The Pennsylvania State University

SLAB-ON-GROUND CONSTRUCTION FOR HOMES

by

F. A. Joy and G. J. Stout

Better Building Report No. 1

FEBRUARY, 1959

ENGINEERING RESEARCH BULLETIN B-76
College of Engineering and Architecture
University Park, Pennsylvania

Price $1.00
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College of Engineering and Architecture
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With funds appropriated by the Commonwealth of Pennsylvania, the College of Engineering and Architecture of The Pennsylvania State University has undertaken a study of house construction methods. The specific purpose is to help the builder of homes in his struggle to produce a good product at minimum cost. Efficiency without sacrifice of quality will be the keynote -- efficiency through good design, good planning, labor-saving techniques, and simplified construction practice.

The work is centered in the Engineering Experiment Department, of which E. R. Queer is director. Staff members of other departments of the College are available for consultation within their particular fields.

At the outset, the best practices now in use are being explored, and their advantages will be reported. Later, new methods will be devised, and these will be proved in actual house construction. Close contacts are being developed with the home builders of Pennsylvania to learn their problems and to find answers for them. These contacts will include meetings both in the field and on the University campus.

The findings of building research at Penn State will be published in a series of Better Building Reports, to be issued as Engineering Research Bulletins. This report, the first in the series, offers a preferred design for slab floor construction. We recommend its economy to you -- the builder -- for any suitable site.

F. A. Joy
G. J. Stout

University Park, Pennsylvania
February 15, 1959
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**SUMMARY**

Houses with slab-on-ground floors are gaining in popularity, mainly because of lower cost. Foundations for such houses may be of the common continuous-footer type, with walls of either concrete or block to which sills are bolted. A newer and cheaper system is the grade-beam foundation, which uses shallow walls of reinforced poured concrete resting on piers. The piers are made by simply boring holes in the ground and filling them with concrete.

A suitable site and correct grading are necessary. A satisfactory floor slab requires reinforcement to prevent cracking, a vapor barrier to protect it from ground moisture, and sufficient insulation around the edges to ensure that the house will be comfortable and economical to heat. Plumbing and heating installations are quite different from those in houses with basements.

Floor coverings should be carefully chosen and applied to avoid undesirable effects of moisture from the ground and from the air above. Asphalt tile is widely used; other types of flooring require more attention to moisture control.

An analysis of costs from actual jobs is presented. Adjusted for local rates, these figures should enable the builder to make good estimates.

**INTRODUCTION**

Building homes without conventional basements is not new. In warmer and more humid parts of the country, basements serve little purpose and are often a nuisance. Large builders in the North have recently begun using basementless construction because its lower cost permits lower selling prices. Many such houses have been built by speculative developers of extensive tracts featuring small, low-cost homes. Reluctance of others to build or accept basementless houses has been due to the belief that the house is uncomfortable, that the lack of basement storage space is a serious drawback, or that construction of a good concrete slab-on-ground is difficult.

Depending on the difficulties of excavation, the extra cost of the basement for a one-story house of average size (1200 sq. ft.) will be $1200 or more, not including any basement finishing. Unless there are definite advantages because of sidehill location, more desirable floor space can be provided above grade. The money saved will build at least 10 per cent more living area or provide adequate unfinished storage space on the first floor. Many objectionable features of basementless houses have been eliminated by improved design. New heating systems and new methods for insulation and moisture control have made it possible to build slab-on-ground floors that are acceptable from the standpoint of comfort. They
can be covered with many kinds of flooring materials, including wall-to-wall carpeting.

The people most interested in low-cost homes are the younger generation. Many of them are living in trailers or one-floor apartments. Basementless homes appeal to them because of the lower initial investment. Such homes also appeal to older people, for whom stair climbing requires extra effort and is a hazard. Builders can capitalize on these selling points.

**SITE AND GRADING**

Slab-on-ground houses may be built either with grade beams and piers or with a continuous-footer foundation. Grade beams are satisfactory for sites that are nearly level. The continuous footer can be used where there is considerable slope.

Building a house with slab floor is simplified if the site is well drained and the soil consists of a well-compacted sand or gravel. Few places in Pennsylvania are so favored. Many areas have soils with high clay content and drainage characteristics that complicate the construction of any type of house. For every kind of construction, risky terrain requires special treatment.

To be well above surface water, the finished floor of a slab-on-ground house should be at least 8 in. and preferably 10 to 12 in. above the final grade after landscaping has been completed. The slope of land away from the foundation wall should be at least 4 per cent in all directions for a distance of 25 ft. (1-ft. drop), or if the lot line is less than 8 ft. away, the drop should be not less than 4 in. A level lot with the street already in will require considerable filling to provide the 4 per cent grade all around. The slab itself, in that case, may rest on as much as 16 in. of fill plus whatever depth of topsoil was removed.

Proper grading of the yard and surroundings is extremely important. In many cases, dampness or water troubles have been traced directly to grading that provided no control of runoff from soil or roof. Where the soil is heavy, it is imperative that gutters and downspouting are properly installed and that the water from them is conducted away from the house wall. It is equally important that soil near the foundation should slope away slightly, permitting free flow of water to a lower elevation.

Ornamental plantings and lawn near the foundation wall are of aesthetic value and their use should be encouraged. There is need, however, for caution when preparing, establishing, and maintaining such
plantings. The slope of ground away from the foundation wall should always be maintained. A wide overhang to the roof helps to keep surface water away from the house.

Plantings other than grass generally should come no closer to the house than the eave line. Although shrubbery helps dry out soil near the foundation wall, it also interferes with the free flow of water, and working around the shrubbery often changes the grade or slope of the soil. Large roots of trees may penetrate under a grade beam, and it is possible that under some conditions this could cause damage.

THE FOUNDATION

When the location of the house has been decided, the topsoil should be removed and saved for use on lawn and plantings. Topsoil has poor load-bearing capacity. Removing roots and rubble is important even though it means that more fill will be needed. Pieces of wood under a floor invite termites, and these destructive insects may already have infested such material. Also, roots and remains of other living organisms in topsoil will rot, leaving a poor support for the slab above.

Native subsoil is quite compact, much more so than fill soil. Since soil under a slab must be firm, the less filling and disturbance to the natural soil, the less compacting work will be needed. Simplest construction is in locations that are nearly level and require little excavating or filling within the foundation walls. A layer of coarse material under the slab (the "base course" described later) and the concrete slab itself often are sufficient to bring the floor level up to the minimum 8 in. above the outside finished grade. At most, only a few inches of fill will be needed.

In case the native soil is disturbed or filling is unavoidable, the soil should be thoroughly compacted by wetting and tamping. Filling should be done in thin layers, followed by compacting. A layer more than 5 in. deep cannot be satisfactorily compacted at one time with hand tampers. More fill may be added after the foundation has been completed.

After removing topsoil and leveling the building site, stakes should be set up to mark the location of the house. Outside wall lines should be established by strings attached to batter boards. The footer is located directly under or outside these exterior wall lines, as shown in Fig. 1. The piers for a grade beam are located as shown in Fig. 2.

The continuous footer is made by pouring concrete directly into a trench, the depth of which is determined by the frost line in the region. It should be 36 to 42 in. for southern Pennsylvania, and 48 in. for the
Fig. 1. Continuous-footer foundations for (A) frame wall and (B) brick veneer wall. Either L-type or vertical insulation can be used with both kinds of construction.
northern part. The depth may need to be more where filling has been
done, because footers must be placed on satisfactory load-bearing soil.
The top of the poured footer need not be troweled, but it should be level
if a block wall is to be laid on it.

Foundation walls for a frame house can be of 8-in. blocks or poured
concrete. The top should come up to within 2 in. of the level of the fin­
ished floor, allowing space for sills. If the wall is concrete block, the
top course should be of 8-in. cap blocks, which will bring the top to the
desired level. The cap course tapers to approximately the width of the
sill (A of Fig. 1).

A typical block wall for a 1200 sq. ft. house with footer 1 ft. deep
requires from 400 to 450 blocks. The cost of 8-in. blocks is 40 to 50
cents per block laid in place, or $160 to $225 for the entire wall. A
poured concrete wall of the same dimensions will require approximately
10 cu. yd. of concrete, costing about $15 per cubic yard. Commercially
fabricated steel forms for concrete walls are expensive but can be set
up quickly and are re-usable. Custom construction of forms increases
the cost of a poured concrete wall.

The foundation design for a brick veneer house uses 10-in. blocks
topped by 4-in. blocks under the sill, as shown in B of Fig. 1.

Foundation walls for slab floors are usually not waterproofed, nor
is drain tile placed outside the footer as in basement construction, since
water under a slab is not a hazard unless the free surface or water table
rises so high that water enters heating ducts. This occurrence is rare;
when it does happen, the source may be surface water or sometimes
ground water. If proper grading cannot be provided to control surface
water, the wall on one or more sides of the house may be waterproofed
if it is built of blocks, which are quite porous. Poured concrete of good
quality is adequately watertight. Ground water seeping from a higher
level may occasionally require a tile drain. But either of these hazards,
if not foreseen, will not become a calamity, since the correction can be
applied after the house is built.

A general idea of grade-beam construction is shown in Fig. 2. In
this case, the foundation is a reinforced concrete beam poured in place
on concrete piers. The piers are concrete posts 10 to 12 in. in diameter,
formed by simply digging holes in the ground and filling them with con­
crete. Digging may be done quickly with a power auger (Fig. 3). The
depth of the holes is 36 in. or more, depending on frost line and soil
character. The bottom should be on good load-bearing soil, not on fill.
In each pier is placed a 5/8-in. reinforcing rod, which protrudes 11 in.
from the top into the grade beam and may help to locate the horizontal
reinforcing rods when the beam is poured.
Fig. 2. Grade-beam and pier foundations for (A) frame wall and (B) brick veneer wall.
Fig. 3. Boring pier holes with power take-off attachment for tractor. Four men and this machine can prepare pier holes for an average house in one hour.

The grade beam supports the weight of walls and also the roof when partitions are not load bearing. Although poured on the ground between forms, the beam is really supported by the piers. Any suitable beam section may be chosen. For a one-story or two-story frame house or a one-story brick veneer house, the beam shapes shown in Fig. 4 are recommended. Each of these sections is 12 in. deep and suitable for 6-ft. to 8-ft. pier spacing. Wider spacing or heavier loads require a deeper beam. Larger piers may also be needed. Good concrete (at least 2500-lb., 28-day strength) and properly placed reinforcing rods are essential for good beams. The concrete must be well rodded into the forms. A mechanical vibrator is a timesaver and ensures full-strength concrete.

The strength of a grade beam depends on its reinforcing rods. Four 1/2-in. rods placed as shown in Fig. 4 are commonly chosen, but two 3/4-in. rods (one high and one low) are an alternative. The simplest method of holding these horizontal rods in place is to wire them to the vertical rods in the piers.
Fig. 4. Grade-beam and pier details for (A) frame wall and (B) brick veneer wall, showing maximum pier spacing and placement of reinforcing rods.
Reinforcing rods usually are 20 ft. long. Ends should be lapped 12 in. or more. Low-level rods should be lapped at the piers; high-level rods, midway between piers. At the house corners, the rods should be bent at least 4 ft. from their ends to avoid a lap in the corner. The corner rods may be placed first for greater convenience.

Forms for pouring concrete may be built on the job, but ready-made steel forms are available (Fig. 5) and will save their cost in the long run. In some places these forms may be rented, a typical charge being $100 for 30 days. Only 3 cu. yd. of concrete may be needed for the beams and piers of a house that would require 10 cu. yd. for a poured foundation wall.

As noted before, proper grading away from the house is essential, since the grade beam is shallow. Excessive water under the slab floor, and frost heaving that might result from excessive water under the beam, are avoided by good drainage.
The foundation is made properly level on top to receive the house sills, which should be bolted down for better wind resistance. Bolts 3/8 x 8 in. are set about 4 ft. apart in the soft concrete (or in the mortar between blocks), with their threaded ends protruding 1 1/2 in. The nuts and washers are countersunk into the sill so that there is no obstruction above it. The floor slab can then be finished flush with the sill top, which serves as a screed in leveling the concrete. Slight irregularities should be corrected by putting wedges under the sills, thus ensuring a good level floor.

**UNDER-SLAB UTILITY LINES**

Water, oil, gas, and sewer piping are roughed-in, and under-slab air ducts for the heating system are assembled and installed before the slab is poured.

Methods of heating are described in another section. The choice for a one-story house, providing economy with satisfaction, will probably be a downflow furnace placed near the center of the house. Warm air is forced through ducts under the slab to registers near the outside walls of the rooms (Fig. 6).

Several types of ducts are available. Ducts that can be damaged by long exposure to moisture must be fully enclosed by concrete. It is usually cheaper to use asbestos-cement ducts, because they are light and strong and may be placed directly on the soil.

The downflow furnace can be installed on the floor, over a plenum or distributing box that is easily made of poured concrete. A boxlike plywood form, of correct size for the furnace and about 18 in. deep, is placed on the ground with its top at the floor line. Each duct butts against the box in a rough fit and may be steadied by nails driven within the duct circle. This joint need not be airtight, since it will be fully enclosed in concrete, but adhesive tape is useful to cover cracks where concrete mix might enter. The concrete for the plenum is sometimes poured in three separate steps. When the fill and gravel base are in, a ditch is left around the box; the first concrete fills this and is allowed to set. Then the slab is poured, completing the plenum walls. Later, the form is knocked out and the plenum floor is poured to finish the job.

Register boxes are available as ready-made sheet metal fittings. Such a fitting, placed with its top at floor level, establishes the position of the duct at that end. The top of the duct should be 4 in. below the floor line, and the duct should slope downward about 4 in. to the plenum. The lower level at the plenum avoids high floor temperature, which might be annoying.
Fig. 6. Six-inch warm air ducts of asbestos cement attached to form for the plenum. Joints are taped. Mounds of soil or concrete under the pipes hold them in place when fill and gravel are added.

All joints except those at the plenum will be surrounded by fill. The use of good adhesive tape on the joints is recommended, but fits should be tight enough to exclude dirt after the tape has rotted. Duct joints and long runs must be firmly supported on gravel, bricks, or a pad of concrete to hold their position while fill is being added.

For FHA insurance on the mortgage, this design should have the approval of the local FHA office.

PERIMETER INSULATION

A slab floor built in Pennsylvania must be insulated. Otherwise it is cold in winter, and economy and comfort are sacrificed. But insulation is required only at the perimeter. In the middle of the floor, if the house is heated throughout the winter, heat enters the ground but is stored there without excessive loss.
Fig. 6. Six-inch warm air ducts of asbestos cement attached to form for the plenum. Joints are taped. Mounds of soil or concrete under the pipes hold them in place when fill and gravel are added.

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Two good methods of placing perimeter insulation, the L-method and the vertical, are shown in Figs. 1 and 2. Both provide a full thickness between the slab edge and the foundation, which is cold. For either position the same amount of insulation is recommended, but the choice of position is dictated by the kind of insulation, as noted later. For slabs on flat sites in Pennsylvania, insulation 1 in. thick is acceptable, but a thickness of 1 1/2 or 2 in. is desirable.

If the foundation is exposed more than 12 in. above grade, the thickness of insulation should be increased 1/2 in. for each additional foot (or fraction) of exposed height, and the "L" should be turned inward not more than 2 in. above the grade line. The purpose of this is to prevent freezing under the slab.

Insulating material installed in the ground is subject to water, rot, and termite damage, as well as compression. Few materials are available that can be expected to stand up under such treatment for the life of the building. One is foamed glass. This rigid but fragile product is not to be confused with glass fiber or wool. It is available in thicknesses of 1 1/2 and 2 in. Standard widths may be easily cut as required and installed either in vertical or L-shaped position.

Some foamed plastics, especially polystyrene, are believed to resist rot adequately, but their moisture resistance is lower. Cheaper than foamed glass, easy to apply, and consequently popular, they are satisfactory when installed above the outside grade, that is, in the L-shaped position.

Insulating materials made from mineral or glass fibers should be used with caution, recognizing that their water resistance depends on a waterproof cover or protector that may be damaged in application. They may be safely used only in the L-position and above grade. If the moisture-proof cover is on only one side, it must be faced toward the slab, that is, inward at the slab edge or upward under the slab. Products made from plant fibers, though excellent for many purposes, are not recommended for damp ground even though they have moistureproof coverings.

The vapor barrier sheet under the slab should be placed between the slab and the insulation for either position of the insulation, as shown in Figs. 1 and 2. These constructions meet FHA requirements.

When the heating system has under-slab ducts as described in the preceding section, insulation between the warm duct and the cold foundation is needed. Vertical insulation (foamed glass) all around is excellent. Another assembly, also recommended, saves material cost by using foamed glass only at each register box (Fig. 7). A strip 18 x 24 in. is placed on smoothed soil under the box. Then a similar piece is attached
Construction sequence for assembly using foamed glass insulation at register box only.

Fig. 7.
to the grade-beam or block foundation with mastic. Finally, a sheet of heavy roofing paper is laid over the fragile insulation to protect it from damage in later work. Insulation of another type is placed in the L-position all around the perimeter, close to the slab.

**PROTECTION FROM GROUND MOISTURE**

Ground water under the slab rises by capillarity through fine-grained soil, particularly clay. Surface water gets under the slab as a result of incidents such as snow dams, gutter failure, and grade reversal close to the foundation, especially where shrubs are planted. Vapor also rises under the slab from the warm, damp soil.

Moisture will penetrate upward through the slab and damage some floorings or their adhesive attachment to the slab. Two methods of protection are used, and both (together) are recommended in Pennsylvania: (1) a "capillary break" or base of coarse gravel, and (2) a vapor barrier.

The gravel base, at least 4 in. thick, is spread directly below the slab and thoroughly tamped in place. Crushed stone or bank-run gravel, containing no fines that will pass a 1/4-in. screen, is good. Fine sand is not approved, and cinders are unsuitable because of their chemical action on pipes.

The vapor barrier is a sheet or film spread on top of the gravel base to arrest vaporized ground moisture. It also stops the concrete mix from running down into the gravel base. Only a few materials can endure dampness from the soil year after year. The vapor barrier must also be tough enough to resist damage from the traffic over it during the laying of the floor slab. Polyethylene sheets 6 mils (0.006 in.) thick and up to 40 ft. wide are available and are recommended for this purpose. The price is around 3 cents per square foot. On a smooth base, necessary joints are acceptable without sealing if they are carefully lapped 6 in. Holes for piping are few and small. The details of placement shown in Figs. 1 and 2 meet FHA requirements.

Incidentally, large plastic sheets of this kind have other uses, especially for covering the concrete slab while it is curing. The slab should not be dried out too rapidly.

On a high site with good drainage, if suitable coarse material for the gravel base is difficult to obtain, it is possible to omit the gravel and use only a properly applied vapor barrier. But the choice of flooring is then limited to asphalt, rubber, and vinyl tile without fabric backing. Carpeting may also be used. Eliminating the base course makes the job cheaper, but it is not generally approved.
REINFORCING THE SLAB

Floor slabs are usually 4 in. thick. Spans of only 15 to 20 ft. on good load-bearing soil require no reinforcing. Most house floors are larger, however, and some reinforcement is desirable to keep the slab from breaking under temperature change or load. The usual treatment is to put standard 6 x 6-in. No. 10 welded wire fabric over the vapor barrier as the last step before pouring the slab. Using rakes to spread the concrete mix in the process of pouring, workmen lift the mesh slightly so that it remains approximately in the middle of the 4-in. slab thickness (Fig. 8). Extra-wide spans of concrete, or those in which heating pipes are embedded, are subject to greater strains, and a heavier wire fabric (No. 8 or No. 6 wires) should be used.

When interior partitions help support the roof, it is desirable to increase the thickness of the slab to about 6 in. for a width of 16 in. under those partitions. For usual loads, no reinforcement other than the wire fabric is needed for those thickened areas.
THE FLOOR SLAB

Authorities on concreting object to the word "pour," insisting that concrete is "placed" because it will not pour without excess water. The more familiar expression is used here, with the caution that excess water weakens the product and increases its porosity to moisture, as well as causing annoying separation and surface pools when the concrete is being worked. Concrete that will test 2500 psi (pounds per square inch) at 28 days is satisfactory if flooring is to be used.

A 2500-lb. concrete is the minimum strength recommended. This can be prepared by using 230 lb. of sand, 395 lb. of gravel, and 7 1/4 gal. of water, to one bag of portland cement.

Floor slabs are commonly poured 4 in. thick, with the top of the slab level with either the top of the foundation wall or the sill, usually the latter. This simplifies leveling and troweling operations. Concrete must be kept moist for at least three days for proper curing. Covering the entire slab with a sheet of polyethylene helps in this regard. In cold weather, the slab must be protected against freezing for at least two days. It should not be poured when temperatures are below 40° F. unless means are at hand to protect it. Some operators use large polyethylene sheets, with edges weighted down, and large-capacity blowers and oil heaters to make balloon-type tents under which operations can proceed in severe weather.

Troweling may be done by hand, but machine troweling is rapid and inexpensive (Fig. 9). The finished floor surface must be level and smooth, especially since thin flooring conforms to the slab surface and, when polished, shows even small defects in the slab.

FLOOR COVERINGS

The choice of finishes or floor coverings for a well-constructed slab floor is determined by considerations of cost or personal taste. Certain types of finishes, because of their depth or the method of application, place special requirements on the construction of the slab. The use of such finishes should be anticipated before the slab is poured. Several kinds of finishes and coverings are discussed briefly in the following paragraphs.

Waxed Concrete. An inexpensive and rather attractive floor is obtained by simply waxing a smooth-finished concrete. Improved appearance can be achieved by using color in the final coat of concrete to provide some decorative effect. Many colors are available, but colored concrete is usually unpatterned. This type of floor is well suited to porches, workrooms, recreation rooms, and the like, and is gradually becoming more popular for regular living quarters.
Fig. 9. Machine troweling as final operation on completed slab. Sill, plenum (left foreground), and plumbing access openings are flush and do not interfere with this operation. Grade stakes have been driven down and covered.

Asphalt Tile. Asphalt tile is the least expensive floor-surfac­ing material. It costs little more than two coats of high-grade paint. Adhesives for asphalt tile are satisfactory except under the most severe moisture conditions. There is a wide choice of colors, patterns, and designs, light colors being generally more expensive than dark. Complaints against this flooring are that it "looks cheap," feels cold, and shows indentations from furniture that make it unsightly and difficult to clean.

Other Tile-Type Products. Vinyl, cork, rubber, and linoleum tile (but not linoleum sheets or rolls, except as will be noted) may be used on slab floors. Wood block (parquet) and laminated wood "tiles" 1/8 in. thick have also been applied successfully. All of these materials are more expensive than asphalt tile, and some of them present the same disadvantages. Cork tile has resiliency, but tests indicate that as much comfort may be gained by wearing resilient shoe soles and rubber heels as by installing cork floors.
Ceramic Tile and Terrazzo. These stone-concrete floorings are generally more expensive than asphalt tile but may be less expensive than some others. For ceramic tile and terrazzo, the concrete slab is poured only about 3 1/2 in. thick and allowed to harden. Sills for partition walls can then be put in place. The remaining 1 1/2 in. of floor are added by the flooring contractor, who sets the tile in concrete or applies a mixture of marble chips and concrete which, when ground off and polished, forms terrazzo. The finished floors are attractive, easy to care for, and require no maintenance other than periodic waxing and polishing. These are permanent floors. Objections to them are that they are cold and hard underfoot.

Hardwood Flooring. Regular hardwood flooring can be used over a concrete slab. Precautions necessary for satisfactory application are explained in the leaflet "How to Install Hardwood Strip Floors over Concrete Slabs," obtainable from the National Hardwood Flooring Manufacturers' Association, Sterick Building, Memphis 3, Tennessee.

Carpeting. The popularity of wall-to-wall carpeting over concrete has increased, probably due in some degree to objections to the coldness and hardness of slab floors. A new type of carpeting has a foam rubber pad (rug mat) bonded to the rug fabric. Ordinary carpet costs about 50 cents per square foot more than asphalt tile. This may price carpeting out of the average low-cost small home.

Sheet-Type Products. The use of any kind of sheet material, such as linoleum, Congoleum, or rubber, is not usually recommended for slab-on-ground floors, though manufacturers claim that some adhesives are satisfactory. Many adhesives will not retain their bond under the moist conditions often encountered in slabs even though good vapor barriers have been used. If a sheet-type material is to be applied, the flooring manufacturer's recommendations for adhesives should be carefully followed.

HEATING

Good heating systems are important in northern homes. Space heaters or wall or floor furnaces are the cheapest to install but the least satisfactory for slab-on-ground houses. Preferred heating systems are forced warm air or circulating hot water, with oil or gas as fuel. The choice between warm air and circulating hot water is a matter of personal preference and cost. Electric heating is gaining popularity in some areas.

Most installations use forced warm air in a system of radial ducts (Fig. 6), mainly because the initial cost is lower. An effective variation
adds a perimeter duct that encircles the slab. The perimeter duct supplies heat where it is most needed, that is, along the exterior walls, keeping the edges of the slab from becoming uncomfortably cold. This system costs more than the simple radial arrangement and approximates the cost of circulating hot water. Instructions for installing forced warm air heating systems are obtainable from the National Warm Air Heating and Air Conditioning Association, 640 Engineers Building, Cleveland 14, Ohio.

The most common method of hot water heating uses baseboard radiators along outside walls. Water is kept at a constant temperature in a heating boiler, and is circulated through the radiators only when the room thermostat closes a circuit and starts the circulating pump. Water boilers of this type are more expensive than warm air furnaces. In this system, however, domestic hot water can be provided by an "instantaneous" coil in the boiler, through which hot water is drawn as needed. The saving partially compensates for the extra cost of the boiler and circulator. "Forced Circulation Hot Water Heating Systems," an informative booklet published by the Institute of Boiler and Radiator Manufacturers, 608 Fifth Avenue, New York 20, New York, may be obtained from the publisher (price 75 cents).

Floor panel heating is a system in which the floor slab itself becomes the radiator. It is one way to make certain that floors will not be cold. Boiler and circulator units are the same as those for baseboard radiators, but the water is circulated through pipes or tubing embedded in the concrete slab. The slab is kept at moderate temperature, usually not above 85°F. in coldest weather, which is sufficient for well-insulated northern homes if the floor is not covered with large carpets. Ceiling panels also with circulating hot water may be used to provide additional heating surface if necessary.

The tubing used for floor panel heating is usually 3/4-in. soft copper because it is easily laid. The loops, spaced 12 in. apart, are placed on top of the reinforcing mesh as the final operation before pouring the concrete slab. Because of the 12-in. spacing, the number of linear feet of tubing required is approximately the same as the number of square feet of floor area in the house. Standard wrought iron pipe can be used in the same manner. Though iron pipe is less expensive than copper tubing, it is much more difficult to install, and therefore the total costs are comparable. Booklets on "radiant heating" may be obtained from the Copper and Brass Research Association, 420 Lexington Avenue, New York 17, New York.

Electric heating of homes is attractive in regions of low utility rates. Local power companies can furnish information on installation and comparative costs of heating by this method.
<table>
<thead>
<tr>
<th>Item</th>
<th>Labor</th>
<th>Materials</th>
<th>Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bore 2X pier holes</td>
<td>Skilled 5</td>
<td>Concrete, 2 cu. yd.</td>
<td>Power auger 10 rent</td>
</tr>
<tr>
<td>Pour and level piers</td>
<td>Unskilled 6</td>
<td>Concrete, 2 cu. yd.</td>
<td>Transit 30</td>
</tr>
<tr>
<td>Pier reinforcing rods</td>
<td>Skilled 2</td>
<td>Steel, 84 lb.</td>
<td>1 dep. 30</td>
</tr>
<tr>
<td>Slab on ground</td>
<td>Unskilled 2</td>
<td>Steel, 84 lb.</td>
<td>1 dep. 30</td>
</tr>
<tr>
<td>Set grade-beam forms</td>
<td>Skilled 8</td>
<td>Concrete, 3 cu. yd.</td>
<td>Forms 47</td>
</tr>
<tr>
<td>Pour grade beams</td>
<td>Unskilled 8</td>
<td>Concrete, 3 cu. yd.</td>
<td>Forms 47</td>
</tr>
<tr>
<td>Install sill bolts</td>
<td>Skilled 8</td>
<td>Concrete, 3 cu. yd.</td>
<td>Forms 47</td>
</tr>
<tr>
<td>Remove, clean, and store forms</td>
<td>Unskilled 8</td>
<td>Concrete, 3 cu. yd.</td>
<td>Forms 47</td>
</tr>
<tr>
<td>Excavate for ducts</td>
<td>Skilled 2</td>
<td>Concrete, 84 lb.</td>
<td>1 dep. 30</td>
</tr>
<tr>
<td>Rough-in plumbing and heating</td>
<td>Unskilled 2</td>
<td>Concrete, 84 lb.</td>
<td>1 dep. 30</td>
</tr>
<tr>
<td>Water</td>
<td>Skilled 2</td>
<td>Concrete, 84 lb.</td>
<td>1 dep. 30</td>
</tr>
<tr>
<td>Sewer</td>
<td>Unskilled 2</td>
<td>Concrete, 84 lb.</td>
<td>1 dep. 30</td>
</tr>
<tr>
<td>Fuel line</td>
<td>Skilled 2</td>
<td>Concrete, 84 lb.</td>
<td>1 dep. 30</td>
</tr>
<tr>
<td>Heating ducts (8 registers)</td>
<td>Unskilled 2</td>
<td>Concrete, 84 lb.</td>
<td>1 dep. 30</td>
</tr>
<tr>
<td>Add and tamp fill (if used)</td>
<td>Skilled 2</td>
<td>Concrete, 84 lb.</td>
<td>1 dep. 30</td>
</tr>
<tr>
<td>Vapor barrier (polyethylene)</td>
<td>Unskilled 2</td>
<td>Concrete, 84 lb.</td>
<td>1 dep. 30</td>
</tr>
<tr>
<td>Perimeter insulation (foamed plastic)</td>
<td>Skilled 2</td>
<td>Concrete, 84 lb.</td>
<td>1 dep. 30</td>
</tr>
<tr>
<td>Register box insulation</td>
<td>Unskilled 2</td>
<td>Concrete, 84 lb.</td>
<td>1 dep. 30</td>
</tr>
<tr>
<td>Slab reinforcing mesh</td>
<td>Skilled 2</td>
<td>Concrete, 84 lb.</td>
<td>1 dep. 30</td>
</tr>
<tr>
<td>Pour slab</td>
<td>Unskilled 2</td>
<td>Concrete, 84 lb.</td>
<td>1 dep. 30</td>
</tr>
</tbody>
</table>

**TOTAL**: $1074

**Notes**: All costs are estimated in 1958 dollars.
CONSTRUCTION COSTS

A slab-on-ground floor built with a grade-beam and pier foundation is the cheapest system for northern homes. Costs of such construction generally amount to only a little more than $1.00 per square foot for the floor area of the house. A continuous-footer foundation with concrete block or poured concrete walls will cost about 25 per cent more. These costs include most of the plumbing rough-in, as well as the distributing ducts for warm air from the furnace.

Studies have been made of the costs of construction for different phases of the operation. Results secured during the construction of some typical houses of approximately 1000 ft. area, located on favorable sites cleared and graded as required, are presented in Table 1. Workmen were experienced in slab construction and were not delayed by weather or shortages of materials.

Labor costs shown in the table were figured at $2.50 per hour for skilled labor, and helpers or common labor at $2.00. Costs of material were considered typical for small-volume builders, those who construct not more than 20 houses per year and who purchase their supplies through local channels.

It is obvious that if local costs for labor or materials are different from those listed, the proper adjustments are easily made. However, a difference in size or shape of the foundation will not change the costs proportionally. Materials costs for a concrete floor slab of 2000 sq. ft. should be twice those given in the table. But length of the foundation wall, amount of perimeter insulation needed, number of piers, bolts, and reinforcing rods, and quantity of material for the sills are increased only about 41 per cent when the floor area is doubled. Labor is increased even less, and depreciation not at all.
TERMITE CONTROL

A house built on a slab is as vulnerable to termites as any other, because wood components are so near the ground. The danger of infestation can be reduced by proper attention to some details during construction.

Although subterranean termites are a less serious pest in Pennsylvania than they are in warmer climates, they are a hazard in many parts of the State. The species found here literally devours wood but cannot exist without a moisture supply. To thrive on the wood in a building, termites must maintain contact with damp soil. Control may be secured by severing that contact by means of properly installed metal or other kinds of shielding. Using treated wood and poisoning the termites with gases or other insecticides are methods that are successful under some conditions. (See "Damage to Buildings by Subterranean Termites and Their Control," USDA Farmers Bulletin 1911, obtainable from the Superintendent of Documents, Washington 25, D. C., price 15 cents.)

If sills are treated with pentachlorophenol or copper naphthenate, preferably under pressure or vacuum, termites will usually be effectively stopped from entering the wood parts of a slab-on-ground house. The treatment is only a surface one, however, and if the ends of timber are cut off after treatment, termites can enter through the cuts. They may also gain entrance at bolt holes or other breaks unless adequate attention is paid to treating the cut surfaces.

A particularly vulnerable place in slab construction is the crack or crevice between the slab and the foundation wall. Where perimeter insulation is installed, it should be cut about 1 in. below grade of the finished floor, and hot asphalt should be poured in the opening between the slab and the sill. If the insulation is of a type that will be damaged by so much heat, a cold-working asphalt can be applied.

Another common route of entry is through the grade stakes used in leveling the slab. If left in place, they invite termite attack. Grade stakes should be driven down out of sight while the concrete is fresh, and the concrete smoothed over to close the openings.

The chemical soil treatments generally recommended appear to be unnecessary in the colder parts of Pennsylvania, provided treated sills are installed. Controls of this kind are described in a U. S. Forest Service leaflet, "Soil Treatment, an Aid in Termite Control," which can be obtained from the Superintendent of Documents, Washington 25, D. C. (price 5 cents).
USEFUL PUBLICATIONS

Flooring

"How to Install Hardwood Strip Floors over Concrete Slabs," leaflet, National Oak Flooring Manufacturers' Association, Sterick Building, Memphis 3, Tennessee.

Heating

Instructions for installing forced warm air heating systems, National Warm Air Heating and Air Conditioning Association, 640 Engineers Building, Cleveland 14, Ohio.


Booklets on radiant heating, Copper and Brass Research Association, 420 Lexington Avenue, New York 17, New York.

Termite Control
