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Cost and Time Study for Constructing Raised Wood Floor Systems in the Gulf Coast Region of the United States

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Abstract

This report is the result of a co-operative effort between the USDA Forest Service, Forest Products Laboratory (FPL) Advanced Housing Research Center, the National Association of Home Builders (NAHB) Research Center, and builder members of the Metropolitan Mobile and Baldwin County Home Builders Associations. The study was undertaken to further knowledge that will improve wood utilization and performance in wood-framed housing, specifically in the area of wood raised floor design and wood usage in the Gulf Coast region of the country.

Keywords: floor systems, raised wood floors, Gulf Coast, residential construction, construction costs, construction time, cost comparisons

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Conversion Table

English unit	Conversion factor	SI unit
foot (ft)	0.3048	meter (m)
pounds per square foot (lb/ft^2)	47.880	pascal (Pa)
cubic yard (yd^3)	0.7646	cubic meter (m^3)
square feet (ft^2)	0.092903	square meter (m^2)

Contents

Executive Summary

This study was undertaken to further knowledge about wood utilization and performance in wood-framed housing, specifically raised wood floor foundation design. The study focused on several foundation and elevated first floor systems common to the Gulf Coast region, including two raised concrete slab systems: raised concrete slab on fill within stem wall, and raised concrete slab on fill pad. These were compared with a raised wood floor system on stem wall with a crawl space. While not the most cost-effective raised wood floor foundation system, we chose the stem wall system because the builders participating in the study preferred them. Cost and time considerations involved in constructing each of these foundations were reported for nine builder case studies, including four raised wood floors on stem wall foundations, two raised concrete slabs on compacted fill pads, and three raised concrete slabs on stem wall foundations and compacted fill. Table A covers the average costs of the three foundation and floor assembly construction types.

As anticipated at the outset, a raised concrete slab on a compacted fill pad had the least total cost and the shortest time to construct. However, the average wall height of the two slabs on fill pads was less than 2 ft, which is the prescriptive building code's height limit for this design and a lower average elevation than was required for the topography of the other seven house designs on the lots in this study. A slab on a fill pad does not require a footing or perimeter walls because a turned down, thickened, and reinforced haunch shaped by a trench and slab form serves the two functions at the slab edge. It also takes up more lot space because of the sloped fill pad extensions on all sides of the foundation.

The three raised concrete slabs on compacted fill retained within perimeter stem wall foundations averaged 3 ft in height with first floors sized similarly to the slabs on fill pads. There was an average cost of $7,400 more for the additional 1 ft, 3 in. of foundation wall height, compared with slabs on compacted fill. The raised wood systems cost an average of 27% more than the raised concrete on fill with stem wall (as measured by average total cost). The difference in average elevation of the foundation walls supporting the two floor types was approximately 4 in. (wood measures 3 ft, 5 in., whereas concrete measures 3 ft, 1 in.).

Wall height was a cost driver in the foundations, and the study reflects that by reporting in cost per square foot of foundation wall. However, the cost per square foot of stem wall foundation declined as the wall got higher because the cost of the footing was spread over more area. Footings and foundations of the two raised floor systems with stem walls could be constructed with equal cost, but interior piers and crawl space foundation accessories (vents and access panels) will add cost to the raised wood floor system. Given a defined base flood elevation floor height requirement, there should be no difference in cladding volumes between the two systems, provided finished floor heights are designed to be at the same elevation.

Floor joist and girder costs of the raised wood were on par with the cost of the concrete slab, as were sheathing and insulation costs compared with the fill dirt and compaction, but there was a disparity between the cost of carpentry labor and that of slab labor. This contributed to the cost difference between the two systems.

An optimized cost approach is presented to normalize the variance in wood floor labor and material costs borne by the builders in the study. The optimized approach results in an average cost difference of $2.53 per square foot of foundation wall between wood and concrete on stem walls at the given average foundation heights.

The study relied on project homes volunteered by builders, and the cost comparison is based on regional costs of key components such as concrete, lumber, concrete masonry units, and the associated trade's labor rates, as reported in this study. Potentially less costly foundations, such as pier-and-beam raised wood floor foundations, were not investigated.

Table A—Average installed cost of foundations

Component	Raised wood floor on stem wall crawl space	Raised concrete on fill in stem wall	Raised concrete on compacted fill pad
Total cost ($)	23,752	18,691	11,267
Average foundation height (ft)	3.42	3.08	1.79
Footing (linear ft)	206	237	217
Average cost of foundation ($/ft^2)	34.14	25.82	29.10
Average of 1st floor (ft^2)	1,966	2,292	2,275
Average cost of 1st floor ($/ft^2)	12.08	8.15	4.95

[a]Optimized raised wood floor system. Use Appendix D assumptions. See Value Engineering section for more information.
[b]Established minimum stem wall height.

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Cost and Time Study for Constructing Raised Wood Floor Systems in the Gulf Coast Region of the United States

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Introduction

Numerous foundation designs exist for new residential buildings, including full foundation with basement; full foundation with crawl space; raised floor system on posts, piers, or pilings; slab-on-grade; raised slab on compacted fill; and various other combinations. Choosing a specific foundation type involves assessing desired functionality, aesthetics, and cost. In the Gulf Coast region of the United States, base flood elevation (BFE) may dictate height of the first floor to avoid potential damage or destruction from flooding. Sloped topography and architectural features such as porches or outdoor decks also drive demand for a raised first floor.

Two common construction methods used in the Gulf Coast region to achieve an elevated first floor are the raised concrete slab and the raised wood floor stem wall system. This study endeavored to examine and capture as many cost considerations involved in constructing these foundation types as was feasible. The study was conducted as a series of case studies on sites selected by each builder. Nine foundations were evaluated—four raised wood floors on stem wall foundations, two raised concrete slabs on compacted fill pads, and three raised concrete slabs on stem wall foundations and compacted fill.

Statistical data compiled for the East South Central census area of the country, the region of this study's focus, indicates that 67% of the newly constructed single-family houses that were built during 2008 consisted of concrete slab first floors and 29% consisted of wood floors on basement or crawl space foundations (approximately evenly split between basements and crawl spaces). In the NAHB Research Center, 2008 annual builder practices survey, results indicated the following: slab 67%, crawl space (stem wall) 15%, basements 14%, other (pier or mixed basement/crawl/slab construction) 4%. See http://www.census.gov/geo/www/us_regdiv.pdf for defined area.

Approach

The NAHB Research Center and two associations representing wood product manufacturers solicited participation of builders in the Gulf Coast region for this study. Cost data relevant for constructing houses to the top of their first floor were recorded for nine house sites in Alabama. The first floors for four of the houses were built with wood framing and five were built with concrete slabs. Three of the five concrete slab floors were formed with perimeter stem walls, similar to the wood floor assemblies. The stem walls retained compacted fill material for support of the concrete slabs. The two remaining concrete slabs were supported on compacted fill pads.

Costs represent work that progressed during a 2-year time period and are reported as the amount on the invoices rendered at the time the houses were built, including taxes and incidental fees, such as delivery and fuel surcharges. Appendix A contains relevant costs for materials as a point of reference for the reader.

For eight of the foundations/floor systems in this study, invoices rendered for the activities that were associated with footing, foundation, and first floor assembly were audited and logged. The cost for a ninth house, Lot 2J, was estimated from quotes and quantity take-offs, as construction was in progress at the time this report was completed. For all but the ninth house, delivered quantities were verified against installed quantities, and quantity take-offs were estimated from blueprint drawings.

At several of the sites, labor time studies were conducted to observe the construction process from footing excavation through the finish of the first floor. The builders' construction schedules provide the timeline for other lots.

Background

Foundation Design from the Ground Up

The house foundation and footing system serves a number of purposes. It bears the weight of a building's loads and safely transfers these to the ground, provides the restraint against wind and earthquake forces, prevents movement due to frost heave, isolates a building from ground moisture, and provides a safe pathway to transfer electrical current generated during lightning strikes into the earth.

Each of the most common types of foundations used to support light frame wood buildings, slab, crawl space, and basement may be constructed in several ways to accommodate cost, climate, and site conditions. For example, concrete slab foundations can be built on grade, on top of compacted fill material pads, or on top of compacted fill material retained within stem walls. Crawl space foundations may consist of continuous perimeter stem walls, piers and beams, or a combination of these. Basement foundations may be in-ground (full excavation), walkout (partial excavation within a sloped topography), or some variant of these. Each type of basement foundation typically is constructed of reinforced formed concrete and/or concrete masonry units (CMU). Slab foundations will have concrete first floors, whereas crawl space and basement foundations most commonly have wood first floor systems. The second floors of houses on any of these foundation types are typically wood systems.

Climate and soil conditions often guide selection of the foundation type. Regions with mild winter weather have shallow frost penetration of the soil that minimizes the footing depth required to resist soil movement from frost heave. Where local conditions and house design allow a 12- to 18-in. deep footing, such as in the U.S. South, the decision to increase that excavation by 6 ft to 7 ft to include an in-ground basement foundation presents a substantial cost burden. In more northern climates where frost levels reach more than 48 in., the decision to incorporate additional square footage in a basement is based on a smaller incremental cost to complete than that of a southern region design, so basements are more prevalent. Similarly, challenging soil conditions can result in more expensive foundation systems, such as in parts of Texas where post-tension slab foundations are required to resist damage due to expansive clay soils.

Foundations Investigated

The subjects of this study were raised wood floors on stem wall crawl space foundations compared with two methods of construction of raised slab foundations. The raised wood floor systems on stem wall foundation were framed with either dimensional lumber or I-joists. In each of the cases represented, the builder's team selected the foundation and floor system.

Figures 1 and 2 are stem wall foundations; each would be appropriate for either a raised wood floor or compacted fill and a raised concrete slab. The piers inside the perimeter stem walls of the foundation in Figure 1 will support girders supporting floor joists and other building loads. The excavated trenches in the compacted fill material within a stem wall foundation in Figure 2 will be filled with reinforcement bar (rebar) and concrete when the concrete slab is prepped and placed to serve as grade beams or depressed footings supporting interior building loads. Figure 3 shows the compacted fill prepared for the concrete slab placement.

The compacted fill inside a stem wall foundation, shown in Figures 2 and 3, is a design typically used when elevation difference between grade and finished floor is greater than 2 ft for a ground-supported concrete slab floor. At elevations less than 2 ft above grade, raised slabs may be constructed on raised building pads created with compacted fill material as in Figures 4 and 5. However, the 2006 International Residential Code (IRC) and newer versions limit prescriptive slab construction on clean sand or gravel compacted fill to 2 ft or less and earth compacted fill to 8 in.; this would require engineered designs for greater elevation variances.

Figure 1—Stem wall crawlspace foundation with interior piers, Lot 38.

Figure 2—Stem wall foundation with compacted fill, Lot 11.

Figure 3—Stem wall foundation with slab prepared for concrete placement, Lot 11.

Figure 4—Compacted fill pad, Lot 18 rear.

Figure 5—Compacted fill pad prepared for concrete placement, Lot 18 front.

Case Specifics

Each house had a conditioned, finished, first floor sized between 1,680 and 2,370 ft^2, and each was built on an infill lot within a developed or developing community. The elevation of each finished first floor that was a subject in this study varied from 8 to 72 in. (above finished grade), sometimes within the same house.

On all of the sites represented in the study, the site topography, estimated cost, assumed preferred consumer convention, specified finish flooring (tile or wood), or a combination of these factors guided the selection of foundation/floor system design and type rather than base flood elevation (BFE) requirements.

Cost Considerations

Each lot was constructed according to the builder's standard practices using subcontractors and suppliers in each company's customary supply chain. Costs were compiled from the invoices rendered, and quantities were verified against field counts and/or quantity takeoffs. Tables 1, 2, and 3 show the costs that have been compiled for the three types of foundations in the case study, raised wood on CMU stem wall, raised slab supported on compacted fill retained by a CMU stem wall, and raised slab on compacted fill pad.

Recognized Costs

Each of the foundations in the study was finished with a brick veneer. The footings below the stem wall foundations served as the brick ledge. At turned-down edges of the slabs constructed on compact fill pads, concrete was over-poured under the slab form to serve as the brick ledge. The cost and labor associated with the brick veneer of the foundation was not recorded with the cost of each of the foundations because it was a non-structural cosmetic finish.

The designs used dissimilar hardware for wind uplift force restraint. For example, one design specified that threaded bolts run continuously from grouted CMUs through the highest walls' top plates, whereas another called for sill plate bolts with washers, stud/plate hardware (high and low) in each wall, and tie-down straps at headers. Hardware that was installed to complete the first floor is included in the reported costs.

Inspection fees paid to an engineer for testing the compacted fill beneath the slabs were included at the rate of $60 per lot, the average expense incurred. No special engineering fees directly associated with the foundation were charged. Each of the house plans was prepared by a professional draftsperson and reviewed and sealed by an engineer or architect. Standard foundation details from the 1999 Standard (southern) Building Code Congress International (SBCCI) were included in the architectural plans to represent the footing and grade beams, CMU walls, and compacted fill/slab designs. SBCCI is one of three original regional model building code development groups and a founder of the ICC, International Code Council, fiduciary of the I-code development process, and the International Residential Code.

The 2006 IRC, the building code governing the minimum construction standards for the houses in this study, requires that floors exposed to ambient conditions, as with a vented crawl space foundation, require R-13 insulation, whereas slab edges require no insulation in this climate zone (i.e., Climate Zone 2). Cost estimates for R-19 floor insulation (because that is what the builders installed in all cases), polyethylene vapor barrier, foundation vents, and a crawl space access door are included for each raised wood foundation. These activities tend to be completed toward the end of a building's critical path of construction; thus, these costs were estimated if they had not been recorded when this study was completed.

In some cases, product or cost contributions were extended to the builders participating in the study. In this event, the builder's cost of the product was estimated from current quotations and added to the total cost for the lot.

Unrecognized Costs

The perimeter walls, porches, and garage slabs from an attached garage have been omitted from the costs considered

Table 1—Raised floor cost for wood on stem wall crawl space foundation

	Cost and dimension data for four lot numbers					
	38	39	2W	2J	Average ($)	Cost (%)
Footing ($)						
Concrete	3,669	3,277	1,296	2,407	2,662	11
Labor	1,850	1,855	1,473	1,483	1,665	7
Rebar[a]	813	834	894	881	855	4
Subtotal footing	6,332	5,966	3,663	4,771	5,183	—
Foundation wall ($)						
Concrete	1,627	1,232	1,368	1,055	1,320	6
CMU[b]	3,309	3,634	2,061	2,917	2,981	13
Labor	2,344	3,197	2,176	1,550	2,317	10
Subtotal foundation wall	7,280	8,064	5,605	5,522	6,618	—
Floor system ($)						
Joists/girders[c]	3,366	2,963	6,918	6,853	5,025	21
Sheathing[d]/insulation	2,871	3,228	2,742	3,183	3,006	13
Labor	6,396	4,007	2,486	2,790	3,920	17
Subtotal floor system	12,633	10,198	12,147	12,826	11,951	—
Total ($)	26,245	24,228	21,414	23,119	23,752	100
Average foundation height (ft)	3.84	3.79	2.67	3.38	3.42	—
Footing (linear ft)	215	207	208	193	206	—
Cost of foundation ($/ft^2)	31.71	30.82	38.66	35.37	34.14	—

[a]Rebar includes forms for jumps and rod chairs.
[b]CMU includes accessories, vents, and crawl space access.
[c]Joists include beams, hardware, and brick veneer.
[d]Sheathing includes subdeck insulation, R-19.

Table 2—Raised floor cost for raised slab on fill within stem wall foundation

	Cost and dimension data for three lot numbers				
	22	11	34	Average ($)	Cost (%)
Footing ($)					
Concrete	1,574	2,356	2,252	2,060	11
Labor	912	995	1,019	975	5
Rebar[a]	757	811	867	812	4
Subtotal footing	3,243	4,162	4,137	3,848	—
Foundation wall ($)					
Concrete	1,136	1,999	1,189	1,441	8
CMU[b]	2,458	2,793	2,070	2,440	13
Labor	2,153	2,224	1,795	2,057	11
Subtotal foundation wall	5,747	7,016	5,054	5,939	—
Floor system ($)					
Concrete	3,846	3,653	3,406	3,635	19
Fill[c]	3,860	3,405	3,385	3,550	19
Labor	1,692	1,777	1,688	1,719	9
Subtotal floor system	9,398	8,836	8,479	8,904	—
Total ($)	18,388	20,014	17,670	18,691	100
Average foundation height (ft)	2.89	3.47	2.87	3.08	—
Footing (linear ft)	228	249	233	237	—
Cost of foundation ($/ft^2)	27.86	23.17	26.42	25.82	—

[a]Rebar includes forms for jumps and rod chairs.
[b]CMU includes accessories.
[c]Fill includes compaction inspection.

Table 3—Raised floor cost for raised concrete slab on compacted fill pad

	Cost and dimension data for two lot numbers			
	21	18	Average ($)	Cost (%)
Footing ($)				
Concrete	—	—	—	0
Labor	—	—	—	0
Rebar	—	—	—	0
Subtotal footing	0	0	0	—
Foundation wall ($)				
Concrete	—	—	—	0
CMU	479	281	380	3
Labor	—	—	—	0
Subtotal foundation wall	479	281	380	—
Floor system ($)				
Concrete	6,581	6,132	6,356	56
Fill	2,928	2,720	2,824	25
Labor	1,707	1,706	1,706	15
Subtotal floor system	11,216	10,557	10,887	—
Total ($)	11,696	10,838	11,267	100
Average foundation height (ft)	1.70	1.89	1.79	—
Footing (linear ft)	228	205	217	—
Cost of foundation ($/ft^2)	30.24	27.95	29.10	—

in this study. The resultant focus is on the cost and time to construct raised floor systems within a conditioned building.

As previously stated, the costs reported for the foundations in this study do not include the cost of the brick veneer. Because these costs varied with lot condition and builder and were not specifically associated with any one foundation type represented in the study, we omitted from reporting approximately $2,200 to $3,000 of costs related to clearing the lot, locating the house on the lot, and treating the disturbed area for termites. Where excavation cost specifically related to the foundation was incurred, it has been included with the cost of the footing or the raised slab's form work, consistent with the labor invoice for these activities.

All of the costs associated with development of the architectural design and reproduction of architectural drawings were also omitted from this study for similar reasons. Likewise, costs associated with components and activities that occur after the first floor is in place have not been captured or reported.

The installation costs associated with the rough mechanical, electrical, and plumbing (MEP) trades were not captured because, in all cases, these were charged at the same rate for either a slab or a crawl space with wood floor system design. A raised concrete slab on compacted fill with stem wall is the traditional foundation installed by the builders in this study, and therefore they have no learning curve to produce a low-cost product. The only MEP trade affected by a raised wood floor system installed in lieu of a slab on fill is the plumbing because piping is routed beneath the floor joists rather than in the fill material under a slab.

The environment and timing of the plumber's ground and/or rough-in work changes with foundation type—from working in the open air to operating within a confined crawl space. The slab requires three trips to the jobsite for the plumber: one to install water sleeve and sub-slab drains, one to complete the piping after the frame is under roof, and one to complete the fixtures when the house nears completion. A crawl space foundation, however, allows completion of all supply and drain pipes after the roof has been installed, paring the plumber's activities to two site visits—rough-in and final. The other trades installed rough-in work in the same critical path and layout whether on a raised slab or raised wood floor system.

Cost Comparison

Each of the foundation/floor systems is divided into three distinct assemblies: footing, wall, and floor system. Each of these assemblies is comprised of a few key material and labor categories that will facilitate an examination of cost drivers across foundation types. Appendix B contains the cost detail by lot.

All of the CMU walls were reinforced with vertical rebar, horizontal Dur-O-Wall® sidewall belting (Dur-O-Wall Hauppauge, NY), and each cell was grouted with concrete; thus, the concrete material in the "Foundation wall" section of Table 1 covers the cost of grout and the concrete pump. The CMU total in the same section includes the

Table 4—Comparison of costs with R.S. Means[a] data

	Lot 38 Mobile, AL	Lot 39 Mobile, AL	Lot 22 Spanish Fort, AL	Lot 21 Spanish Fort, AL	Lot 2W Daphne, AL	Lot 18 Spanish Fort, AL	Lot 11 Spanish Fort, AL	Lot 34 Spanish Fort, AL	Lot 2J Montrose, AL, estimated
Type of foundation	Stem wall	Stem wall	Stem wall	Raised pad slab	Stem wall	Raised pad slab	Stem wall	Stem wall	Stem wall
1st floor material	Wood	Wood	Concrete	Concrete	Wood	Concrete	Concrete	Concrete	Wood
Construction start date	8/1/08	3/1/09	10/1/09	3/1/10	4/10/10	5/1/10	5/1/10	7/10/10	8/22/10
Average foundation height (ft)	3.84	3.79	2.89	1.70	2.67	1.89	3.47	2.87	3.38
Δ lot elevation (ft)	4.67	4.67	5.00	2.00	0.00	3.00	5.00	6.00	2.67
1st floor (ft^2)	2,132	2,166	2,256	2,276	1,680	2,274	2,370	2,251	1,885
Footing or fill pad ($)	6,332	5,966	3,243	0	3,663	0	4,162	4,137	4,771
Forms or stem wall ($)	7,280	8,064	5,747	479	5,605	281	7,016	5,054	5,522
Raised floor ($)	12,633	10,198	9,398	11,216	12,147	10,557	8,836	8,479	12,826
Total floor and foundation ($)	26,245	24,228	18,388	11,696	21,414	10,838	20,014	17,670	23,119
Perimeter footing (linear ft)	215	207	228	228	208	205	249	233	193
Cost of foundation ($/ft^2$)	31.71	30.82	27.86	30.24	38.66	27.95	23.17	26.42	35.37
RSM footing[a] ($)	4,046	3,896	4,286	—	3,904	—	4,676	4,373	3,630
RSM foundation wall[a] ($)	6,084	5,778	4,851	2,842	4,072	2,850	6,350	4,915	4,804
RSM 4-in. concrete slab[a] ($)	—	—	6,249	6,306	—	6,300	6,564	6,235	—
RSM compacted fill[a] ($)	—	—	5,969	3,530	—	3,932	7,522	5,914	—
RSM wood deck[a] ($)	13,133	13,341	—	—	9,828	—	—	—	13,100
RSM total cost estimate, unadjusted[a] ($)	23,263	23,016	21,355	12,678	17,803	13,082	25,111	21,437	21,534
Builder over RSM[a]	1.13	1.05	0.86	0.92	1.20	0.83	0.80	0.82	1.07

[a]Sources: Means (2010), Reed Construction Data (2011).

reinforcement material. The labor to grout the wall is included in the "labor" category along with the mason's charge for laying the CMU.

Tables 2 and 3 indicate that the costs associated with the wood floors on stem wall foundations are the highest costs recorded in this study. As a test of the compiled costs' reliability, they are compared with estimates derived from R.S. Means (2010) cost data, unadjusted for location, in Table 4. This table also includes information on the finished square footage, foundation square footage, and average foundation height of each house.

The comparison of actual costs to estimators' guide costs indicates that actual costs of the wood floor systems were up to 20% more than would have been estimated (last row, "builder over RMS"; Lots 38, 39, 2W, and 2J), whereas the other five assembly costs came in below the construction estimation guide results. This would be expected, as the R.S. Means estimation guide includes a location factor adjustment of .81 for Mobile, Alabama. The numbers suggest that the wood floor assemblies could benefit from value engineering and competitive bidding; some of the areas that surfaced during the study will be covered in the Value Engineering Strategies section of this report.

The raised concrete slabs on fill within stem walls (Lots 22, 11, and 34) actual costs range from 8% to 18% under the estimation guide, and the slabs on fill pads (Lots 21 and 18) range from 8% to 17% below the estimates.

The stem wall foundation for the raised wood floor system and for the concrete slab supported on compacted fill require essentially the same labor and material inputs prior to placement of the finished first floor, with either fill and concrete or wood and sheathing. The wood floor systems require interior footings and piers, for which costs are reflected in the "footing" and "wall" categories, respectively, in Table 1. The interior load support in both of the slab foundation types was installed as depressed footings below the slab and captured in the costs in the "floor" section of Tables 1 and 2. Technically, there is no additional labor charge for the installation of depressed footings and turned down slab edges, which suffice for footings in slabs formed on compacted fill pads. Nor is there an additional charge for footing and foundation complexity, such as jump conditions and inside and outside corners. The builder pays for the concrete, pump, accessories (wire mesh, poly), and labor separately. The builders charge by finished square foot of slab and order and install the concrete and accessories without regard for cost effectiveness.

Under this type of cost scheme, the interior building load supports required for a raised wood floor system (interior footings, piers, and beams) will always stand out as added cost in comparison to a slab, because of the simplicity of accommodating interior loads engineered for concrete on compacted fill. As noted below Table 1, each of the raised wood floors on stem wall foundations "wall" totals includes vents, access panels, and polyethylene vapor barrier to finish the crawl space at a cost of $860. Thus "footing" and "wall" costs of raised slab and raised wood floors with stem wall foundations should vary by the cost of interior supports and crawl space finishing details in the wood-floored house.

Table 5—Construction schedules for lots in this study

Activity	Days to complete: Estimated	Raised wood, estimated	Lot 38, actual	Raised concrete, estimated	Lot 11, actual	Concrete on pad, estimated	Lot 18, actual
Haul dirt for fill	1.5	0.0	0.0	1.5	1.0	1.5	1.5
Compact fill	1.5	0.0	0.0	1.5	2.0	1.5	1.5
Form slab	1.0	0.0	0.0	0.0	0.0	1.0	1.0
Excavate/form footings	1.0	1.0	1.0	1.0	1.0	0.0	0.0
Footing inspect	1.0	1.0	1.0	1.0	6.0	0.0	0.0
Pour footings	1.0	1.0	1.0	1.0	0.0	0.0	0.0
Lay block	4.0	4.0	7.0	4.0	8.0	0.0	0.0
Grout block	1.0	1.0	2.0	1.0	3.0	0.0	0.0
Rough plumbing	1.0	0.0	0.0	1.0	2.0	1.0	3.0
Plumbing inspection	1.0	0.0	0.0	1.0	2.0	1.0	1.0
Slab prep	1.0	0.0	0.0	1.0	1.0	1.0	9.0
Slab inspection	1.0	0.0	0.0	1.0	1.0	1.0	1.0
Slab pour	1.0	0.0	0.0	1.0	0.0	1.0	0.0
Remove forms	1.0	0.0	0.0	0.0	0.0	1.0	3.0
Install joists	3.5	3.5	8.0	0.0	0.0	0.0	0.0
Install underlayment	1.5	1.5	1.0	0.0	0.0	0.0	0.0
Jobsite idle, weekend	—	4.0	Included	4.0	Included	2.0	Included
Total calendar days to completion	—	17.0	21.0	20.0	27.0	12.0	21.0

Time to Construct

Construction Critical Path Schedules

The builders in the study estimated the completion schedules for each of the foundation/floor systems in the study. We set a minimum of three calendar weeks for construction. However, failed inspection, inspection delay, weather, and other scheduling conflicts resulted in each of the foundation types being completed anywhere from five to nine calendar days more than estimated. Lots 11 and 18 were being built at the same time in locations less than one mile apart and were subjected to five days of weather delays. Table 5 contains the estimated and actual construction schedules for representative raised wood, raised concrete, and concrete on pad foundation and floor systems.

Time

To aid in the cost comparisons in this study, the time to construct was compiled when feasible. Time was recorded at 5-min intervals for the duration of the work in progress. Appendix C contains the timesheets compiled on the lots observed.

Tables 6 and 7 excerpt some of the labor hours observed and contract costs for the three components of the foundation/floor assembly of Lots 38 and 39. All of the labor hours recorded for Lot 38 were observed by researchers in the field. Only the labor hours specific to the wood floor assembly were observed for Lot 39. Thus, the labor hours attributed to the footing and foundation of Lot 39 were estimated as those observed for lot 38. The lots were next door to each other, built on the same topography with the same subcontractors for the same builder. Lot 38 was started in August 2008 and Lot 39 was started in March 2009.

Comparing the two tables indicates that the contract cost for carpentry labor dropped approximately 37% on Lot 39, and the job was completed in 75% of the time. Based on the gross labor rate observed for Lot 38 (contract price divided by hours observed), the revised contract price might have been predicted. This is explored in the Value Engineering Strategies section. We saw a 25% improvement in time to construct, which may be attributed to the team honing its skill and approach as they learned the process.

Results

The cases used in this study indicate that the raised wood floor system and raised concrete slab on fill with stem wall foundations were comparable in construction critical path time. The raised wood systems cost an average of 32% more than the raised concrete on fill with stem wall (as measured by average cost of square foot of foundation wall). The difference in average elevation of the foundation walls supporting the two floor types was approximately 4 in. (wood measures 3 ft, 5 in. compared with concrete, which measures 3 ft, 1 in.).

Figure 6, a graph of the points collected in the study, represents cost per square foot of foundation wall and the average foundation height. The graph shows that the concrete raised slabs in the study cost less than the foundations with raised wood floors, which is supported by the comparisons in Table 4.

Trend lines developed from the plotted points are parallel, suggesting that the lines will not intersect (or costs will not be equal) at a higher foundation elevation. (The minimum code prescribed foundation height for a crawl space design is 2.5 ft, so the wood trend line's upper end limit is

Table 6—Observed labor hours compared with contract cost for Lot 38

Component	Footing	CMU walls	Wood deck
Aggregate assembly (h)	79.33	145.75	119.75
Labor contract cost ($)	1,850	2,344	6,396
Contract cost of labor (%)	17	22	60
Gross hourly rate (observed time)	23.32	16.08	53.41

Table 7—Observed labor hours compared with contract cost for Lot 39

Component	Footing[a]	CMU walls[a]	Wood deck
Aggregate assembly (h)	79.33	145.75	92.00
Labor contract cost ($)	1,855	3,197	4,007
Contract cost of labor (%)	20	35	44
Gross hourly rate (observed time)	23.38	21.94	43.55

[a]Hours estimated.

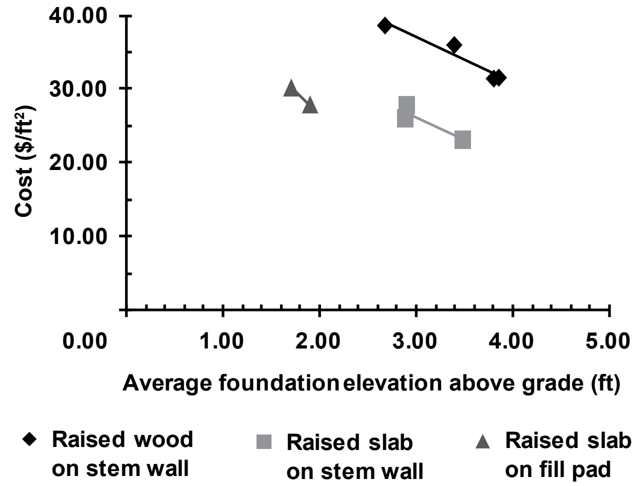

Figure 6—Cost per square foot of foundation wall.

that which is shown.) The trend lines indicate that cost per square foot of foundation declines as the elevation of the wall increases, or as the cost of the footing is spread across a larger area of foundation.

These costs represent two builders' experience on several lots over a 2-year period of time.

Value Engineering Strategies

Competitive Bids

Carpentry costs per square foot for the four raised wood floors in the study varied from $3.00 (recorded in year one for Lots 38 and 39) to $1.48 (recorded in year two for Lots 2W and 2J). The work spanned two years during which supply and demand conditions varied widely within the new residential construction market. However, the houses in the study are located within a 25-mile radius, so it is likely that they could have shared the same labor pool. Nationally, carpentry labor rates increased just less than 10% during the 2-year study period—an oppositely directed trend from that observed during the present study.

In the book *Building Construction Cost Data* (66th to 68th annual editions) published by Reed Construction Data for the years 2008–2010 indicates the following: the carpenter rate (per hour including fringes) for 2008 is $38.10, for 2009 is $39.95, and for 2010 is $41.55. The percent delta is 9.06%. The delta is the ratio comparing the change in the price of the underlying asset to the corresponding change in the price of a derivative (Sometimes referred to as the hedge ratio).

The carpentry crew at the low end of the range of cost per square foot of installed floor system added 72% additional cost per square foot to its established cost of $2.05 in order to frame the other components of the house (i.e., first- and second-floor interior and exterior walls, second floor, and conventionally framed steep-sloped hip roof). The added cost does not seem to be proportionate to the scope of the added work. (The observation relates to framing complexity of the entire structure as opposed to supporting time studies.)

Optimize Floor Systems

Each of the four raised wood floors in the study was designed with floor joists spaced at 16 in. on center and 23- to 32-in. OSB floor underlayment. By increasing the floor framing spacing to 19.2 in. on center, less framing material could have been used while still providing a relatively stiff-feeling floor system. The conservative and more costly designs were used because designers and/or builders consistently were concerned with eliminating noticeable floor vibration and deflection. It is generally agreed that the code minimum deflection criteria for residential construction may not meet performance expectations (i.e., the feel) of modern-day buyers or the subsurface criteria for masonry floor finishes.

However, floor deflection can be given design consideration without strict adherence to a certain spacing and joist dimension. For example, the floor system of Lot 39 (Fig. 5) contained 2 by 10 joists of SYP #2 at 16 in. spacing with the greatest clear span of 11 ft, 0 in. (joist length of 12 ft, 4 in. with 8-in. CMU bearing each end). Consulting the Southern Pine Council's (SPC) *Maximum Spans Southern Pine Joists & Rafters, 2010* (SPC span tables, http://www.southernpine.com/span-tables.asp) indicates that the first floor joists with the greatest clear span could have been specified with 2 by 8 #2 SYP to meet design values of 50 lb/ft^2 live load and 10 lb/ft^2 dead load with deflection of L/480; a deflection value 33% stiffer than the minimum code criteria. Or, to meet deflection of L/600, 2 by 12s spaced at 24 in. on center could have been specified. Table 8 contains excerpts from the SPC

Table 8—Southern yellow pine (SYP) floor joist span tables

		SYP #2 better visually graded		
Deflection criteria		L/360	L/480	L/600
Adjustment factors		1.00	0.91	0.84
		Span (ft) (inside to inside of bearings)		
Dimension	Spacing (in.)	40 lb/ft^2 live/ 10 lb/ft^2 dead		
2 by 8	16.0	12.83	11.68[a]	10.78
2 by 8	19.2	12.08	10.99	10.15
2 by 8	24.0	11.00	10.01	9.24
2 by 10	12.0	18.00	16.38	15.12
2 by 10	16.0	16.08	14.63	13.51
2 by 10	19.2	14.67	13.35	12.32
2 by 10	24.0	13.08	11.90	10.99[b]
2 by 12	12.0	21.75	19.79	18.27
2 by 12	16.0	18.83	17.14	15.82
2 by 12	19.2	17.16	15.62	14.41
2 by 12	24.0	15.42	14.03	12.95[c]
		50 lb/ft^2 live/ 10 lb/ft^2 dead		
2 by 8	16.0	11.92	10.85[a]	10.01
2 by 8	19.2	11.25	10.24	9.45
2 by 8	24.0	10.00	9.10	8.40
2 by 10	12.0	16.75	15.24	14.07
2 by 10	16.0	14.67	13.35	12.32
2 by 10	19.2	13.42	12.21	11.27
2 by 10	24.0	12.00	10.92[b]	10.08
2 by 12	12.0	19.83	18.05	16.66
2 by 12	16.0	17.16	15.62	14.41
2 by 12	19.2	15.67	14.26	13.16
2 by 12	24.0	14.00	12.74	11.76[c]

[a]Adequate design for Lot 39 1st floor joists at 16-in. spacing.
[b]Alternate design for Lot 39 1st floor joists at 24-in. spacing.
[c]Alternate design for Lot 39 1st floor joists at 24-in. spacing. Source: SPC (2010).

span tables with adjustment factors applied for higher deflection criteria. The L/480 and L/600 columns were created for this study from factors covered in the SPC span tables. Builders and designers may find it useful to have the tables with higher deflection criteria and higher live and dead loads at hand.

Alternatives highlighted in Table 8, such as changing the 2 by 10 spacing to 24 in. on center or opting for even more stringent deflection and using 2 by 12s spaced at 24 in. might have reduced the total cost of the raised wood floor for Lot 39 by as much as $430, based on the spring 2009 invoices rendered for the lot.

The 3-ply 2 by 12 floor girders installed in Lots 38 and 39 met the design loads at a cost of $3.15 per linear foot, whereas the 2-ply 9 1/2 in. LVL girders in Lot 2W cost over three times that at $9.70 and the 3-ply at $14.55.

Continuous Versus Spot Footings

For two houses, Lots 38 and 39, continuous interior footings supporting piers required 13 cubic yards of concrete (Figs. 7 and 8). The continuous footings were installed to eliminate differential settlement of the piers. Differential settlement of piers can be avoided by a continuous reinforced footing that may bridge a poor subsoil condition beneath a pier, as with this case. Differential settlement also can be avoided by sizing the footing and pier to sustain the calculated building load, removing all organic matter from the footing hole, and installing the footing below the frost depth. The amount of concrete required for interior footings could have been reduced by 8 cubic yards of concrete if spot footings 24 in. deep had been specified instead of the continuous footings. Individual footings might have saved $800 in the extant market during the summer of 2008.

Alternative Piers

Piers formed with sonotubes and filled when the block wall was grouted might have provided additional labor savings over CMU piers. Interior treated wood posts could have also provided labor savings compared with the CMU piers that were used.

Lower Piers to Allow In-Line Framing

This option would design the piers at a lower elevation than the stem wall so that the girders can be dropped below the floor joists. Framing floor joists into the side of girders requires increased hardware and labor. Shorter pier height also adds to savings.

Reduce Interior Supports at Design Stage

Reduce the number of interior piers by using longer spanning floor joists. Eliminating piers, girders, and continuous footings would minimize costs.

Pier Spacing

When interior piers are supported with continuous footings, specify piers at close spacing so that dimensional lumber girders can be used.

Minimize Waste with a Bill of Materials and Cut List

The audited cases in this study consistently indicated that joist shipments did not match the estimates in length, quantity, or cost. Quoted prices were not honored despite delivery within the price hold period and supplier substitution of longer lengths was charged to the builder. As an example, Lot 2 (W, J), with a quantity and exact length floor joist layout incorporated into the architectural plans, received more than 100 linear feet of excess I-joist material at an additional cost greater than $300. Similar excess shipments of lumber were apparent in reviewing the invoices for each of the raised wood floors. To optimize the raised wood floor system's affordability, builders and trade partners should address and solve this systemic inefficiency.

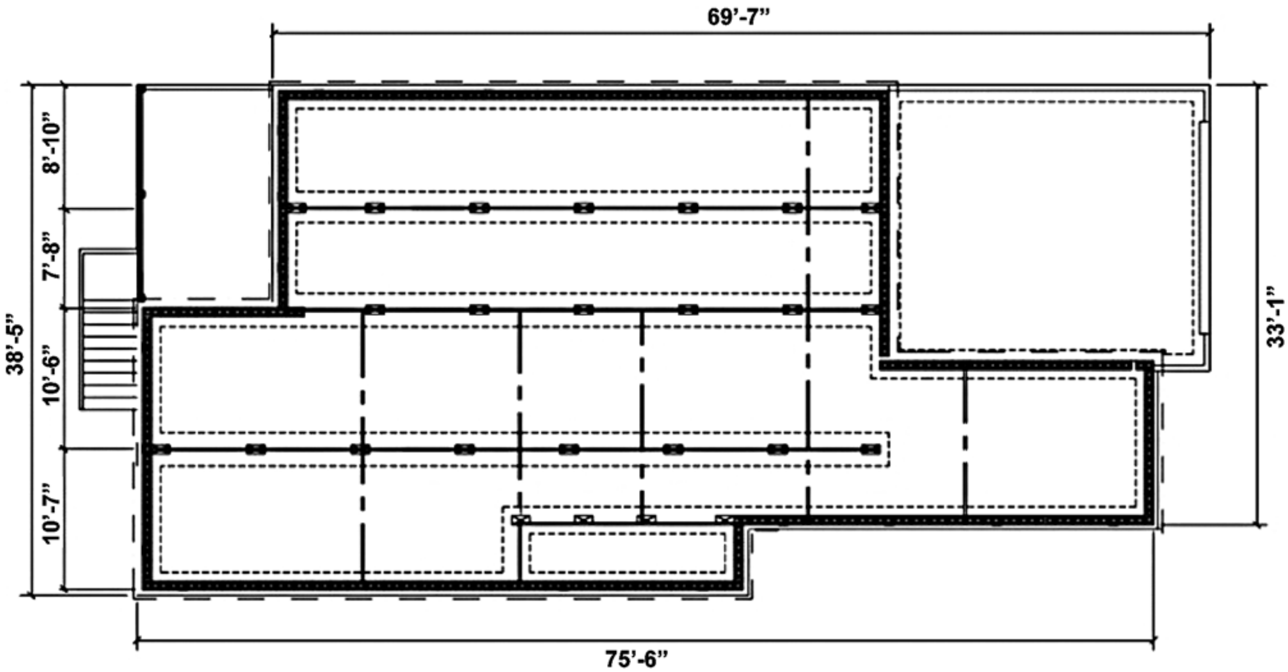

Figure 7—Lot 39 foundation plan.

Figure 8—Lot 38 continuous interior footings and piers.

Figure 9—Lot 11, rear elevation.

Promote the Attributes of a Crawl Space

The four houses with crawl spaces in this study did not capitalize on the added space feature of the area below the first floor. Two of the crawl spaces had enough height to accommodate the same horizontal air handlers that were located in the attics of these houses. The crawl space summer temperature is usually close to the ambient temperature and at least –1 °C (30 °F) lower than the attic, which properly detailed, would provide a less harsh environment for the HVAC units and the ductwork and also increase energy efficiency. Installation of the MEP systems within the first floor assembly allows simple air and moisture sealing of the floor system to increase energy efficiency and indoor air quality.

One of the raised concrete slab with stem wall houses was built on a lakefront lot sloping down toward the water’s edge in the rear. Had that house been built with a crawl space the under floor area potentially could have provided easily-accessible storage for small boats and equipment (Fig. 9).

Optimized Case with Value Engineering Strategies

To explore whether these two types of foundations would be more cost competitive to build in some other case, specific costs (Table 9) were normalized and totaled in Table 10. The process of normalizing in this example set cost of concrete, CMU and footing labor cost, carpentry labor cost, and carpentry materials (dimensional lumber, 2 by 10 for Lots 38 and 39, and 2 by 12 for Lots 2W and 2J) equal at the quantities used. Quantities for dimensional lumber were calculated

Table 9—Costs used for hypothetical case

	Cost ($)	Unit
Concrete	76	Cubic yard
Footing labor	4	Linear foot
Carpentry	1.48	Finished ft^2
CMU labor	1.25	Block
2 by 12 beams	1.34	Linear foot

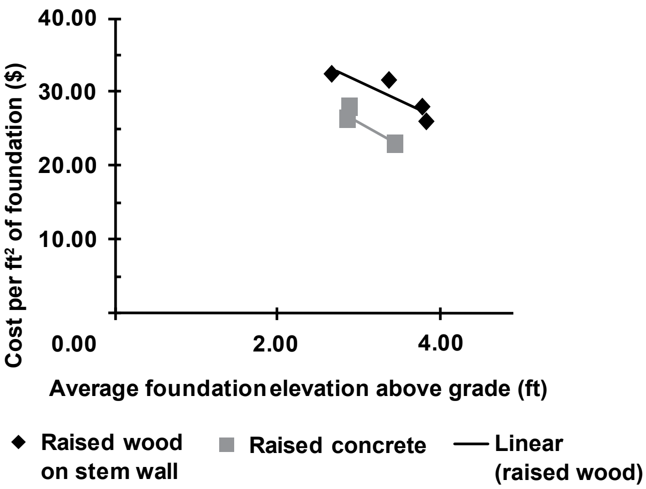

Figure 10—Optimized cost per square foot of foundation wall with costs set equal.

to include several areas of lots 2W and 2J, with 2 by 12 on 12 in. on center spacing to maintain stringent deflection criteria. Three-ply 2 by 12 beams replaced the 2-ply LVL in Lot 2W. The estimation detail for these is contained in Appendix D.

Figure 10, a graph of the optimized study cases with key costs set equal for all points, indicates that foundation costs per square foot can be lowered when the same market costs prevail. Including additional value engineering and material reductions could bring the raised wood and the raised concrete foundation costs closer together.

Conclusion

Footings and foundations of the two types of raised floor systems could be constructed with equal costs, however, interior piers and crawl space foundation accessories add cost to the raised wood floor system. With specific layouts and quantities of dimensional lumber, the floor/foundation systems of the two types can approach equal cost. The optimized cost approach taken results in an average cost difference of $2.53 per square foot of foundation. Using the raised wood average foundation size of 704 ft^2, the added cost of these components, which are unique to the raised wood foundation, would be $1,751.

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Table 10—Hypothetical case results

	Raised wood				Raised concrete		
Foundation type	Lot 38	Lot 39	Lot 2W	Lot 2J	Lot 22	Lot 11	Lot 34
Cost of foundation wall ($/$ft^2$)	25.45	27.71	31.93	31.42	27.67	22.99	26.65
Height (ft)	3.84	3.79	2.67	3.38	2.89	3.47	2.87

Appendix A. Relevant Indices

Appendix A—Relevant indices and costs

	Lot 38 Mobile, AL	Lot 39 Mobile, AL	Lot 22 Spanish Fort, AL	Lot 21 Spanish Fort, AL	Lot 2W Daphne, AL	Lot 18 Spanish Fort, AL	Lot 11 Spanish Fort, AL	Lot 34 Spanish Fort, AL	Lot 2J Montrose, AL
Concrete, ($) per yd^3, delivered[a]	96.47	99.19	74.00	72.00	72.00	74.35	76.32	—	—
Date foundation start	7/08	3/09	10/09	3/10	4/10	5/10	5/10	—	—
Footing labor, dig and pour (per ft)	5.00	5.00	4.00	4.00	4.00	—	4.00	—	—
CMU labor, per block (average)	2.00	1.85	1.54	—	1.25	—	—	—	—
Concrete labor, slab, per ft^2	1.05	—	0.75	0.75	0.75	0.75	0.75	—	—
Concrete, per cubic yard, delivered[a]	12.50	12.50	79.55	76.32	76.32	74.35	76.32	—	—
Carpentry labor, deck, per ft^2	3.00	1.85	—	—	1.48	—	—	—	—
Rebar #4 1/2 in. 20 ft	7.89	—	6.50	—	6.35	—	—	—	—
Rebar #5 5/8 in. 20 ft	12.69	12.50	9.75	—	6.56	—	7.69	—	—
2 by 4 9 ft lodgepole	—	—	—	—	—	—	2.55	—	—
2 by 4 104 5/8 in. SPF[b]	4.21	—	—	—	3.21	—	—	—	—
2 by 4 18 ft lodgepole	—	3.61	—	—	5.64	—	5.22	—	4.96
2 by 4 18 ft SPF	5.34	—	—	—	—	—	—	—	—
2 by 6 14 ft treated	—	—	—	—	10.36	—	—	—	6.85
2 by 10 14 YP[c]	—	9.35	—	—	5.92	—	—	—	—
2 by 10 16 YP	10.66	12.96	—	—	—	—	—	—	—
TJI 360 16 in. by 24 ft	—	—	—	—	73.78	—	—	—	—
2 by 12 14 ft #2 pine	13.83	—	—	—	14.74	—	14.74	—	9.43
2 by 12 16 ft #2 SYP	—	—	—	—	21.07	—	—	—	13.47
2 by 12 18 ft #2 SYP	—	—	—	—	24.77	—	—	—	—
4 by 8 23/32 in. or 3/4 in. OSB T&G[d]	21.53	20.08	—	—	27.03	—	—	—	—
7/16 in. OSB 4 by 10	—	—	—	—	17.66	—	—	—	—
7/16 in. OSB 4 by 8	—	—	—	—	12.10	—	9.90	—	—
1 3/4 in. by 11 7/8 in. LVL[e] 24 ft	115.52	—	—	—	—	—	157.93	—	—

[a]Concrete price reported as the effective price; cost plus delivery/fuel surcharge plus sales tax, plus pump if applicable, divided by cubic yards delivered. All costs from invoices rendered at time of foundation construction including sales tax which ranged from 6%–9.5%, dependent on county. The current market for 2 by 12 is below $1/lin. ft (August 2010), verified by two suppliers, Lot 2J.

[b]Southern Pine flooring.

[c]Yellow pine.

[d]Oriented strandboard tounge and groove.

[e]Laminated veneer lumber.

Appendix B. Detail on Cost—Raised Wood

Lot 38			Qty	Cost per	Extension
Concrete			32	96.47	3,086.88
	Pump				582.00
Labor	Footing		370	5.00	1,850.00
Rebar	#5 Rebar		65	12.50	812.65
Subtotal Footing					6,331.53
Concrete	Grout		11	96.47	1,044.53
	Concrete Pump		3	194.00	582.00
CMU	CMU		920	1.55	1,429.14
	CMU		30	1.91	57.23
	Accessories				965.34
	Foundation vents		30	10.74	322.18
	Access Door		1		53.55
	Poly vapor barrier - taped				482
Labor	Block Labor		922	2.00	1,844.00
	Labor to Grout Block				500.00
Subtotal Wall					7,279.96
Joists/Beams/Plates	Deck Lumber				2,463.54
	Hardware				310.38
Brick Veneer	1st floor band joist		158	3.75	592.51
Sheathing/Insulation	23/32" OSB		88	18.42	1,621.03
			2132	0.59	1,250.00
Labor	Carpentry Quote		2132	3.00	6,396.00
Subtotal Floor					12,633.46
Total Raised Wood					26,244.95

Lot 39			Qty	Ea.	Extension
Concrete			28	99.19	2,777.32
	Pump				500.00
Labor	Footing Labor		371	5	1,855.00
Rebar			1334	0.625	833.75
Subtotal Footing					5,966.07
Concrete	Grout		8	91.56	732.48
	Concrete Pump				500.00
CMU	CMU		270	1.544	416.88
	CMU		10	1.70	16.98
	CMU		1030	1.62	1,668.60
	Accessories				658.71
	Access & vents & poly				873.73
Labor			1318	2	2,636.00
	Grout Labor				561.00
Subtotal Wall					8,064.38
Joists/Beams/Plates	Deck Lumber				2,902.00
	Hardware				216.07
	Brick Veneer at 1st fl		137.5	3.75	515.63
Sheathing	OSB		88	20.28	1,784.64
Mobile Lumber	Insulation		1,891	0.59	1,108.70
Labor	Draw #1		1891.00	1.85	3,498.35
	Draw #2				172.22
Subtotal Floor					10,197.61
Total Raised Wood					24,228.06

Lot 2J ESTIMATED			Qty	Ea.	Extension
Concrete	Footing		27	70.62	1,906.74
	Pump				500.00
Labor	Footing labor		258	4.00	1,032.76
	Peir Labor				450
Rebar	Accessories				881.04
Subtotal Footing					4,770.54
Concrete	Grout		8.00	70.62	564.96
	Pump				490.00
CMU	Block Material		840	1.59	1,336.79
Est. Mobile I	Accessories	412.75			722.31
	Access, vents, Poly				857.73
Labor	CMU Labor		840	1.25	1,050.01
	Grout				500.00
Stemwall Subtotal					5,521.80
Joists/Beam	Beams				433.94
	I-Joists		1,514	3.161	4,785.07
	Rim Boards		193	3.1065	600.14
	Hardware/Misc.				310.06
	Brick Veneer at Bands		193	3.75	723.75
Sheathing	OSB		68	27.80	1,882.78
	Insulation		1885	0.69	1,300.65
Labor	Labor - Carpentry		1,885	1.48	2,789.80
Subtotal Floor					12,826.19
Total Raised Wood					23,118.53

Lot 2W			Qty	Ea.	Extension
Concrete	Footing Concrete		18	72	1296.00
	Pump				0
Labor	Footing Labor		256	4	1024.00
	Pier Labor		450.00		450.00
	Rebar				893.22
Subtotal Footing					3,663.22
Concrete	Grout		11.5	76.32	877.68
	Pump				490.00
CMU	Block		865	1.7555	1518.51
	Accessories				780.73
Labor	CMU		864	1.25	1080.00
	Access & vents & poly				857.73
Subtotal Wall					5,604.65
Joists/Bea	Deck Luml	11.875 IJ	1330		5,305.00
		Rim	176		incl
		LVL- 9 1/4	246	4.85	1,193.10
	Brick Veneer		112	3.75	420.00
Sheathing	OSB		65	27.03	1,756.95
	Ins.		1680	0.59	984.99
Labor			1680	1.48	2,486.40
Subtotal Floor					12,146.44
Total Raised Wood					21,414.31

Appendix B. Detail on Cost—Raised Concrete with Stem Wall Foundation

Lot 22		Extension	Qty	Cost
Concrete	Footing Concrete	1,073.93	13.5	79.55
	Concrete Pump	500.00		
Labor	Footing labor	912.00	228	4
Rebar	#4 Rebar	757.33		
Subtotal Footing		3,243.26		
Concrete	Grout	636.40	8.00	79.55
	Pump	500.00		
CMU	8"	1,280.12	800	1.60
	12"	792.00	360	2.2
	Accessories	385.75		
Labor	Block Labor	1,034.59	796	1.3
	12"	558.00	360	1.55
	Repair	240.00		
	Grout Labor	320.00		
Subtotal Wall		5,746.86	5,746.86	
Concrete	Concrete	2,147.85	27	79.55
	Pump	718.53		
	Accessories	1004.99		
	Inspection	60		
Fill	Compact Dirt	650.00		
	Fill Dirt	3,125.00	25	125
Labor	Labor - Slab Concrete	1,692.00	0.75	2256
Subtotal Floor		9,398.37	5,467.00	
Total Raised Concrete		18,388.48		

Lot 11		Extension	Qty	Cost
Concrete	Footing	1,882.45	23	76.51
	Pump	397.50		
Lopez Concrete	Footing Labor	1,018.00	255	4
Estimate	#4 Rebar	869.93		
Footing Subtotal		4,167.88		
Concrete	Grout	1,380.91	18	76
	Pump	612.50		
CMU	8"	1,145.25	764	1.5
	12"	781.00	355	2.2
	Accessories	866.83		
6/9/10 Fweinmar	Block Labor	926.00	741	1.25
	12"	568.00	355	1.6
	Grout Labor	730.00		
Subtotal Wall		7,010.49		
Concrete	Concrete	2,289.68	30	76.32267
	Pump	500.00		
	Accessories	863.62		
	Inspection	60.00		
Fill	Compact Dirt	485.00		
	Fill Dirt	2,860.05	23	124.35
Labor	Labor - Slab	1,777.24	2370	0.75
Subtotal Floor		8,835.59		
Total Raised Concrete		20,013.96		

Lot 34		Extension	Qty	Cost
Concrete	Footing	2,012.08	26.3	76.505
	Pump	500		
Labor	Footing labor	1,016.00	254	4.00
Rebar	Rebar	841.70		
Subtotal Footing		4,369.78		
Concrete	Grout	564.96	9.00	70.62
	Pump	500		
CMU	CMU	1,497.48	1041	1.44
	CMU	136.10	80	1.70
	Accessories	585.37		
Labor	Block Labor	1,357.50	1086	1.25
	Grout Labor	360.00	9	40
Subtotal Wall		5,001.42		
Concrete		2,163.11	31	70.62
	Pump	500		
	Accessories	562.8		
Fill	Compact Dirt	450.00		
	Fill Dirt	2,875.00	23	125
	Inspection	60.00		
Labor	Labor - Slab Concrete	1,688.25	2,251	0.75
Subtotal Floor	**Subtotal**	8,299.16		
Total Raise Concrete		17,670.36		

Appendix B. Detail on Cost—Raised Concrete on Compacted Fill Pad

Lot 21		Extension	Qty	Cost
Subtotal Footing		o		
Forms		479.30		
Subtotal Wall		479.30		
Concrete		4721.28	62	76.32
	Pump	657.50		
Fill	Compact	650.00		
	Dirt	1,869.00	15	124.6
	Accessories	1,302.21		
	Sand	250		
	Inspect	60		
Labor	Slab	1,707.00	0.75	2276
Subtotal Floor		11,216.99		
Total Concrete on Pad		11,696.29		

Lot 18		Extension	Qty	Cost
Subtotal Footing		o		
Forms		281.00		
Subtotal Wall		281.00		
Concrete		4363.64	59	73.96
	Pump	500.00		
Fill	Compact	410.00		
	Dirt	2,250.00	18	125
	Accessories	1,267.76		
	Inspect	60		
Labor	Slab	1,705.50	0.75	2274
Subtotal Floor		10,556.90		
Total Concrete on Pad		10,837.90		

Appendix C. Detail on Time to Construct

Raised Foundation Study		Job # 3281
Time Study Data:		Raised Wood Floor
Site:		Lot 38 Woodlands
Date:		7/14 thru 8/6/08
Summary of:		Foundation and 1st Deck

	Week 1		Week 2	Week 3					
Days to Complete	7/14/2008	Dig - 2 Pour - 1 Cure - 2	Build 3 Idle 1 Grout 1	Plate, Joist, Bridging - 3.5				Sheath - .5	
		Subcomponent							
Task	Stakeout	Footing	Block Foundation	Plate Foundation	Tie-down hardware	Floor Joists and Beams	Bridging	Deck Sheathing	Total
Obtain Materials	0	0	978	80	0	85	0	0	1,143
Measure	480	496	920	170	0	287	0	0	2,353
Cut	0	209	289	213	0	535	15	84	1,345
Position - lay block, set joist	0	594	2,369	60	20	865	533	470	4,911
Plumb/Square/Level	0	0	0	0	0	220	0	0	220
Fasten/Screw/Adhere/Glue	0	491	0	0	115	835	208	250	1,899
Shim/Block/Drill	0	0	0	0	0	15	0	0	15
Compact/Dig	0	859	0	0	0	0	0	0	859
Mix Mortar/Grout	0	0	790	0	0	0	0	0	790
Brace/Stake	400	276	0	0	0	0	0	0	676
Backfill/Pour Concrete	0	510	0	0	0	0	0	0	510
Operate Equipment	0	99	0	0	0	0	0	0	99
Scaffold/Brace	0	0	0	0	0	0	0	0	0
Read Plans/Talk Bus.	0	94	79	0	0	300	0	85	558
Tools Setup/Breakdown	0	360	573	40	0	350	20	10	1,353
Clean Site/Clean Surface	0	210	1,767	0	0	95	0	80	2,152
Idle waiting on crew member	0	75	57	0	0	0	0	0	132
Rework	0	117	744	0	0	0	0	0	861
Personal	0	0	179	30	0	695	150	270	1,324
Total Minutes	880	4,390	8,745	593	135	4,282	926	1,249	21,200
Total Hours	14.67	64.67	145.75	9.88	2.25	71.37	15.43	20.82	344.83
Aggregate Hours/Assembly		79.33	145.75					119.75	344.83

Raised Foundation Study	Job #3269
Time Study Data:	Raised Wood Floor
Site:	Lot 39
Summary of:	Labor Minutes Observed

	Subcomponent				
Task	Stakeout and Footing	Block Foundation	Floor Joists and Beams	Deck Sheathing	Total
Obtain Materials			0	0	0
Measure			75	0	75
Cut			1360	0	1360
Position - lay block, set joist			1650	520	2170
Plumb/Square/Level			0	0	0
Fasten/Screw/Adhere/Glue			950	340	1290
Shim/Block/Drill			0	0	0
Compact			0	0	0
Mix Mortar/Grout			0	0	0
Scaffold/Brace			0	0	0
Backfill			0	0	0
Operate Equipment			0	0	0
Scaffold/Brace			0	0	0
Read Plans/Talk Bus.			60	20	80
Tools Setup/Breakdown			195	0	195
Clean Site/Clean Surface			0	0	0
Idle waiting on crew member			0	0	0
Rework			0	0	0
Personal			270	80	350
TOTAL			4560	960	
Total labor hours			76	16	
Total Hrs. for Assembly[A]	79	146		92	317

[A]Footing/Block hours extrapolated from lot 38.

Appendix D. Detail on Hypothetical Costs with Key Cost Components Set Equal

Appendix D—Costs used for hypothetical case

	Cost ($)	Unit
Concrete	76	Cubic yard
Footing labor	4	Linear foot
Carpentry	1.48	Finished ft^2
CMU labor	1.25	Block
2 by 12 beams	1.34	Linear foot

Lot 38 HYPOTHETICAL			Qty	Cost per	Extension
Concrete			32	76.00	2,432.00
	Pump				582.00
Labor	Footing		370	4.00	1,481.38
Rebar	#5 Rebar		65	12.50	812.65
Subtotal Footing					5,308.01
Concrete	Grout		11	76.00	822.93
	Concrete Pump		3	194.00	582.00
CMU	CMU		950	1.55	1,475.74
	CMU		30	1.91	57.23
	Accessories				918.34
	Foundation vents		30	10.74	322.18
	Access Door		1		53.55
	Poly vapor barrier - taped				482
Labor	Block Labor		922	1.25	1,152.50
	Labor to Grout Block				500.00
Subtotal Wall					6,366.47
Joists/Beams/Plates	Deck Lumber				2,463.54
	Hardware				310.38
Brick Veneer	1st floor band joist		158	3.75	593.15
Sheathing/Insulation	23/32" OSB		88	18.42	1,621.03
			2132	0.59	1,250.00
Labor	Carpentry Quote		2132	1.48	3,155.36
Subtotal Floor					9,393.47
Total Raised Wood					21,087.94
avg foundation ht					3.84
lnf					215
sf foundation					$25.45
RSM					$23,263
Builder Over RSM					0.91

Lot 2W HYPOTHETICAL			Qty	Ea.	Extension
Concrete	Footing Concrete		18	76	1368.00
	Pump				0
Labor	Footing Labor		256	4	1024.00
	Pier Labor				450.00
	Rebar				893.22
Subtotal Footing					3,735.22
Concrete	Grout		11.5	76	874.00
	Pump				490.00
CMU	Block		865	1.7555	1518.51
	Accessories				780.73
Labor	CMU		864	1.25	1080.00
	Access & vents & poly				857.73
Subtotal Wall					5,600.97
Joists/Beams/Plates	Deck Lumber	2x12	1474	1.34	1,974.34
		Rim	176	1.34	235.74
		LVL- 9 1/4	369	1.34	494.26
	Brick Veneer		112	3.75	420.00
Sheathing	OSB		65	27.03	1,756.95
	Ins.		1680	0.59	984.99
Labor			1680	1.48	2,486.40
Subtotal Floor					8,352.68
Total Raised Wood					17,688.87
avg foundation ht					2.67
lnf					208
sf foundation					$31.93
RSM					$17,803
Builder Over RSM					0.99

Lot 39 HYPOTHETICAL			Qty	Ea.	Extension
Concrete			28	76	2,128.00
	Pump				500.00
Labor	Footing Labor		371	4	1,484.00
Rebar			1334	0.625	833.75
Subtotal Footing					4,945.75
Concrete	Grout		8	76	608.00
	Concrete Pump				500.00
CMU	CMU		270	1.544	416.88
	CMU		10	1.70	16.98
	CMU		1030	1.62	1,668.60
	Accessories				658.71
	Access & vents & poly				873.73
Labor			1318	1.25	1,647.50
	Grout Labor				561.00
Subtotal Wall					6,951.40
Joists/Beams/Plates	Deck Lumber				2,902.00
	Hardware				216.07
	Brick Veneer at 1st flr		137.5	3.75	515.63
Sheathing	OSB		88	20.28	1,784.64
Mobile Lumber	Insulation		2,165	0.59	1,269.35
Labor	Draw #1		1891.00	1.48	2,798.68
	Draw #2		274.00	1.48	405.52
Subtotal Floor					9,891.88
Total Raised Wood					21,789.03
avg foundation ht					3.79
lnf					207
sf foundation					$27.71
RSM					$23,016
Builder Over RSM					0.95

Lot 2J ESTIMATED/HYPOTHETICAL			Qty	Ea.	Extension
Concrete	Footing		27	76.00	2,052.00
	Pump				500.00
Labor	Footing labor		258	4.00	1,032.76
	Pier Labor				450
Rebar	Accessories				881.04
Subtotal Footing					4,915.80
Concrete	Grout		8.00	76.00	608.00
	Pump				490.00
CMU	Block Material		840	1.59	1,336.79
Est. Mobile lumber	Accessories	412.75			722.31
	Access, vents, Poly				857.73
Labor	CMU Labor		840	1.25	1,050.01
	Grout Labor				500.00
Stemwall Subtotal					5,564.84
Joists/Beams/Plate	Beams				433.94
	2x12		1,662	1.34	2,226.16
	Rim Boards		290	1.34	387.77
	Hardware/Misc.				310.06
	Brick Veneer at Bands		193	3.75	723.75
Sheathing	OSB		68	27.80	1,882.78
	Insulation		1885	0.69	1,300.65
Labor	Labor - Carpentry		1,885	1.48	2,789.80
Subtotal Floor					10,054.91
Total Raised Wood					20,535.54
avg foundation ht					3.38
lnf					193
sf foundation					$31.42
RSM					$21,534
Builder Over RSM					0.95

Lot 22		Extension	Qty	Cost
Concrete	Footing Concrete	1,073.93	14.130592	76.00
	Concrete Pump	500.00		
Labor	Footing labor	912.00	228	4
Rebar	#4 Rebar	757.33		
Subtotal Footing		3,243.26		
Concrete	Grout	608.00	8.00	76.00
	Pump	500.00		
CMU	8"	1,280.12	800	1.60
	12"	792.00	360	2.2
	Accessories	385.75		
Labor	Block Labor	1,034.59	796	1.3
	12"	558.00	360	1.55
	Repair	240.00		
	Grout Labor	320.00		
Subtotal Wall		5,718.46	5,718.46	
Concrete	Concrete	2,052.00	27	76.00
	Pump	718.53		
	Accessories	1004.99		
	Inspection	60		
Fill	Compact Dirt	650.00		
	Fill Dirt	3,125.00	25	125
Labor	Labor - Slab Concrete	1,692.00	0.75	2256
Subtotal Floor		9,302.52	5,467.00	
Total Raised Concrete		18,264.23		
avg foundation ht		2.89		
lnf		228		
sf foundation		$27.67		
RSM		$21,355		
Builder Over RSM		0.86		

Lot 34		**Extension**	Qty	Cost
Concrete	Footing	1,998.80	26.3	76
	Pump	500		
Labor	Footing labor	1,016.00	254	4.00
Rebar	Rebar	841.70		
Subtotal Footing		4,356.50		
Concrete	Grout	564.96	9.00	76.00
	Pump	500		
CMU	CMU	1,497.48	1041	1.44
	CMU	136.10	80	1.70
	Accessories	585.37		
Labor	Block Labor	1,357.50	1086	1.25
	Grout Labor	360.00	9	40
Subtotal Wall		5,001.42		
Concrete		2,327.90	31	76.00
	Pump	500		
	Accessories	562.8		
Fill	Compact Dirt	450.00		
	Fill Dirt	2,875.00	23	125
	Inspection	60.00		
Labor	Labor - Slab Concrete	1,688.25	2,251	0.75
Subtotal Floor		8,463.95		
Total Raise Concrete		17,821.87		
avg foundation ht		2.87		
lnf		233		
sf foundation		$26.65		
RSM		$21,437		
Builder Over RSM		0.83		

Lot 11		**Extension**	Qty	Cost
Concrete	Footing	1,740.40	23	76.00
	Pump	397.50		
Lopez Concrete	Footing Labor	1,018.00	255	4
Estimate	#4 Rebar	869.93		
Footing Subtotal		4,025.83		
Concrete	Grout	1,380.91	18	76
	Pump	612.50		
CMU	8"	1,145.25	764	1.5
	12"	781.00	355	2.2
	Accesseries	866.83		
6/9/10 Fweinmann	Block Labor	926.00	741	1.25
	12"	568.00	355	1.6
	Grout Labor	730.00		
Subtotal Wall		7,010.49		
Concrete	Concrete	2,280.00	30	76
	Pump	500.00		
	Accessories	863.62		
	Inspection	60.00		
Fill	Compact Dirt	485.00		
	Fill Dirt	2,860.05	23	124.35
Labor	Labor - Slab	1,777.24	2370	0.75
Subtotal Floor		8,825.91		
Total Raised Concrete		19,862.23		
avg foundation ht		3.47		
lnf		249		
sf foundation		$22.99		
RSM		$21,534		
Builder Over RSM		0.92		