## Chapter 2

**LAYING THE GROUNDWORK**

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Laying the Groundwork

Tasks related to site preparation and construction of footings and foundations, including a retaining wall, are discussed in this chapter.

Site Preparation

Before excavation for a new house is begun, the subsoil conditions must be determined by test borings and/or by checking existing houses constructed near the site. It is good practice to examine the type of foundations used in neighboring houses because the findings may influence design of the new house. For example, if a rock ledge were encountered at the chosen site, its removal would be costly. A high water table may require change of design from a full basement to a crawl space or concrete slab construction. If the area has been filled, the footings should always extend through to undisturbed soil. Any variation from standard construction practices increases the cost of the foundation and footings.

Site access and services

Before construction begins, provision must be made for equipment and delivery trucks to have access to the site; for sources of basic power, telephone, and water during construction; and for storing large quantities of a variety of materials throughout the construction process.

In providing access to the building lot for such heavy vehicles as cement trucks and loaded delivery trucks, the major factors to be considered are the season of the year, the soil conditions, and the slope of the building site. It may be necessary to excavate an access road and to provide some form of temporary road surface such as crushed stone.

Electric power and water are needed for many tasks in the building process. To provide electric power, the utility company may have to install a temporary electric service entrance. To provide water, a well may have to be drilled or temporary water service be installed at a nearby fire hydrant. Desirable support services at the building site include a telephone and toilet facilities.

Plans must be made for storage of materials at the site in such a fashion that they do not interfere with building activities. Plan the location of building materials delivered to the site to give easy access for delivery trucks and convenience for construction activity. Trees and other vegetation removed in clearing the site should be piled away from the construction area and out of the path of trenches, wells, or septic tanks. Top soil that has been removed can be saved for landscaping. Subsoil removed during the excavation for a basement foundation can be saved and used for backfill. Erosion control may be important and adequate control can often be provided temporarily by well-placed straw bales.

Placement of the house

A preliminary plot plan is submitted for approval with the request for a building permit. A final plot plan is prepared after surveying the site and determining house placement. Zoning regulations usually specify such matters as minimum setback and side-yard requirements, and the house must be placed on the lot to conform to those regulations.

When the plot of land is surveyed, the corners are marked by the surveyor. The surveyor should also mark the corners of the area within the lot in which the house may be built to comply with local regulations.

In preparation for establishing the exact placement of the house corners, stakes should be driven in the ground to mark the approximate location of the driveway and house. This approximate positioning should take the terrain into account, avoiding rock outcroppings and preserving trees that are to remain. Space should be reserved for a septic field and/or a water well, if applicable. The positioning of the water well with respect to the septic field is frequently controlled by health department regulations. Locating the water well should also recognize the need to provide access for a drilling rig. For energy efficiency, the side of the house with the most windows should face to the south.

All trees should then be removed from the areas to be driveway, within the house foundation, or within 15 to 20 feet of the house foundation. Clearing this area provides space for excavation and for a bulldozer to backfill around the house without getting too close to the foundation wall. It may be desirable to retain trees elsewhere on the lot. Deciduous trees may be left standing to shade the south side of the house in the summer while admitting the sun in the winter. Evergreen trees may serve as a wind break on the north side of the house and should be retained on the east and west sides of the house to shade it from low-angle morning and evening sunlight in the summer.

The next step is to locate the exact corners of the house. This must be done accurately and must establish
squaredness because all subsequent construction is based on this determination. In order to facilitate the process, the exact length of the diagonal of each rectangular section of the house outline should be calculated. (See the technical note on square corners.) Use three steel tape measures to lay out two adjoining sides of the house and the associated diagonal. The measuring tapes should be held level and plumb bobs used to establish the corner points on the ground. Stakes should be driven at each of the three corners and a nail driven in the top of each stake should be used to mark the exact location of the plumb bob. The fourth corner should be established by using two of the steel tape measures to measure the exact lengths of the two remaining sides. The fourth corner stake should be driven into the ground and a nail driven into the top of the stake under the tip of the plumb bob to indicate the exact corner location.

An alternative approach to establishing the exact corners of the house outline is to measure and stake the two corners for one side. Starting from one end, measure the length of a adjoining side. Using the “3-4-5” rule for a perfect 90° corner, measure along one of the sides some number of 3-foot units (3, 6, 9, or 12 ft). Measure along the other side a like number of 4-foot units (4, 8, 12, or 16 ft). If the corner is exactly 90°, the length of the diagonal (the hypotenuse of the triangle formed by the two measured sides) will be a like number of 5-foot units (5, 10, 15, or 20 ft). Adjust the position of the added side and stake the third corner. Proceed around the outline of the house measuring the lengths of the sides and adjusting to ensure that all corners are exactly 90°.

When the location of the house has been exactly established, the next step is to set the batter boards (fig. 2) to retain the exact outline of the house during construction of the foundation. The height of these boards is sometimes used to establish the height of the footings and foundation wall.

Drive three 2- by 4-inch or larger stakes of suitable length at 4 feet (minimum) beyond the lines of the foundation at each corner. Use a surveyor's level to establish level marks on the stakes. At each corner, nail 1-by 6-inch or 1-by 8-inch batter boards horizontally so the tops are all at the same level at all corners. Stout string is next held across the top of boards facing each other at two corners and adjusted so that it is exactly over the nails in the tops of the corner stakes at either end; a plumb bob is handy for setting the lines. A sawkerf or nail is placed at the outside edge of the board where the lines cross so that the string may be replaced if broken or disturbed. After similar cuts or nails have been located in all eight batter boards, the lines of the house will have been established. Check the diagonals again to make sure that the corners are square and adjust as necessary.

A precise plot plan may be prepared after the exact house location has been established and should then be filed with the original plot plan and building permit. The final plot plan should show the lot outline as established by the surveyor and the outline of the house foundation and driveway. If applicable, the plot plan should also show the location of the septic system and water well.

Excavation and Footings

Various types of earth-moving equipment are employed for basement excavation. Top soil is often stripped and stockpiled with a bulldozer or front-end loader for future use. The excavation can be done with a front-end loader, power shovel, or similar equipment. Backhoes are used to excavate for the walls of houses built on a slab or a crawl space, if soil is stable enough to prevent caving. This eliminates the need for forming below grade if footings are not required.

Excavation is carried down, preferably only to the level of the top of the footings or the bottom of the basement floor, because some soils become soft upon exposure to air or water. Unless formboards are to be used, it is not advisable to make the final excavation for footings until it is nearly time to pour the concrete.

The excavation must be wide enough to provide space to work when constructing and waterproofing the foundation wall, and for laying drain tile, if necessary (fig. 3). The steepness of the back slope of the excavation is determined by the subsoil encountered. With clay or other stable soil, the back slope can be nearly vertical but, with sand, an inclined slope is required to prevent caving.

Some contractors only rough-stake the perimeter of the building for the removal of the soil. When the proper floor elevation has been reached, the footing layout is made and the soil removed to form the footing. After the concrete for the footings is poured and set, the foundation wall outline is established on the footings and marked for the placement of the formwork or concrete block wall.

Footings

Footings act as the base of foundation wall and transmit the superimposed load to the soil. The type and size of footings should be suitable for the soil condition, and in cold climates the footings should be far enough below finished grade level to be protected from frost. Local codes usually establish this depth, which is often 4 feet or more in northern sections of the United States and in Canada.

Poured concrete is generally used for footings, although developments in treated wood foundation systems permit all-weather construction and provide reliable foundations as well. Gravel, being less expensive than concrete or
wood, is recommended as footings for foundation walls of pressure-treated wood (see the section on foundation walls).

Where fill has been used to raise the level of the house, the footings must extend below the fill to undisturbed earth. In areas having fine clay soil, which expands when it becomes wet and shrinks when it dries, irregular settlement of the foundation system and building may occur. A professional engineer should be consulted when building a house on this expansive clay soil.

Wall footings. Well-designed foundation wall footings are important in preventing settling or cracks in foundation walls. To determine the size of footings, one method often used with normal soils is based on the proposed wall thickness. As a general rule, the footing depth should be equal to the wall thickness (fig. 4A), and the footings should project beyond each side of the wall one-half the wall thickness. The footing bearing area, however, should be designed on the basis of the load of the structure and the bearing capacity of the soil (see table 1). If soil is of low load-bearing capacity, wider footings with steel reinforcement may be required. Local regulations often specify dimensions for wall footings and also for column and fireplace footings.
Table 1—Foundation wall footing widths for typical single-family dwelling loads for various allowable soil bearing capacities

<table>
<thead>
<tr>
<th>Total design load (lb) per linear foot of footing</th>
<th>Footing widths (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,500 lb/ft²</td>
</tr>
<tr>
<td>1,000</td>
<td>8</td>
</tr>
<tr>
<td>1,500</td>
<td>12</td>
</tr>
<tr>
<td>2,000</td>
<td>16</td>
</tr>
<tr>
<td>2,500</td>
<td>20</td>
</tr>
</tbody>
</table>


The following are a few rules for footing design and construction:

1. Footings should be at least 6 inches thick.
2. If footing excavation is too deep, fill with concrete—never replace soil.
3. Use formboards for footings where soil conditions prevent sharply cut trenches.
4. Place bottom of footings below the frost line.
5. Reinforce footings with steel rods where they cross pipe trenches.
6. In freezing weather, heat the footings or cover with straw.

Pier, post, and column footings. Footings for piers, posts, or columns (fig. 4B) should be square and should include a pedestal on which a load-bearing member will rest. A 4-inch or 6-inch solid-concrete cap block laid flat on the footing can serve as a pedestal. More esthetically pleasing pedestals may be installed, but they require the construction of a form and the pouring of concrete. The finished pedestal height must be at least equal to the thickness of the concrete floor slab; its sides may be vertical or may slope outward; and its top dimensions must equal or exceed the dimensions of the base of the pier, post, or column it will support. Bolts for the bottom bearing plate of steel posts and for the metal post bases for wood posts are usually set when the pedestal is poured. At other times, steel posts are set directly on the footing and the concrete floor poured around them. Concrete is
never poured around wooden posts. Concrete blocks are sometimes used as pedestals, especially in crawl space construction.

Footings vary in size depending on the superimposed load, the allowable soil bearing capacity, and the spacing of the piers, posts, or columns. Common sizes are 24 by 24 by 12 inches and 30 by 30 by 12 inches (see table 2).

Table 2—Column footing sizes for typical single-family dwelling loads for various allowable soil bearing capacities

<table>
<thead>
<tr>
<th>Total design load (lb)</th>
<th>1,500 lb/ft²</th>
<th>2,000 lb/ft²</th>
<th>2,500 lb/ft²</th>
<th>3,000 lb/ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>5,000</td>
<td>22 x 22</td>
<td>19 x 19</td>
<td>17 x 17</td>
<td>16 x 16</td>
</tr>
<tr>
<td>10,000</td>
<td>31 x 31</td>
<td>27 x 27</td>
<td>24 x 24</td>
<td>22 x 22</td>
</tr>
<tr>
<td>15,000</td>
<td>33 x 33</td>
<td>30 x 30</td>
<td>27 x 27</td>
<td></td>
</tr>
<tr>
<td>20,000</td>
<td>34 x 34</td>
<td>31 x 31</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Footings for fireplaces, furnaces, and chimneys should ordinarily be poured at the same time as other footings.

Stepped footings. Stepped footings are often used where the lot slopes to the front or rear and the garage or living areas are at basement level. The vertical part of the step is poured as part of the footing. The bottom of the footing is always placed on undisturbed soil and located below the frost line. Each run of the footing should be horizontal.

The vertical step between footings should be at least 6 inches thick and the same width as the footings (fig. 5). The height of the step should not be more than three-fourths of the adjacent horizontal footing width nor exceed 2 feet. On steep slopes, more than one step may be required. On very steep slopes, special footings may be required. For example, two separate footings may be required. The lower footing is poured and the lower wall is constructed up to the level of the upper footing. Forms for the upper footing are then built to extend the upper footing over the top of the lower wall. The extended portion of the upper footing is reinforced and tied to the lower wall with steel reinforcing rods. Alternatively, reinforced concrete lintels can be used to bridge from the upper footing to the lower wall. Because of the complexity of these designs, an engineer should be consulted.

Ordering concrete

Concrete and masonry units such as concrete block serve various purposes in most house designs, including houses on concrete slab and crawl space houses with poured concrete or concrete block foundation walls.

For small jobs, instructions for do-it-yourself mixing are usually available on the bag of Portland cement. The mixture generally includes one part air-entrained Portland cement, two parts sand, and four parts 1%-inch crushed rock. These are mixed together and water is then added, little by little, until the mixture is completely wet but can still be piled. Too much water weakens the concrete.
A great amount of concrete is supplied by ready-mix plants, even in rural areas. Concrete in this form is normally ordered by the number of bags per cubic yard and the maximum size of the gravel or crushed rock. A five-bag mix is considered adequate for most residential work. A six-bag mix is commonly specified where high strength or reinforcing is required.

The size of gravel or crushed rock that can be obtained varies in different locations, and for the smaller gravel sizes it may be necessary to change the cement ratio from that normally recommended. Generally speaking, it is good practice to use more cement when the maximum gravel size is smaller than 1½ inches. When maximum gravel size is 1 inch, add one-quarter bag of cement to the five-bag mix; when maximum size is ¾ inch, add one-half bag; and when maximum size is ¼ inch, add one full bag.

**Pouring concrete**

Concrete should be poured (or placed) continuously and kept practically level throughout the area being poured. The concrete should be rodded or vibrated to remove air pockets and force the concrete into all parts of the forms.

In hot weather, protect concrete from rapid drying. It should be kept moist for several days after pouring. Rapid drying significantly lowers its strength and may result in early destruction of the exposed surfaces of sidewalks and drives.

In very cold weather, keep the temperature of the concrete above freezing until it has set. The rate at which concrete sets is affected by temperature, being much slower at or below 40 °F than at higher temperatures. In cold weather, it is good practice to use heated water and aggregate during mixing. In severely cold weather, insulation or heat should be used until the concrete has set. Further discussion of working with concrete under various weather conditions is presented in the section on all-weather construction in chapter 8. A technical note on concrete presents a discussion of various characteristics of concrete that can be altered by various additives to meet specific needs.
Foundation

Foundation walls form an enclosure for basements or crawl spaces and carry wall, floor, roof, and other building loads. The two types of walls used most commonly are concrete cast in place (poured) and concrete block. Pressure-treated wood foundation walls are being increasingly used and are accepted by most codes. Preservative-treated posts and poles offer many possibilities for low-cost foundation systems and can also serve as a structural framework for the walls and roof.

Height of foundation walls

It is common practice to establish the depth of the excavation and consequently the height of the foundation, by using the highest elevation of the excavation’s perimeter as the control point (fig. 6). This method insures good drainage if a sufficient height of foundation is allowed for the sloping of the final grade (fig. 7). Foundation walls at least 7 feet 4 inches high are desirable for full basements; walls 8 feet high are common.

Foundation walls should be extended at least 8 inches above the finished grade around the outside of the house. This helps protect the wood finish and framing members from soil moisture. Also, wooden building materials should start well above the grass level so that, in termite-infested areas, there will be an opportunity to observe any termite tubes between the soil and the wood and to take protective measures before damage develops. Enough height should be provided in crawl spaces to permit periodic inspection for termites and for installation of soil covers to minimize the effects of ground moisture on framing members.

To enhance drainage away from the foundation, the finished grade at the building line should be 4 to 12 inches or more above the original ground level, having the higher values in this range in sloping lots (fig. 7). In very steeply sloped lots, a retaining wall is often necessary.

For houses having a crawl space, the distance between the ground level and underside of the joists should be at least 18 inches. Where the interior ground level is excavated or otherwise below the outside finish grade, 4-inch foundation drains covered with draining gravel and 15-pound roofing felt should be installed around the interior base of the wall and extended to the finished grade outside the foundation.

Basement foundation walls of treated wood

Basements constructed of pressure-treated lumber and plywood have achieved substantial acceptance in many areas of the United States and Canada. (See chapter 8 for precautionary information on pressure-treated wood.) Thousands of homes have been built by this method, which offers unique advantages. With basement walls of treated wood, electrical wiring is readily installed, insulation may be installed between the studs, and standard interior wall finish materials are easily nailed over the studs. Other advantages include suitability for construction in cold weather and the potential for prefabrication. Typical wall panels, including footing plates (fig. 8), can be fabricated from pressure-treated wood. The panels may be erected rapidly on site, reducing construction time and avoiding delays caused by weather. Because carpenters erect the panels, there are fewer trades to coordinate. Where basement walls extend above grade, they are easily painted or covered with the same siding materials as the house walls.

Preservative treatment for residential all-weather wood foundations is prescribed in American Wood Preservers Bureau Standard FDN. Each piece of lumber that has been treated in accordance with this standard bears the AWPB stamp. Lumber and plywood treated in accordance with this standard is extremely durable (see chapter 8). Only treated lumber and plywood bearing an AWPB FDN stamp should be used.
Construction of a pressure-treated wood basement begins with excavation to the required level in the usual manner. Plumbing lines to be located below the basement floor area are installed as necessary. The entire basement area is then covered with a layer of crushed stone or gravel a minimum of 4 inches thick, extending approximately 6 inches beyond the footing line. The stone or gravel bed is carefully leveled. The gravel or crushed stone serves to distribute footing loads 4 inches or more on each side of the footing plate. Wall panels are then installed on top of the footing plate, fastened together and braced in place. Joints are caulked, and the entire exterior of the foundation wall that is below grade is draped with a continuous sheet of 6-mil polyethylene.

The stone or gravel bed is covered with 6-mil polyethylene over which a standard concrete slab floor is poured. A sump and pump may be desirable to assure a dry basement. The first-story floor must be securely fastened to the top of the wood basement walls to resist the inward force of backfill. Where soil pressure is substantial, it may be necessary to use framing angles at this point. Solid blocking should be installed 48 inches on center in the joist space at end walls to transmit foundation wall loads to the floor. The wood foundation wall should not be backfilled until the basement floor and the first-story floor are in place.

Standard engineering procedures can be used in designing basement walls of treated wood. As with other basement wall designs, the controlling factors are the height of backfill and the soil conditions. Table 3 summarizes typical framing requirements for different heights of fill, and typical sizes of footing plate for one- and two-story houses up to 28 feet wide. Pressure-treated ½-inch-thick standard C-D grade (exterior glue) plywood should be installed with the face grain across studs. Blocking at horizontal plywood joints is not required if joints are at least 4 feet above the bottom plate. These specifications are based on a soil condition with 30 pounds per cubic foot equivalent fluid weight.

**Poured concrete basement foundation walls**

Thicknesses and types of wall construction are ordinarily controlled by local building regulations. Thicknesses of poured or cast-in-place concrete basement walls vary from 8 to 10 inches and concrete block walls from 8 to 12 inches, depending on height of story and length of unsupported walls.
Table 3 – Framing requirements for pressure-treated wood basement walls

<table>
<thead>
<tr>
<th>No. of stories</th>
<th>Height of fill (in.)</th>
<th>Nominal stud size</th>
<th>Minimum required “f”-value</th>
<th>Minimum required “E”-value</th>
<th>Nominal footing plate size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24</td>
<td>2 x 4</td>
<td>1,130</td>
<td>1,400,000</td>
<td>2 x 8</td>
</tr>
<tr>
<td>48</td>
<td>2 x 4</td>
<td>1,435</td>
<td>1,600,000</td>
<td>2 x 8</td>
<td></td>
</tr>
<tr>
<td>72</td>
<td>2 x 6</td>
<td>1,260</td>
<td>1,600,000</td>
<td>2 x 8</td>
<td></td>
</tr>
<tr>
<td>86</td>
<td>2 x 6</td>
<td>1,520</td>
<td>1,800,000</td>
<td>2 x 8</td>
<td></td>
</tr>
</tbody>
</table>

| 2              | 24                  | 2 x 4             | 1,435                      | 1,600,000                 | 2 x 10                   |
| 48             | 2 x 6               | 1,000             | 1,400,000                  | 2 x 10                    |
| 72             | 2 x 6               | 1,260             | 1,600,000                  | 2 x 10                    |
| 86             | 2 x 6               | 1,520             | 1,800,000                  | 2 x 10                    |

- Assumes studs spacing of 12 inches and 30 pounds per cubic foot equivalent fluid weight of soil.
- See technical note on design values for common species and grades of lumber.

Clear wall height should be no less than 7 feet from the top of the finished basement floor to the bottom of the joists; greater clearance is usually desirable to provide adequate headroom under girders, pipes, and ducts. Above the footings, many contractors pour 8-foot-high concrete walls which provide a clearance of 7 feet 8 inches from the top of the finished concrete floor to the bottom of the joists. Concrete block walls, 11 courses above the footings with 4-inch solid cap block, produce a height of about 7 feet 4 inches from the basement floor to the joists.

Crawl space foundation wall heights are determined by the depth of frost level and by the height needed to maintain adequate under-floor access. They are usually 18 to 24 inches from the ground to the bottom of the floor framing members.

Poured concrete walls (fig. 9) require forming that must be tight, well-braced, and tied to withstand the forces of the pouring operation and the fluid concrete.

Poured concrete walls should be double-formed (with formwork constructed for each wall face). Reusable forms are used in the majority of poured walls. Panels can consist of wood framing with plywood facings and are fastened together with clips or other ties (fig. 9). Wood sheathing boards and studs with horizontal members and braces are sometimes used in the construction of forms. As with reusable forms, formwork should be plumb, straight, and sufficiently braced to withstand pouring. Frames for basement windows, doors, and other openings are set in place as the formwork is erected, along with forms for the beam pockets that are located to support the ends of the floor beam.

Reusable forms usually require little bracing other than horizontal members and sufficient blocking and bracing to keep them in place during pouring. Forms constructed with vertical studs and waterproof plywood or lumber sheathing require horizontal whalers and bracing.

Level marks of some type, such as nails along the form, should be used to assure a level foundation top. This provides a level sill plate and floor framing.

The concrete should be poured continuously, and constantly rodded or vibrated to remove air pockets and to work the material under window frames and other blocking. Care should be taken to avoid excessive vibrating because this may cause the gravel or crushed rock in the concrete to settle to the bottom and weaken the wall. If wood spacer blocks are used, they should be removed and not permitted to become buried in the concrete. Anchor bolts for the sill plate, spaced 8 feet on center, should be placed while the concrete is still plastic. Concrete should always be protected when outside temperatures are below freezing.

Forms should not be removed until the concrete has hardened and acquired sufficient strength to support loads imposed during early stages of construction. At least 2 days, and preferably longer, are required when temperatures are well above freezing, and perhaps a week when outside temperatures are below freezing. Never backfill until both the floor framing and basement slab are in place.

Poured concrete walls can be damp-proofed with a heavy cold coat or hot coat of tar or asphalt. This coat should be applied to the outside from the footings to the finish gradeline, when the surface of the concrete has dried enough to assure good adhesion. Such coatings are usually sufficient to make a wall watertight against ordinary seepage such as may occur after a rainstorm. In addition, the backfill around the outside of the wall may consist of gravel. The objective of a gravel backfill is to prevent soil from holding water against the foundation wall and to allow the water to flow quickly down to the drainpipes at the base of the wall. Instead of gravel backfill, a drainboard composed of plastic fibers or polystyrene beads can be installed against the foundation wall. The material serves the same function as the gravel backfill. In poorly drained soils, a membrane may be necessary as described in the section on masonry basement foundations.

Masonry basement foundations

Concrete blocks are available in various sizes and forms, but the blocks most commonly used are 8, 10, or 12 inches wide. Modular blocks that allow for the thickness and width of the mortar joint are usually about 7/8 inches high and 15/8 inches long. Such blocks form a wall with mortar joints spaced 8 inches from centerline to centerline vertically and 16 inches from centerline to centerline horizontally.
Figure 9 – Forming for cast-in-place concrete foundation walls.

Block courses start at the footing and are laid up with mortar joints of about 3/8 inch, usually in a common bond (staggered vertical joints). Joints should be tooled smooth to resist water seepage. Full bedding of mortar should be used on all contact surfaces of the block. When pilasters (column-like projections) are used to carry the concentrated loads at the ends of a beam or girder, they are placed on the interior side of the wall and terminated at the bottom of the beam or girder they support. Pilasters can be formed by laying up wider blocks than are used in the rest of the wall, from the footing to the bottom of the supported beam.

Basement door and window frames should be set with keys for rigidity and to prevent air leakage (fig. 10).

Anchor bolts for sills are usually placed through the top two rows of blocks (fig. 10). The bent bottom end of the anchor bolt should be positioned under the lower block and the block openings should be filled solidly with mortar or concrete.

When an exposed block foundation is used as a finished wall for basement rooms, the stack bond pattern may be employed for a pleasing effect. This consists of placing blocks one above the other, resulting in continuous vertical mortar joints. However, when this system is used, it is necessary to incorporate joint reinforcing in every second course. Reinforcement usually consists of small-diameter steel trusses 6, 8, or 10 inches wide and 16 feet long that are laid flat on the bed of mortar between block courses. To gain additional strength, reinforcing rods can be installed vertically in some of the block cores which are then filled with concrete.

Freshly laid block walls should be protected when temperatures are below freezing. Freezing of the mortar before it has set often results in low adhesion, low strength, and joint failure.

The wall may be waterproofed by applying a coating of cement-mortar over the block with a cove formed at the
Juncture with the footing (fig. 10). When the mortar is dry, a coating of asphalt or other waterproofing will normally assure a dry basement. Other methods include the application of a 6-mil polyethylene film over the asphalt to provide a water barrier or the installation of the drainboard against the asphalt coating before backfilling, as described previously.

**Basement Floor and Crawl Space**

**Drain tile**

Foundation or footing drains must often be placed (a) around foundations enclosing basements or habitable spaces below the outside finish grade (fig. 11), (b) in sloping or low areas, or (c) any location where it is necessary to drain away subsurface water as a precaution against damp basements and wet floors.

Drains are installed at or below the level of the area to be protected. They should drain toward a ditch or into a sump where the water can be pumped to a storm sewer. Perforated plastic drain pipe, 4 inches in diameter, is ordinarily placed at the bottom of the footing level on top of a 2-inch gravel bed (fig. 11). Another 6 to 8 inches of gravel is used over the pipe. In some cases, 12-inch-long tile is used to form the drain. Tiles are spaced about 1⁄8 inch apart and joints are covered with a strip of asphalt.
felt. Drainage is toward the out-fall or ditch. Dry wells for drainage water are used only when the soil conditions are favorable for this method of disposal. Local building regulations vary and should be consulted before construction of the drainage system.

**Basement floors**

Basements are normally finished with a concrete floor whether or not the area is to contain habitable rooms. Structurally, the floor keeps the soil pressure from pushing in the bottom of the foundation wall. Concrete floors are cast in place after all improvements such as sewer and water lines have been connected. Concrete slabs should not be poured on recently filled areas unless such areas have been thoroughly compacted.

At least one floor drain should be installed in a basement floor, usually near the laundry area. Large basements may require two or more floor drains. Positioning and installation of the drain and piping should precede the pouring of the concrete floor.

Four inches of compacted gravel should be installed as a base for the concrete. The purpose of the gravel base is to break the capillary action between the soil and the concrete. This helps to make a drier floor. The gravel also serves temporarily to store ground water that may seep beneath the slab. Instead of being forced to the floor surface through cracks in the slab, the water is able to migrate to floor drains beneath the slab.

A 6-mil polyethylene film should also be used on top of the gravel base to keep moisture from migrating through the slab into the basement.

*Figure 11 – Drain tile for soil drainage at outer foundation walls.*

Basement floor slabs should be either level or sloped toward floor drains. Before the concrete is poured, lengths of 2- by 4-inch lumber (called 2 by 4’s, though actually 3½ inches wide) are installed on edge on the basement floor at 8-foot intervals. The top edges of the 2 by 4’s are used to set the depth of the concrete for the floor slab and to determine the level or slope of the surface. The elevation of the tops of the 2 by 4’s should be decided with a surveyor’s level. A less precise alternative is to measure down from the bottom edge of the floor joists installed overhead.

The concrete is then poured. A straight 10-foot length of 2 by 4 is used as a screed spanning the 2 by 4 forms installed on the floor at 8-foot intervals. The screed is worked back and forth to bring the concrete to the level of the top edges of the 2 by 4 forms. Concrete should be added to low spots beneath the screed.

The 2 by 4 forms should be removed as soon as the screeding process is completed. The disturbed concrete should then be leveled, adding concrete as needed.

**Crawl spaces**

In some areas of the country, houses are often built over crawl space rather than over a basement or on a concrete slab. It is possible to construct a satisfactory house over crawl space by using (a) a good soil cover, (b) a small amount of ventilation, and (c) sufficient insulation to reduce heat loss.

Houses cost less to build over crawl space than over a full basement. Little or no excavation or grading is required except for footings and walls. In mild climates, footings are located only slightly below the finish grade. However, in the northern states and in Canada where frost penetrates deeply, the footing is often located 4 or more feet below the finish grade. In this case, full basement or raised entry construction may offer much more space at little additional cost. The footings should always be poured over undisturbed soil and never over fill unless special piers and grade beams are used.

**Treated wood crawl spaces.** Crawl space foundation walls can be constructed of FDN-stamped pressure-treated lumber and plywood, as described in the section on treated wood basement foundations. The use of wood offers opportunities for prefabrication not possible with concrete or masonry foundations.

Panels are assembled in the same manner as pressure-treated wood basement foundation walls using pressure-treated studs, plates, and plywood facing. However, because a crawl space requires no more than 24 inches of headroom, the ½-inch-thick plywood facing needs to extend only 2 feet down from the top plate to the level of
the crawl space floor, while the unfaced studs continue
down to the frost line (fig. 12). Pressure-treated 2- by
4-inch studs may be spaced at 24 inches on center for
single-story construction. For two stories, a spacing of 12
inches on center is necessary.

Construction begins with excavation to the level of the
crawl space floor. If local frost conditions require greater
depth, a trench of appropriate width is dug around the
perimeter, allowing the wall to extend down to the
required depth. A layer of crushed stone or gravel with a
minimum depth of 4 inches is then deposited at the bot-
tom of the trench and carefully leveled. Wall panels are
installed over footers placed on the gravel and braced in
place, plywood joints are caulked, and the wall is covered
with 6-mil polyethylene below grade on the exterior.

A wood-frame center-bearing wall may also be used.
Such a wall should be assembled from 2- by 4-inch studs
spaced at 24 inches on center. A plywood facing is not
required. The walls may be supported on a stone or
gravel bed in a shallow trench (fig. 12). As an alterna-
tive, center support may be provided by a conventional
beam supported on columns or piers.

Figure 12 – Pressure-treated-wood crawl-space footing and foundation wall.
Masonry crawl spaces. Construction of a masonry wall for a crawl space is much the same as for a full basement, except that no excavation is required within the walls. Waterproofing and drain tile are normally not required for this type of construction. Masonry piers replace the wood or steel posts used to support the center beam of the basement house. Footing size and wall thicknesses vary with location and soil conditions. A common minimum thickness for walls in single-story frame houses is 8 inches for hollow concrete block and 6 inches for poured concrete. Minimum footing thickness is 6 inches; width is 12 inches for concrete block and 10 inches for poured concrete.

Poured concrete or concrete block piers are often used to support floor beams in crawl-space houses. They should extend at least 12 inches above the groundline. Minimum size for a concrete block pier should be 8 by 16 inches with a 16- by 24-inch concrete footing that is 8 inches thick. A solid cap block is used as a top course. Poured concrete piers should be at least 10 by 10 inches in size with a 20- by 20-inch footing that is 8 inches thick.

Unreinforced concrete piers should be no greater in height than 10 times their least cross-sectional dimension.

Concrete block piers should be no higher than four times the least cross-sectional dimension. Spacing of piers should not exceed 8 feet on center under exterior wall beams and interior girders set at right angles to the floor joists and should not exceed 12 feet on center under exterior wall beams set parallel to the floor joists. Exterior wall piers should not extend above grade more than four times their least dimension unless supported laterally by masonry or concrete walls. The size of the pier for wall footing should be based on the load and the bearing capacity of the soil.

Other Features

Sill plate anchors

In wood-frame construction, the sill plate should be anchored to the foundation wall with %-inch bolts spaced about 8 feet apart (fig. 13A). In some areas, sill plates are fastened with masonry nails or power-actuated nails, but such nails do not have the uplift resistance of bolts. In areas of high wind and storm, well-anchored plates are very important.
A sill sealer is often used under the sill plate on cast-in-place walls to fill any irregularities between the plate and the wall. Anchor bolts should be embedded 8 inches or more in poured concrete walls and 16 inches or more in block walls with concrete-filled cores. The bent end of the anchor bolt should be hooked under a block and the core filled with concrete. If termite shields are used, they should be installed under the plate and sill sealer.

Some contractors construct wood-frame houses without using a sill plate. The floor system must then be anchored with steel strapping, which is placed during the pouring of concrete or in the joints between precast blocks. The strap is bent over and nailed to the floor joist or header joist (fig. 13B). The use of concrete or mortar beam fill provides resistance to entry by air and insects.

**Reinforcing poured walls**

Poured concrete walls normally do not require steel reinforcing except over window or door openings located below the top of the wall. Construction of such openings, however, requires that a properly designed steel or reinforced concrete lintel be built over the frame (fig. 14A). Rods are set in place about 1% inches above the opening while the concrete is being poured. Frames should be prime painted or treated before installation. For Concrete block walls, a similar lintel is commonly used of reinforced, poured, or precast concrete.

Where concrete work includes a connecting porch or garage wall not poured with the main basement wall, it is necessary to provide reinforcing rod ties (fig. 14B). The rods are placed during pouring of the main wall. Depending on the size and depth, at least three ½-inch reinforcing rods should be used at the intersection of each wall. Keyways may also be used to resist lateral movement. Such connecting walls should extend below normal frost line and be supported by undisturbed ground. Porch walls require footings if they extend more than 3 feet from the main wall or if the porch walls are to carry a roof load. Wall extensions in concrete block walls are also built of block and are constructed at the same time as the main walls over a footing placed below frost line.

**Masonry veneer overframe walls**

If brick or masonry veneer is used for the outside finish over wood-frame walls, the foundation must include a supporting ledge or offset about 5 inches wide (fig. 15). This results in a “finger space” of about 1 inch between the veneer and the sheathing for ease in laying the brick.

When a block foundation is constructed, the supporting ledge for the brick veneer can be provided by using two different block sizes. For example, 12-inch block can be installed from the footing to the level where the brick veneer is to begin; 8-inch block can be used from that point upward to support the house framing. A combination of 10-inch and 6-inch block can also be used. The resulting 4-inch ledge requires that the brick veneer be installed with a ½-inch overhang to provide “finger space” for laying the brick.

Providing a brick veneer ledge for a house with pressure-treated wood foundation may be accomplished by building a wall of pressure-treated 2- by 4-inch framing outside the primary foundation wall. This requires the primary wall to have a 2- by 12-inch bottom plate which also supports the outer 2- by 4-inch wall. No sheathing is applied to the outer wall.

A base flashing or 6-mil polyethylene film is used at the brick course below the bottom of the sheathing and framing to collect condensation that may run down the wall behind the brick. The vertical leg of the flashing should be behind the sheathing paper. Weep holes, to provide drainage, are located on 4-foot centers at this course. They are formed by omitting the mortar in a vertical joint between bricks. Galvanized steel brick ties, spaced about 32 inches apart horizontally and 16 inches vertically, should be used to bond the brick veneer to the framework. Where sheathing other than wood is used, the ties should be secured to the studs.

Brick should be laid in a full bed of mortar. Mortar should not be dropped into the space between the brick veneer and the sheathing. Outside joints should be tooled to a smooth finish to achieve maximum resistance to water penetration.

Masonry laid during cold weather should be protected from freezing until after the mortar has set.

**Notch for wood beams**

When basement beams or girders are wood, the wall notch or pocket for such members should be large enough to allow a ½-inch clearance, at least, for ventilation at the sides and ends of the beam (fig. 16). Unless pressure-treated wood is used, there is risk of decay where beams and girders are so tightly set in wall notches that moisture cannot readily escape.

**Protection against termites**

Certain areas of the country are infested with wood-destroying termites. This is true, in particular, along the Atlantic Coast, in the Gulf States, the Mississippi and Ohio Valleys, and southern California. In such areas, wood construction over a masonry foundation should be protected by one or more of the following:
1. Poured or precast concrete foundation walls.
2. Masonry unit foundation walls capped with reinforced concrete.
3. Metal shields made of rust-resistant material. Metal shields are effective only if they extend beyond the masonry walls and are continuous, with no gaps or loose joints.
4. Preservative treatment of wood. This protects only the members treated.
5. Treatment of soil with insecticide. This is one of the most common and most effective protective measures.
For more information, see the section on termite protection in chapter 8.

**Crawl-space ventilation and soil cover**

Crawl spaces below the floor of basementless houses and under porches should be ventilated and protected from ground moisture by a soil or ground cover (fig. 17). A soil cover, preferably 6-mil polyethylene, is normally recommended under all conditions to protect wood framing members from ground moisture. Using a soil cover permits the use of smaller, inconspicuous vents.

Such protection minimizes the effect of ground moisture on wood framing members. High soil moisture content and humidity may cause the moisture content in the wood to rise high enough to permit staining and decay to develop in untreated members.

Where there is a partial basement that has an operable window and is open to the crawl space area, no wall vents are required. Use of a soil cover in the crawl space area in nevertheless recommended.

For crawl spaces with no adjoining basement, the net ventilating area required with a soil cover is 1/1,600 of the ground area. For a ground area of 1,200 square feet (ft²), the required ventilating area is 0.75 ft². This should be divided between two small vents located on opposite sides of the crawl space. Vents should be covered with a corrosion-resistant screen of No. 8 mesh (fig. 17). It should be noted that the total free (net) area of the vents is somewhat less than the total area of opening, because of the presence of the vent frames, and the screening and louvers. The net free area is indicated on vents purchased from a building supplier.
Where no ground cover is used, the total free (net) area of the vents should equal 1/160 of the ground area. For a ground area of 1,200 ft² a total net ventilating area of about 8 ft² is required. This can be provided by installing four vents, each with 2 ft² of free ventilating area. A larger number of vents of smaller size, providing the same net ratio, can be used. The vents that are installed should be the type that can be closed during cold weather to reduce heat loss and the possibility of frozen pipes.

Concrete Floor Slabs on Ground

The number of new one-story houses with full basements has declined in recent years, particularly in the warmer parts of the United States. As previously noted, this results in part from the lower construction costs for houses without basements. It also reflects a decrease in need for basement space.
Traditionally, basements provided space for a central heating plant, for storage and handling of bulk fuel and ashes, and for laundry and utility equipment. Increased use of electricity, oil, and natural gas for heating has virtually eliminated the need for large coal furnaces and for storage for coal and ashes. Space on the ground floor level can be provided for a compact arrangement of modern heating plant, laundry, and utilities, and the need for a basement often disappears.

A common type of floor construction for houses without basements is a concrete slab. Sloping ground or low areas are usually not ideal for slab-on-grade construction because structural and drainage problems can add to costs. However, split-level houses often have a portion of the foundation designed for a grade slab. In such instances, the slope of the lot is taken into account and can become an advantage.

**Basic requirements for floor slabs**

Basic requirements for construction of concrete floor slabs include the following:

1. Finished floor level should be above natural ground level high enough for finished grade around the house to be sloped away for good drainage. The top of the slab should be no less than 8 inches above ground.
2. Top soil should be removed and sewer and water lines installed, then covered with 4 to 6 inches of gravel, crushed rock, or clean sand, well tamped in place.
3. A vapor retarder consisting of a heavy plastic film, such as 6-mil polyethylene, should be used under the concrete slab. Joints should be lapped at least 4 inches. The vapor retarder should not be punctured during placing of the concrete. Certain types of rigid foam insulation such as extruded polystyrene can serve as a vapor retarder beneath the slab if the joints are taped.
4. A permanent, waterproof, nonabsorbent type of rigid insulation should be installed around the perimeter of the slab. Insulation may extend down on the inside or outside of the slab vertically and under the slab edge horizontally a total distance of 24 inches.
5. Concrete slabs should be at least 3½ inches thick.
6. After leveling and screeding, the surface should be finished with wood or metal floats while concrete is still plastic. If a smooth, dense surface is needed for the installation of wood or resilient tile with adhesives, the surface should be steel troweled.

**Combined slab and foundation**

A combined slab and foundation, sometimes referred to as a thickened-edge or monolithic slab, is a useful choice in warm climates where frost penetration is not a problem and soil conditions are especially favorable. It consists of a shallow footing, reinforced at the perimeter and poured with the slab over a vapor retarder (fig. 18). The bottom of the footing should be at least 1 foot below the natural gradeline and should be supported on solid, unfilled, well-drained ground.

**Independent concrete slab and foundation walls**

In climates where the ground freezes to any appreciable depth during the winter, the walls of the house must be supported by foundations or piers that extend below the frost line to solid bearing on unfilled soil. When the walls have such support, the concrete slab and the foundation wall are usually separate. Two typical systems meet these conditions (figs. 19 and 20).

Reinforced grade beams separate from the concrete slab are used in many parts of the country (fig. 19). When the soil has inadequate bearing capacity, reinforced concrete piers can be installed beneath the grade beam. These piers carry the load of the house down to rock or stronger soil. The piers are also effective in counteracting frost heave under the grade beam in moderately cold climates.

In more severe climates the foundation wall is typically built as shown in figure 20, using concrete block or poured concrete resting on spread footings. The base of the footings must be below the frost line and their width is determined by the bearing capacity of the soil and the load of the structure.

**Insulation requirements for concrete floor slabs on ground**

Except in warm climates, perimeter insulation for slabs is necessary to reduce heat loss and to provide warmer floors during the heating season. Proper locations for this insulation under several conditions are shown in figures 18, 19, and 20.

Thickness of the insulation depends on the climate and on the materials used. Some insulations have more than twice the insulating value of others. The resistance (R) per inch of thickness, as well as the heating design temperature, govern the amount required. Two general rules are:

1. For average winter low temperatures of 0 °F and higher (moderate climates), the total R should be about 10.0 and the insulation should extend vertically along the side of the slab (fig. 18) or horizontally under the slab (fig. 20) for not less than 2 feet.
2. For average winter low temperatures of ~20°F and lower (cold climates), the total R should be about 10.0 without floor heating and insulation should extend vertically along the side of the slab (fig. 18) or horizontally under the slab (fig. 20) for not less than 4 feet.
Figure 18 – Combined floor slab and footing foundation system.

Figure 19 – Reinforced grade beam for concrete slab giving moderate resistance to frost heave when piers are used.

Table 4 shows these factors in more detail. The values shown are minimal; increased insulation results in lower heat losses.

**Protection against termites**

In areas where termites are a problem, soil should be chemically treated around the perimeter of the slab and around pipe or other penetrations through the slab.

**Insulation**

Properties desired in insulation for floor slabs include:

1. Resistance to heat transmission.
2. Resistance to absorption or retention of moisture.
3. Durability when exposed to dampness and frost.
4. Resistance to crushing by floor loads, weight of slab, and/or expansion forces.
5. Resistance to fungus and insect attack.
Moisture that may affect insulating materials can come from vapor inside the house and dampness in the soil. Vapor retarders and coatings may retard but not entirely prevent the penetration of moisture into the insulation. Dampness may reduce the strength of insulation against crushing, which in turn may permit the edge of the slab to settle. Compression of the insulation reduces its efficiency. However, 4 inches of drained gravel placed between the soil and the insulation breaks the capillary movement of water into the insulation and a 6-mil polyethylene film over the insulation blocks the movement of vapor.

Commonly used insulation materials are extruded polystyrene or expanded polystyrene with a density of 2 pounds per cubic foot (ft$^3$).

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Retaining Walls

Retaining walls are used to alter topography or to provide improved storm-water management. In some local
jurisdictions a special permit is required to erect a retaining wall in excess of a given height such as 36 inches.

Materials used in constructing retaining wall include pressure-treated wood, masonry, and poured concrete.

Pressure-treated rectangular wood timbers or railroad ties may be used to construct retaining walls (fig. 21). The timbers are stacked so that the butted ends of the members in one course are offset from the butted ends of the members in the courses above and below. The bottom course should be placed at the base of a level trench. In well-drained sandy soil there is no need for preparation or materials for special footing. In less well-drained soils, 12 to 24 inches of gravel backfill behind the wall and a 6-inch-deep gravel footing are desirable. Each course of timbers should be nailed to the course below using galvanized spikes with lengths 1/2 times the thickness of the timbers. Every second course of timbers should include members inserted perpendicularly to the face of the wall and nailed with spikes to the lower course. These perpendicular tieback members should extend horizontally into the soil behind the wall for a distance equal to their distance above the base of the wall. The end of the tieback member should be nailed to a deadman timber 24 inches in length that has been buried horizontally in the soil and aligned parallel to the timbers in the wall. These tiebacks and deadmen should be installed every 4 to 6 feet along the retaining wall. The tiebacks and deadmen in a course should be located midway between those in the second course below. The objective of the deadmen and tiebacks is to prevent the finished wall from tipping over because of the pressure from the soil behind the wall.

An alternative retaining wall design is shown in figure 22. Pressure-treated rectangular timbers or railroad ties are set in holes spaced 4 feet apart. Rough-sawn pressure-treated 2-inch lumber is then placed behind vertical members. The 2-inch cross-pieces are held in place by backfilling as they are placed. In poorly drained soils, the backfill should consist of 12 to 24 inches of gravel. In this design the vertical members should be set in post holes to a depth of 4 feet or to frost line depth, whichever is greater, in order to resist tipping from the pressure of the retained soil.

The third retaining wall design involves the use of pressure-treated plywood and pressure-treated 4-inch round or rectangular posts (fig. 23). The posts are set at 24-inch intervals in holes to the depth of the frost line. Pressure-treated ¾-inch plywood is then placed behind the posts and held in place by the backfill. Holes are drilled
Figure 22 – Pressure-treated timber and rough-sawn dimension lumber retaining wall.

Figure 23 – Pressure-treated post and plywood retaining wall.
through the plywood on each side of the posts at two-thirds the height of the wall. Plastic-coated galvanized wire rope is then installed through the holes and around each of the posts and fixed in place by a U-bolt wire rope clip behind the plywood. A 24-inch section of the treated post material is buried in the soil to the depth of the wire rope that is attached to the vertical posts. These deadmen should be buried behind the wall a distance not less than their height above the base of the wall. The free end of each of the wire ropes is then wrapped around the buried post sections and fixed in place by a U-bolt wire rope clip. The wire rope in this retaining wall design serves to tie the vertical posts to the buried deadmen and therefore carries the load of the soil retained by the wall. In order to carry this load the wire rope should have a breaking strength of not less than 1,000 pounds. All cut ends and drilled holes in the pressure-treated wood and plywood should be brushed with a liberal treatment of preservative chemical. As with other retaining wall designs, 12 to 24 inches of gravel backfill behind the wall is recommended in poorly drained soils.

A reinforced concrete block retaining wall is shown in figure 24. An extra wide footing is dug to a depth below the frost line. Before concrete is poured, steel reinforcing rods with 5/8-inch-diameter and a 90° bend are installed. These rods, placed on 16-inch centers, extend from the

Figure 24 – Reinforced concrete block retaining wall (maximum 4 feet high above grade).
back to the front of the footing and then turn upward to the height of the wall. The location of the vertical portion of the rod should be close to the soil side of the concrete block core voids. After the footing concrete has hardened, 2-core, 12-inch concrete blocks are laid so that the upturned reinforcing rods pass through the open cores of the block. After the block mortar has set, a wooden form is constructed on top of the blocks to form the mold for a 4-inch reinforced concrete beam. Two straight 5/8-inch steel reinforcing rods spaced 4 inches apart are laid on the beam form and wired to the vertical reinforcing rods. Concrete is then poured into the beam form and rodded into the open block cores. After the concrete has set, 12 to 24 inches of gravel should be used as backfill behind the wall to provide drainage and to minimize the pressure from behind the wall caused by freezing.

The retaining wall can be constructed solely of poured concrete instead of concrete block (fig. 25). The footing for the wall is dug to a depth below the frost line. A form is then built in which to pour the concrete for the footing and wall as a single unit. The form for the face of the wall should be vertical but the back of the wall should be built at an angle to provide a wall that is thicker at the base. Reinforcing rods 5/8 inch in diameter should be placed in the form and wired together to form a lattice with the rods spaced on 12-inch centers. Concrete is poured in the form to the depth of the footing and allowed partially to set before the concrete is poured for the vertical portion of the wall. Backfilling the wall with 12 to 24 inches of gravel is recommended.