offset waste line is shown in Figure 14. For bathtub and water closet connections, a relatively large hole should be left in the slab to allow for positioning the waste line when making on-site connections. The void in the slab should then be filled with either non-shrink grout or concrete. The use of flexible pipe (polybutetylene lines or soft copper) could make the connection of water supply lines easier.

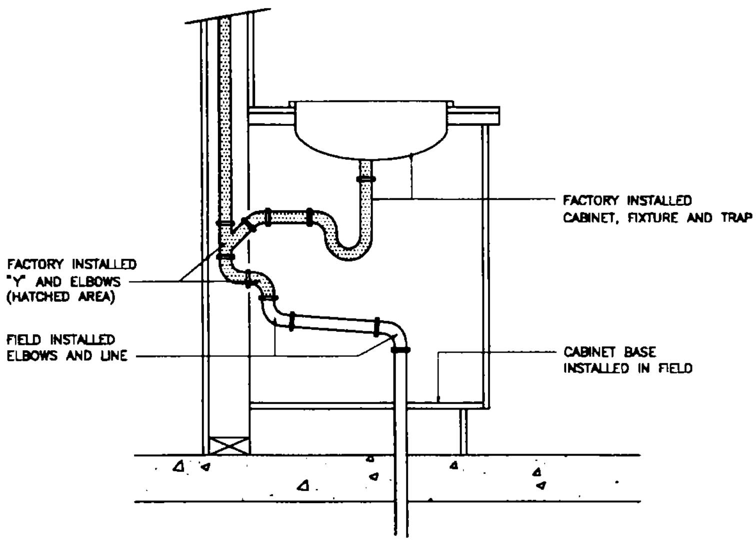

Figure 14. Offset Waste Line

Mechanical

The mechanical system for a slab-on-grade one story building can be placed in the slab or attic space. Placing the duct lines in the slab would create additional site work, which is already common practice for stick-built homes. The most favorable recommendation would be to place the ducts in the attic space so the majority of the mechanical work can be done in the factory.

Status of demonstration home

This task was not finished when this report was submitted. Schult Homes is still planning to build the demonstration in late 1994 or early 1995. Despite the lack of data and observations from the demonstration, the analysis conducted to date under this project indicates that floorless modular technology is a viable alternative to current modular construction techniques.

CONCLUSIONS AND RECOMMENDATIONS

Results of this study indicate that the concepts discussed in this report for reducing the cost of floor systems in modular homes are technically feasible. The removable floor system appears to be the best option at this point. This is based on the minimal disturbance that the removable floor would have on production and transport. This approach could be used in meeting both project objectives: producing a modular unit for a slab-on-grade foundation and eliminating the redundant floor/ceiling assembly in multiple-story modular homes.

The preliminary cost analysis shows significant potential to reduce the cost of modular units by eliminating the redundancy in the floor/ceiling assembly or by setting the units on a slab-on-grade foundation. The potential cost savings may approach $3,100 to $5,200 for the floor/ceiling assembly and the slab-on-grade, respectively. However, additional site costs would offset some portion of the potential savings. For example, there will be an initial investment in the removable floor decks. There will also be costs associated with setting fixtures, installing finish floors, and other finish work at the site.

Although reaction to the project objectives was mixed, several of the manufacturers believe there is a market for slab-on-grade modular construction. Two of the eight manufacturers visited have a strong interest in this potential market. We were unable to locate any manufacturers currently setting homes on a slab-on-grade foundation, although some have set garages and commercial buildings on them. One of the manufacturers has used a removable floor system to eliminate the redundant floor/ceiling assembly on multiple-story homes. The builder that expressed the strongest interest in the demonstration project is most interested in entering the market in Texas, where modular construction has been excluded in the past because of local preference for slab-on-grade foundations. None of the others expressed strong interest in this concept.

Even though the objectives in this project are technically feasible and the potential cost-savings are high, there remain serious questions about the costs that will be added elsewhere in the modular process. For example, a greater amount of site work and production changes in the plant will no doubt decrease some of the potential cost savings. There is also the resistance that any innovation faces when first entering the market. Many of these issues can be addressed through a demonstration of the process.

Since the construction of the demonstration home was not undertaken during the course of this study, these final issues could not be studied in detail. Further work should be undertaken to examine construction related issues and evaluate actual installed costs compared to conventional construction.

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