Vapor barriers under concrete slabs

Should the concrete be placed directly on the vapor barrier?

By **Bruce A. Suprenant**

Many architects and engineers require the use of a vapor barrier under concrete slabs. Even though the use of a vapor barrier might be common, the specified location of the vapor barrier varies. Some specifiers require a sand layer or a crushed base over the vapor barrier. Others insist that the vapor barrier be placed directly under the slab. Specifiers must carefully consider the effect of the location of the vapor barrier on the performance of the concrete slab.

Why use vapor barriers?

Vapor barriers are traditionally specified to minimize moisture inflow through concrete that's in contact with water or water vapor from a high water table. Vapor barriers are used to protect floor coverings or electronic equipment that might be damaged from moisture moving upward through the concrete slab. Recently, vapor barriers have also been used to minimize the infiltration of radon.

The American Concrete Institute's (ACI) Committee 302 "Guide for Concrete Floor and Slab Construction" suggests that a vapor barrier may not be necessary where no drainage or soil problems exist and in arid regions where irrigation and heavy sprinkling are not done (Ref. 1). However, some specifiers always use a vapor barrier because it is inexpensive to install at the time of construction and moisture problems are difficult to correct after construction.

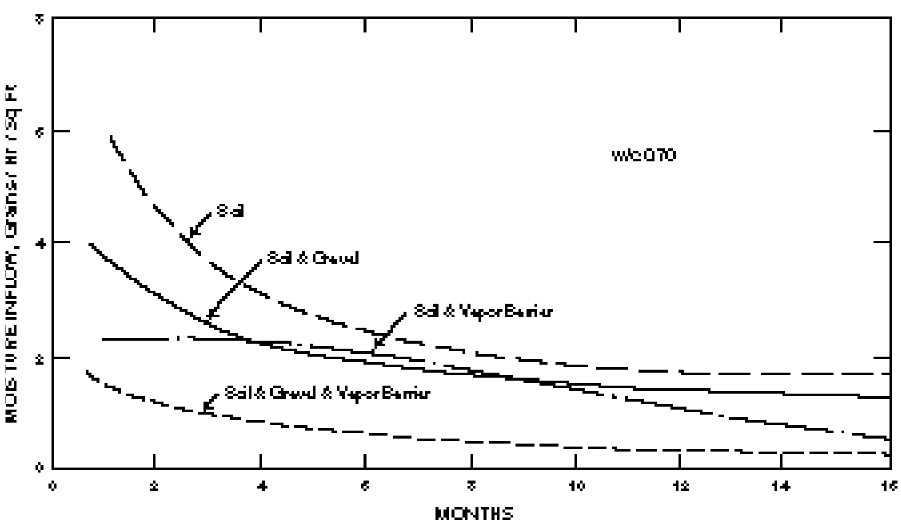

Figure 1. *A vapor barrier is effective in preventing water inflow from the groundwater through the concrete slab. Using a vapor barrier in combination with a granular capillary break provides the greatest resistance to water inflow.*

Vapor barrier performance

Vapor barriers effectively minimize water inflow, but some water vapor may still pass through them. The Portland Cement Association (PCA) conducted moisture migration tests in which concrete slabs were placed directly on a wet clay subgrade (Ref. 2). Tests were run with and without a vapor barrier and with and without a gravel layer that served as a capillary break. Vapor barriers used were 4-mil polyethylene and 55-pound roofing felt.

As Figure 1 shows, using a vapor barrier, with or without a gravel layer, lowered the amount of water passing through the slab from below. After 2 months of testing concrete with a water-cement ratio of 0.70, moisture inflow through the slab with no vapor barrier was about three times higher than inflow through the slab with a vapor barrier.

Figure 1 also shows that a granular capillary break reduces the water inflow even without a vapor barrier. However, the vapor barrier applied over a granular layer greatly reduced the moisture movement through the concrete slab from the water below.

Vapor barrier properties and installation methods

Polyethylene sheeting is the most common vapor barrier material. A 4- to 6-mil-thick polyethylene sheet is typically placed on a compacted subgrade or on a sand layer spread over the subgrade.

Some specifiers prefer thicker polyethylene sheeting, especially if the barrier will be placed in contact with a crushed stone base. Others recommend using sheet membranes or asphalt core board. The thicker, stronger materials resist punctures better during construction. They also allow less water vapor to pass. Regardless of the sheeting thickness, vapor barrier joints should be airtight with proper laps to help prevent water vapor movement.

ACI 302 recommends using a 3-inch-thick sand layer over the vapor barrier before concrete is placed. However, some architects and engineers suggest using a ½- to 1-inch sand layer since even if compacted, the 3-inch sand layer can be easily displaced during concrete placement. Then the sand may mix with the concrete or the slab thickness may vary. Both result in a weaker slab. Also, a thick sand layer may lead to pumping at the joints when the slab is subjected to forklift traffic.

Still other architects and engineers prefer placing a crushed stone layer over a 50-mil-thick polyethylene sheeting that won't be punctured by the stone. The crushed stone is not easily displaced during concrete placement, can support construction equipment for compaction, and eliminates any pumping at the joints. Additionally, a thin layer of sand is usually used on top of the crushed base to minimize subgrade drag between the crushed stone and the concrete slab.

Although ACI 302 recommends putting a sand layer on the vapor barrier, some specifiers require placing concrete directly on the vapor barrier. When this is done, however, finishers may purposely punch holes in the vapor barrier to reduce bleedwater rise and allow the slab to set quicker. If it's important that the vapor barrier not be punctured, onsite inspection will be necessary. If the vapor barrier is used only to reduce subgrade friction, punching holes in the vapor barrier may be permitted (Ref. 3).

Vapor barrier effect on subgrade friction

Some engineers believe that placing the vapor barrier in contact with the concrete slab reduces subgrade friction. Reducing friction between the slab and subgrade allows more shrinkage contraction to occur. As more movement occurs, fewer cracks should form.

Studies have shown, however, that subgrade friction doesn't have much influence on movement of short slabs caused by changes in slab temperature or moisture content (Ref. 5, 6, and 7). One investigator calculated a maximum frictional restraint stress of only 13 psi at the center of a pavement with contraction joints on 20-foot centers (Ref. 7). For short slabs, the investigator recommended designing for curling stresses and ignoring the restraint of shrinkage contraction.

Vapor barrier effects on concrete properties

Vapor barriers can affect the behavior of the concrete slab and signifi-

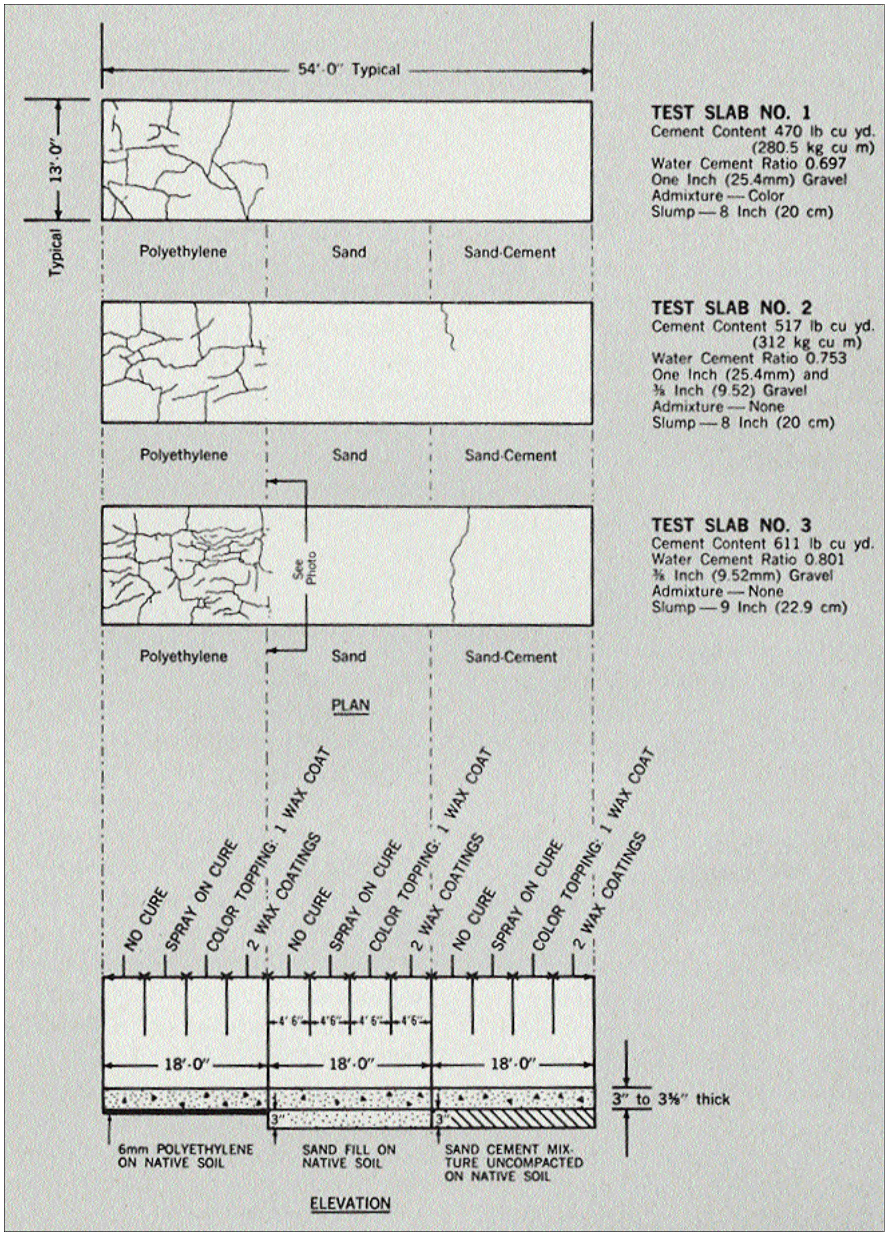

Figure 2. *Concrete slabs placed over polyethylene cracked, while slabs placed over a sand base didn't crack. Details of the test slab program show three different base conditions as well as four curing conditions on each of the bases for each slab. Three different concrete mixes are described on the right.*

cantly influence finishing time, cracking, and strength. Both the engineer and contractor need to understand how concrete properties are affected by the vapor barrier.

Finishing time. Placing concrete directly on a vapor barrier increases the amount of bleedwater that rises to the top surface. Because of this, it also increases the waiting time needed between bull floating and further finishing. Finishers must wait for the bleedwater to disappear before troweling.

If the finishers are too eager and start to work while the bleedwater is still visible, surface defects are likely to occur. Thus placing concrete directly on a vapor barrier increases finishing time and the possibility of surface defects. ACI 302 also says that a vapor barrier directly under a concrete slab aggravates plastic shrinkage cracking (Ref. 1).

The PCA tests did show that when a concrete slab was placed directly over a vapor barrier, instead of over a sand layer, water flow from the concrete was greater at early ages (Ref. 2). The researchers believed this was due to more evaporation of the mix water. When vapor barriers were not used, some mix water could be lost to the subgrade below, thus reducing the amount of mix water evaporation measured at the top surface.

Cracking. Nicholson studied effects of vapor barriers on cracking behavior by placing concrete over polyethylene sheeting, a 3-inch sand layer with no vapor barrier, and a 3-inch sand-cement layer with no vapor barrier (Ref. 8). The results, shown in Figure 2, were dramatic. There was extensive cracking in the slabs placed on polyethylene and little cracking in the slabs placed over sand or cement-treated sand. Nicholson attributed the reduction in cracking to absorption of concrete mix water by the sand base.

It's interesting to note that the concrete mixes used in the study varied in water-cement ratio from 0.7 to 0.8 and had a slump from 8 to 9 inches. The dramatic reduction in cracking and the water loss from the concrete into the sand base were probably more significant for these high water-cement concrete mixes than they would have been for concrete mixes with a low water-cement ratio and slump.

Strength. Nicholson also cored the concrete placed over polyethylene sheeting, a 3-inch sand layer, and a 3-inch sand-cement layer. Concrete placed over a sand bed was more than 30% stronger than concrete cast on the polyethylene (Ref. 9).

Interestingly, one PCA publication suggests that less water should be used in concrete that will be placed directly over a vapor barrier (Ref. 10). The theory is that placing concrete on a granular layer lowers the water-cement ratio, thereby increasing concrete strength. Since the vapor barrier prevents this water loss, the water-cement ratio should be adjusted downward at the time of batching to provide the same equivalent strength as concrete on a sand layer.

For the high-water-cement-ratio concretes tested by Nicholson, the sand bed would be an obvious benefit. The difference in strength between concrete placed directly on a vapor barrier versus a sand layer, like the difference in cracking, should be less significant at lower water-cement ratios.

Blumer believes that a sand layer decreases concrete strength by removing water from the concrete that is necessary for proper curing (Ref. 11). Because of this, Blumer says the vapor barrier should be placed in contact with the slab, just as polyethylene sheets are used on top of the slab, to minimize water loss and promote cement hydration.

If the water-cement ratio is at least 0.42, there's enough water in the concrete to fully hydrate all of the cement (Ref. 12). If the concrete was placed with a water-cement ratio lower than 0.42, then the loss of water to the sand layer might be important. However, most commercial slab-on-grade concretes are placed with a water-cement ratio of 0.45 to 0.55. Also, the amount of water lost to the sand layer depends on whether the sand is wet or dry.

Vapor barrier effects on slab curling

ACI 302 indicates that placing concrete in direct contact with a vapor barrier increases slab curling (Ref. 1). Since the bottom of the slab loses no moisture and the top dries rapidly, shrinkage at the slab surface pulls the edges upward. Placing the concrete on a sand layer is expected to help reduce curling by minimizing the difference in moisture content between the top and bottom of the slab.

A sand layer may also reduce curling caused by localized moisture content differences beneath a slab. In a study of pavement warping, moisture measurements of the subgrade soil showed that a free-draining granular layer helped to distribute water more uniformly below the slab so that differences in moisture content weren't as great (Ref. 4). Although there was a greater total slab uplift caused by swelling soils, differential uplift was smaller.

Should the vapor barrier be in contact with the concrete?

Because concrete properties and finishing methods probably have a greater effect on concrete performance than the vapor barrier, it is not surprising that architects, engineers, and contractors disagree on the correct location of the vapor barrier. Some have seen good slab performance and some have seen poor results when concrete was placed directly on a vapor barrier.

I believe that the location of the vapor barrier for interior concrete probably doesn't matter if a high-quality concrete with a low water content and water-cement ratio is used and it's finished correctly. Under these conditions, the concrete performance will be the same regardless of whether the concrete and vapor barrier are separated by a sand layer.

For concretes with high water contents and high water-cement ratios, placing the concrete over an aggregate layer is beneficial. It speeds up finishing, increases strength, and reduces the possibility of finishing defects and curling.

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