Insulated Slabs: Details and Practices

by Kenneth Labs

Most residential foundations in the Northeast are deep, with full basements. As a result, details for slab-on-grade foundations are less commonly known. Many builders simply apply the same details used in more southerly climates, where slabs are more prevalent. This isn't ideal, particularly now that energy concerns have led to the use of more insulation. Foundation details need to take into account the added insulation. This article is based on principles discussed in the Builders Foundation Design Handbook (University of Minnesota Underground Space Center, 500 Pillsbury Drive SE, Minneapolis, MN 55455, 349 pages; $33).

Insulation: Where and How Much?

Insulation may be located either inside or outside the foundation wall, and it may be positioned either vertically or horizontally. Insulated concrete masonry can also be used. Computer studies show that the position does not greatly affect performance, as long as the insulation is continuous from the wall plate down. Exterior insulation is easily damaged during and after construction, and requires protective treatment that increases its cost. Interior insulation is subject to less abuse, but it may complicate detailing. Some pros and cons of different placements are noted in the accompanying details.

Exterior horizontal ("flowerbed") insulation raises the frost depth and allows for use of shallow footings. This idea was developed in Canada for warehouse and industrial floors, and is explained in the Handbook (also see "Shallow Foundations Promoted," March 1988 issue). Don't try shallow footings without proper design information! Your building inspector may not approve it anyway since it's still a novel idea in the U.S.

Table 1 gives recommended insulation levels for three different sets of fuel prices, based on construction costs and economic variables such as mortgage and inflation rate. The recommendations show the trade-off between the cost of insulation installed in new construction and money saved through reduced fuel consumption over the life of a typical mortgage. Since the amount of money saved in reduced fuel consumption depends on the cost of fuel, the cost-effective amount of insulation also depends on fuel cost — future fuel cost. When developing this table for the Handbook, we didn't want to guess at future costs, so we computed the recommendations at different costs. We'll let you do the guessing.

Practices and Details

The details and practices listed here are for non-structural slabs that are fully supported by the ground. They do not apply to "active" soils, which shrink and swell with changes in moisture content. These are just a few of the many possible ways to combine materials and assemblies. Some features are recommended only under certain circumstances (such as a site that requires radon or termite control), while other add to or compete with one another as alternate methods serving the same purpose (such as slab reinforcement versus use of control joints). As a result, some features are marked optional on the drawings. And some should be considered with the cautions noted in the commentary.

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Table 1: Perimeter Insulation Recommendations at Three Different Fuel Costs

Fuel Type	*Cost of Fuel ($.)*		
Natural Gas (per therm)	.37	.56	.84
Oil (per gallon)	.53	.79	1.19
Propane (per gallon)	.34	.52	.78
Electricity (per kwh)	.019	.028	.042

Location	*HDD*	*Width of insulation* and R-value*		
Bismarck, ND	9,075	4'R5	4'R5	4'R10
Minneapolis, MN	8,000	2'R5	4'R5	4'R10
Chicago, IL	6,175	2'R5	4'R5	4'R10
Denver, CO	6,025	2'R5	4'R5	4'R5
Boston, MA	5,600	2'R5	4'R5	4'R5
Seattle, WA	5,125	2'R5	4'R5	4'R10
Kansas City, MO	4,800	2'R5	2'R5	4'R5

From the Building Foundation Design Handbook, *prepared for the Department of Energy by the University of Minnesota.*

*Insulation may be installed either vertically or outside of frost wall, or horizontally under slab.
Example: Let's say we're building a house in a 7,000 HDD climate, like central Massachusetts. We will heat with oil, which we guess will average $1.00 per gallon over the coming years. There is no 7,000 HDD location on the table, but since the recommendations for Minneapolis (8,000 HDD) and Denver (6,175 HDD) are the same, these will also apply to us. We also reason that the solution for $1.00 per gallon oil is halfway between the recommendations for $.70 and $1.19 oil, so we want a 4 foot wide board at R7.5, which is 1 1/2 inches extruded polystyrene. Note that as heating costs increase, the amount of insulation that is cost effective also increases.

① ***Concrete for house floor slabs, mix, and workmanship,***

a) 28-day strength: 3,500 psi desirable; 2,500 psi acceptable.

b) Slump: 3 to 4 inches desirable; 4 to 6 inches acceptable.

c) Fine aggregate: ASTM C33 and C330 specifications are acceptable; 100 percent aggregate passing 3/8 inch sieve, 95 to 100 percent passing the no. 4 sieve, 80 to 90 percent passing no. 8, 50 to 75 percent passing no. 15, 30 to 50 percent passing no. 30 10 to 20 percent passing no. 50, and 2 to 5 percent passing no. 100.

d) Low percentages of aggregate passing the No. 50 and No. 100 sieves are likely to increase bleeding (water rising to the surface during curing), in which case a lower slump is desirable.

e) Slab surface tolerance: Maximum depression between high spots measured with a 10-foot straight-edge should not exceed 5/16 inch for house slabs.

f) Cracking tolerance: Shrinkage (horizontal) and settlement (vertical) cracks greater than 1/16 inch may be considered excessive for residential work.

g) Curling may be minimized by increasing 28-day strength to 4,000 psi; decreasing slump to 2 to 3 inches; casting on a sand layer; using maximum allowable size aggregate and minimum proportion of sand; long-term wet curing.

② ***Wire mesh reinforcing.***

a) Wire mesh adds no significant strength to the slab, has little effect on curling, and is not necessary if control joints are acceptable for crack control.

b) Reinforcing is recommended in areas of high radon and termite hazard.

c) Wire mesh can be used to increase the spacing of, or to eliminate, control joints in slabs within specific limits; use of 6x6 W1.4xW1.4 is adequate for slabs up to 25 foot square, 6x6 W2.1xW2.1 for up to 45 foot square; and 6x6 W2.9x2.9 for up to 65 foot square.

d) Reinforcing should be supported on metal, plastic, or 6,000 psi precast concrete chairs (not clay bricks, which absorb water rapidly and may cause cracking). Alternatively, pour 2 inches of the slab, lay the mesh, then pour the remaining 1 1/2 inches or 2 inches of concrete.

e) Reinforcing should extend to within 2 inches of, but not further than 5 inches from, the slab edge or control joint. Lap wire mesh 8 inches.

f) Pulling mesh laid on the subgrade up through the concrete during the pour is not recommended.

③ ***Concrete joints.***

a) Concrete (contraction) joints are sufficient as a means of crack accommodation in slabs where floor joints are acceptable with respect to plan layout, flooring materials, and lack of radon and termite hazard.

b) Joints should be laid out to form floor panels as nearly square as possible, not exceeding a ratio of 1 1/2 to 1.

c) Joint spacing depends on shrinkable potential, which in turn depends on the amount of water in the mix, curing conditions, and the porosity and size of the aggregate. The NAHB recommends the spacing shown below for house floors.

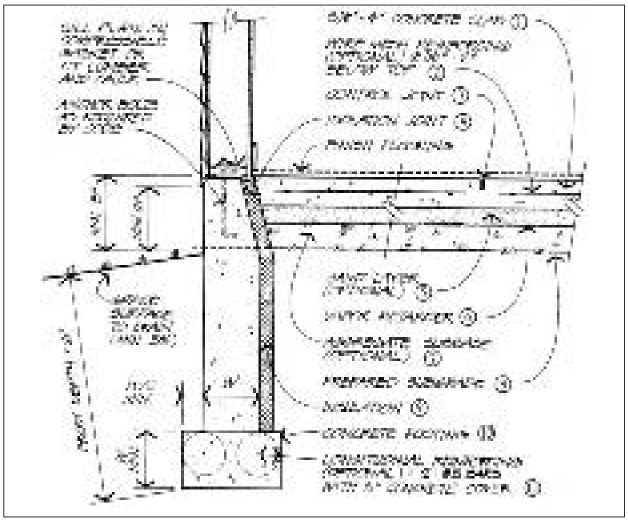
Type of Concrete Aggregate	Joint Spacing (feet)
Crushed granite	25
Crushed limestone Flinty limestone Calcareous gravel	20
Siliceous gravel Gravel (less than 3/4 inch) Slag	15

d) Joint spacing can be increased if the panels framed by the control joints are reinforced, according to 2c above.

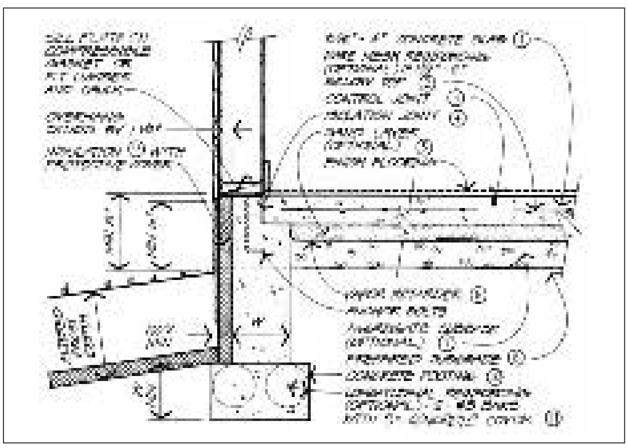
e) Joints should be 1/4 to 1/3 the slab thickness in depth, and may be formed, tooled, or saw cut.

④ ***Isolation joints***

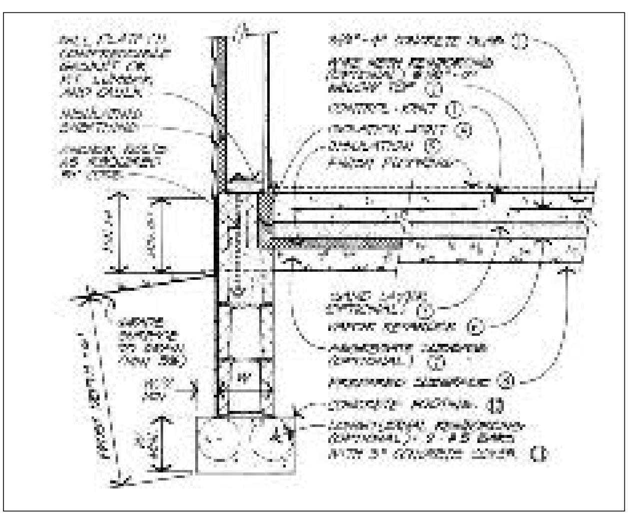
These are recommended wherever elements with different loads and settlement potential meet. In addition to the wall/floor joint, isolation should be provided at the fireplace foundation/slab, column/slab, foundation wall/patio slab, and driveway/garage slab joints. Isolation joints may be formed with a variety of bond-breaking materials, provided they create wide enough joints to prevent transfer of load through the joint material. In areas of high radon hazard, the joint should be designed to accept a pour-in sealant.



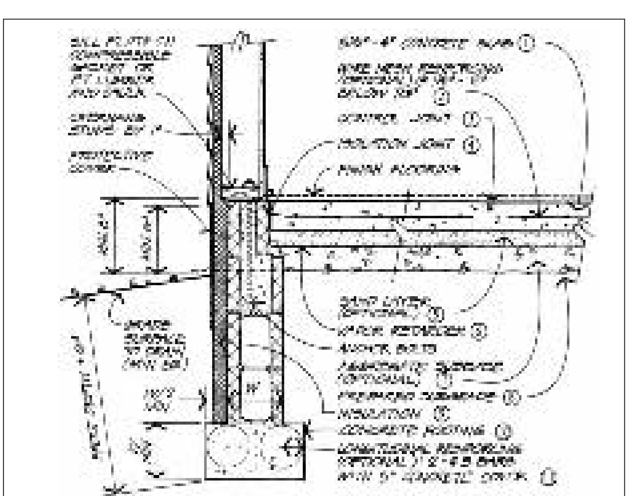
Detail 1: Interior insulation on cast concrete wall. *Casting a slant to the top of the wall conceals the wall/floor joint containing up to 2 inches of insulation under an overhanging 2x6 stud. This slant also allows the slab to float free of the wall and to settle independently of it. The insulation could also extend horizontally under the slab.*



Detail 2: Exterior insulation on cast concrete wall. *This common practice of pouring the slab on a shelf in the stem wall is discouraged (unless structurally reinforced for edge support). While convenient for concealing the joint, settlement will lead to cracking in the slab around the perimeter. Extending the insulation out horizontally from the top of the footing ("flowerbed insulation") can raise the frost depth and reduce the depth of footing necessary, but this requires good engineering (described in the Handbook).*



Detail 3: Interior insulation on masonry wall. *This detail uses a 6-inch concrete masonry unit (CMU) top course with 2 inches of insulation as an isolation-joint filler to float the slab free of the 8-inch wall beneath. Overhanging studs and baseboard conceal the joint. The insulation could just as easily be installed vertically at the inside face of the wall. It should overlap the 2-inch joint insulation to provide a continuous thermal barrier.*



Detail 4: Exterior insulation on masonry wall. *Insulating on the exterior of masonry makes it difficult both to conceal the joint and to provide isolation between the slab edge and stem wall. The detail shown allows 2 inches of foundation insulation when an inch of insulating sheathing is applied or 1 inch without the insulating sheathing. The isolation joint configuration is less than ideal, but it avoids the undesirable condition shown in Detail 2.*

(5) ***Sand layer.*** A sand layer 2 to 4 inches thick protects the vapor retarder during the pour and allows excess water to drain out of the concrete as it is placed. This may help the concrete to set up faster for finishing, and may reduce shrinkage cracking and curling. The value of sand layer for crack control depends on curing conditions and the amount of water in the concrete mix. It may be useful when other measures of crack control may have not performed satisfactorily.

(6) ***Vapor retarder.*** In all but the most arid climates, a vapor retarder should be provided under the slab. In addition to blocking vapor diffusion, the retarder prevents capillary transfer of moisture from the soil and blocks entry of moist air and radon gas through joints and cracks in the floor. Vapor retarders serve no purpose under garage floors and other exterior slabs. For some finish floors the vapor retarder may be placed between the slab and the finish flooring.

(7) ***Aggregate sub base.*** An aggregate sub base may serve several functions, but most of these are either not generally necessary or are satisfied by other components of the floor assembly. Considerations include:

a) The base adds insignificant strength to the slab.

b) The base may be useful for levelling a poorly prepared subgrade.

c) The base can even out support for the slab on soils with uneven bearing capacity and over backfilled utility trenches.

d) Coarse aggregate serves as a capillary break, which is not necessary when a vapor retarder is used.

e) Coarse aggregate may be useful as a drainage layer if a portion of the perimeter is below grade.

f) Coarse aggregate is recommended as an underslab suction plenum as part of a radon collection system.

g) Installation of an aggregate sub base is likely to disturb subgrades that have been chemically treated for termite control, while the aggregate itself is not a good substrate for the chemical treatment. When provided, the bottom of the sub base should be located above the surrounding exterior grade, so it does not collect water from the perimeter.

(8) ***Subgrade preparation.*** The subgrade must be frost-free and contain no puddles or muddy spots. It should be cleared of top soil and organic debris, and it should be undisturbed soil (as much as possible) of uniform bearing capacity. Pronounced hard and soft spots should be excavated and refilled and compacted with a soil similar to the surrounding soil. In areas where termite control is necessary, the subgrade should be chemically treated. The subgrade should not be disturbed before the pour. Most of the chemical treatment is retained in the top 3/4 inch of earth, so long term protection relies on the unbroken integrity of a thin and very fragile soil "membrane."

(9) ***Insulation.*** A large portion of the heat loss from slab floor occurs horizontally at the edge of the slab above grade. It is important that either the exterior of the stem wall be insulated, or that the slab edge be isolated from the stem wall by at least R-5.

(10) ***Concrete footing.*** The width of the footing should be sized to distribute the wall load within the limits of the soil-bearing capacity. If the soil requires a footing, more transverse reinforcing is required, and it should be designed by a professional engineer. Transverse reinforcing goes across the width of the footing. Concrete for reinforced footings should have the following specifications:

a) 28-day strength: 2,500 psi desirable; 2,000 psi acceptable.

b) Slump: 5 to 7 inches.

Footings must not be cast on frozen ground, and must be protected from freezing while curing. In the case of an overexcavated trench, no fill should be added; the difference should be made up with concrete. Where footings may bear partially on rock, the American Concrete Institute recommends either 1) removing rock to a depth of 18 inches below the footing and replacing it with a sand cushion, or 2) increasing the entire foundation depth so that all of the footing area is supported by rock.

(11) ***Longitudinal reinforcing.*** Longitudinal reinforcing is not normally required, but it is desirable when the footing spans over backfilled utility trenches and soft spots. It is also desirable when special measures for crack control in superstructure are warranted (masonry veneer walls, for example). Reinforcing should extend beyond trenches by 1 1/2 times the trench width; footing spans over 3 feet should be designed by an engineer. The reinforcement should be located at least 3 inches from footing surfaces cast against the earth, or 2 inches for board-formed surfaces. ■