Where to place the vapor retarder

For slabs on grade, should the vapor retarder be located under a granular layer or directly under the concrete? Here are the pros and cons of each location.

BY BRUCE A. SUPRENANT AND WARD R. MALISCH

In the real estate industry, location is everything. The importance of location also applies to a hotly debated topic in the concrete industry—where to place the vapor retarder (or vapor barrier) for slabs on grade. Some specifiers require concrete to be placed directly on the vapor retarder, and others require placement of a granular blotter layer between the concrete and the vapor retarder. Advocates of each option argue that their preference results in a better concrete slab.

Like all engineering decisions, the location of a vapor retarder often is a compromise between minimizing water-vapor movement through the slab and providing the desired short- and long-term concrete properties. However, specifiers must consider the benefits and liabilities of the choice they make.

The case for a granular layer

Finishers prefer concrete placed on a granular base because the base absorbs mix water, shortens the bleeding period and allows floating to start earlier. Australian researchers noted that 4½-inch-slump concrete placed on a granular base lost its bleedwater sheen about two hours faster than the same concrete placed directly on a vapor barrier (Ref. 1).

Base conditions also affect concrete stiffening. In tests performed by The Aberdeen Group, 2½-inch-slump concrete was used for two 4x4-foot, 4-inch-thick slabs. One slab was placed directly on a vapor retarder and the other on a crushed-stone base. Technicians periodically set a steel-shot-filled rubber boot weighing 75 pounds on the surface and measured the footprint indentation (Fig. 1). Concrete on the stone base had stiffened enough after 90 minutes to allow a ¼-inch footprint

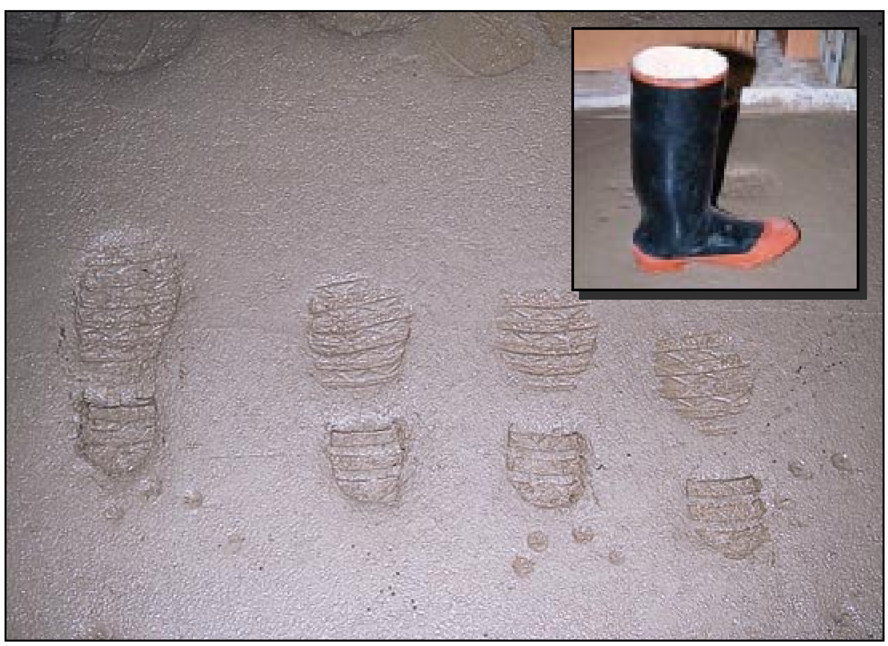

Figure 1. Concrete is generally considered to be ready for floating when finishers leave a ¼-inch-deep footprint in the surface. Using a boot filled with steel shot (inset) to produce footprints, we found that 2½-inch-slump concrete placed on a stone base was ready for floating about 45 minutes earlier than the same concrete placed directly on a vapor retarder.

indentation, an indication that floating could begin. Concrete placed directly on the vapor retarder required 45 more minutes of stiffening time before it was ready for floating.

Specifiers who require a granular blotter layer cite additional benefits, saying there is less chance of :

- Puncturing the vapor retarder
- Surface blistering or delaminations caused by an extended bleeding period
- Settlement cracking over reinforcing steel
- Slab curling during drying
- Cracking caused by plastic or drying shrinkage

Many specifiers recommend a 3- or 4-inch-thick layer of trimmable, compactible, self-draining granular fill for the blotter layer. Although concrete sand is sometimes recommended, it doesn't provide a stable working platform. Concrete placement and workers walking on the sand can disturb the surface enough to cause irregular floor thickness and create sand lenses in the concrete.

The case for placing concrete on a vapor retarder

Floor-covering contractors prefer to install their products on concrete slabs that are placed directly on a vapor retarder. If the vapor retarder effectively reduces moisture inflow from external sources, only water in the concrete pores must exit the slab. They believe the often-required vapor-emission rate of 3 pounds/1,000 square feet/24 hours is achieved faster under these conditions. They also believe the uncovered vapor retarder acts as a slip sheet, reducing slab restraint and thus reducing random cracking.

Placing concrete directly on a vapor retarder also eliminates a potential water reservoir that's created when using a blotter layer. Because more subgrade soil must be removed to accommodate the additional 3- to 4-inch-thick blotter layer, the layer is more likely to be placed below finished-grade level, thus increasing the chance of its holding water.

Specifiers who require concrete to be placed directly on the vapor retarder cite these additional advantages:

- Reduced costs because of less excavation and no need for additional granular material
- Better curing of the slab bottom, since the vapor retarder minimizes moisture loss
- Less chance of floor moisture problems caused by water being trapped in the granular layer
- Less radon-gas infiltration

These specifiers recommend using a low water-cement-ratio concrete and water-reducing admixtures to reduce bleeding, shrinkage and curling of concrete placed directly on the vapor retarder. They believe the higher-quality concrete and better curing reduces cracking and produces a better floor.

Table 1. Amount of water in granular layer per 1,000 square feet of floor*

Layer thickness	Water absorbed	Water in voids	Total water
2 in.	220 lbs	2,080 lbs	2,300 lbs
3 in.	330 lbs	3,120 lbs	3,450 lbs
4 in.	440 lbs	4,160 lbs	4,600 lbs

*Well-graded, compactible granular-base material with assumed density of 130 pounds per cubic foot, 1% absorption capacity and 20% voids. A 7% to 8% moisture content would normally be needed to achieve the compaction density typically required.

Granular layer as a water reservoir

When a low-permeability floor covering will be installed on a concrete floor, special care is needed during construction to control moisture content of the subgrade, subbase or granular layer (if used over the vapor retarder). It's best to place the floor after the building is enclosed and the roof is watertight. On many projects, however, this isn't possible, and the granular layer can become a water reservoir.

Water sources and access points. To provide unrestricted floor access for construction activities such as tilt-up panel forming and casting, columns sometimes aren't erected and column blockouts aren't filled until months after floor placement. But rainwater can enter column blockouts that are left open. It can also penetrate joints and cracks, utility penetrations or open closure strips, and increase the moisture content of the subgrade, capillary break or granular layer.

Excessive sprinkling of a granular layer before concrete placement can create a moisture reservoir that will delay drying of the concrete floor. ACI 302.1R-96 (Ref. 2) recommends that the base be dry at the time of concreting unless severe drying conditions exist.

Wet-curing methods such as ponding or continuous sprinkling allow water to enter joints, cracks and other openings, again contributing to a higher than necessary moisture content beneath the floor slab.

Water from construction operations on a newly placed slab also can increase the granular-layer moisture content by entering joints, cracks or slab openings. Such operations include joint sawing, abrasive wet blasting or wet grinding, which may be needed to achieve a flatter floor profile. Sometimes power washing is used to clean debris or other contaminants from the floor.

Most slabs are constructed using a strip-placement sequence that leaves the granular layer exposed to rainwater in uncompleted portions of the slab. Rollings (Ref. 3) determined that a tile-floor failure was caused by rainwater accumulating in a 3-inch-thick sand layer placed between a 5-inch-thick concrete slab and a polyethylene vapor retarder. One portion of the slab had been left uncompleted for an extended period, exposing the sand layer to prolonged rain and turning it into a reservoir of trapped water.

Water capacity of the granular layer. Table 1 shows the maximum amount of water that can be held in a layer of well-graded, compactible granular-base-course material of various thicknesses. If the floor concrete contained 250 pounds of mix water per cubic yard, 1,000 square feet of 6-inch-thick floor would contain 4,630 pounds of mix water. As shown in Table 1, a 4-inch-thick granular layer under the floor can contain about the same amount of water. And if sand or other high-void-content granular materials are used, the water capacity is much higher.

If the 250 pounds of mix water are used in concrete with a water-cement ratio of 0.50, about 100 pounds of the water will be free water that must evaporate as the floor dries (Ref. 4). Thus a 6-inch-thick, 1,000-square-foot floor slab would hold 1,850 pounds of free (evaporable) water.

Based on Brewer's work (Ref. 5), it would take about 82 days, or roughly three months, for enough free water to evaporate and produce a water-vapor emission rate of 3 lbs/1,000 sf/24 hours. A saturated 2-inch-thick granular layer would need to lose as much water as the concrete. And the water in the layer must move through the concrete. Thus it's likely that a 2-inch-thick saturated, well-graded granular layer could double the time required for the slab vapor-emission rate to reach 3 lbs/1,000 sf/ 24 hrs. It could even prevent the slab from ever reaching that emission rate.

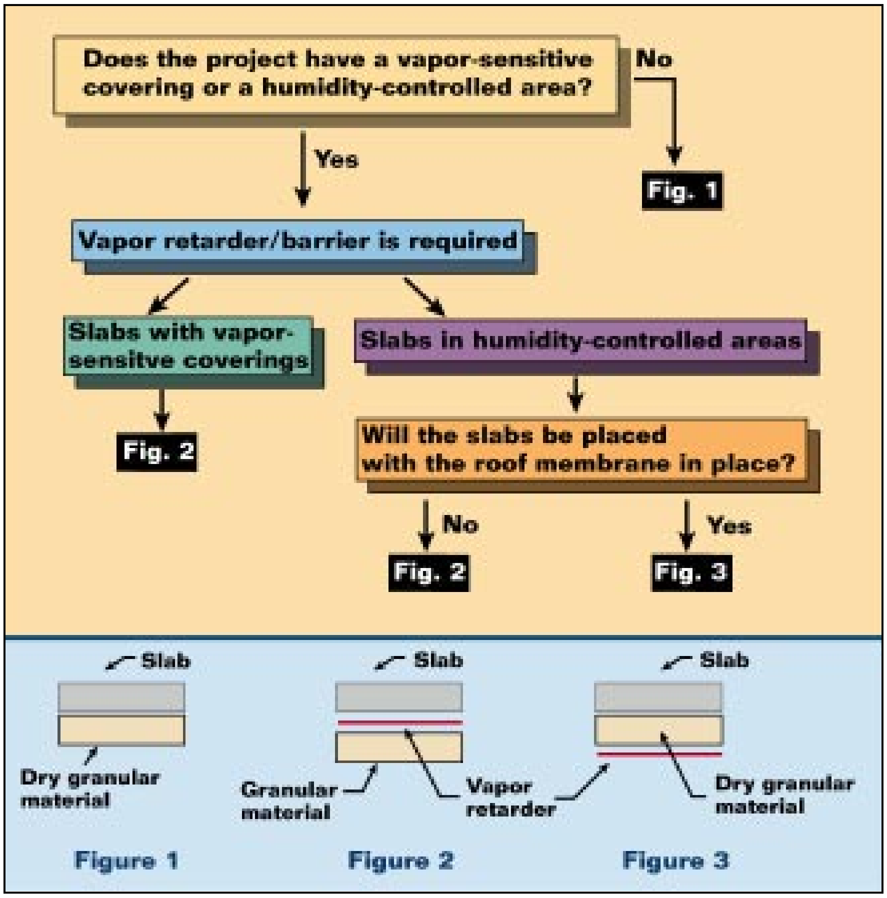

Figure 2. This flow chart helps designers decide if a vapor retarder or barrier is needed and where it should be placed.

Weighing the alternatives

Consulting engineers Jerry Holland and Wayne Walker, Lockwood-Greene Engineers, Atlanta, have developed a flow chart to help designers decide if a vapor retarder is required and, if so, where to place it (Fig. 2).

The chart gives designers the following three options based on the floor's in-service environment and the presence or absence of a vapor-sensitive floor covering:

- Use no vapor retarder
- Use a vapor retarder directly below the slab
- Sandwich a granular layer between the vapor retarder and the slab

ACI Committee 360 is considering inclusion of the flow chart in ACI 360R, *Design of Slabs on Grade*. Because curling is a major concern when concrete is placed directly on the vapor retarder or barrier, notes in the flow chart will provide suggested design options for minimizing curling effects.

Establishing responsibility for moisture-related floor problems

Consider the following scenario based on a concrete subcontractor's actual experience. The subcontractor places and finishes a concrete floor. Flatness and levelness measurements show specification compliance, and test reports indicate the 28-day compressive strength is acceptable. He leaves the job and submits his bill.

Two months later, he's called back by the general contractor. Rainwater has penetrated the slab, which has curled. The floor-covering contractor is concerned about high water-vapor emission rates, and the general contractor worries that the required slab drying time will delay project completion.

The concrete subcontractor is being held responsible for:

- Curling, even though floor flatness met specifications when measured within 72 hours after concrete placement as required by ACI 117-90, *Standard Specification for Tolerances for Concrete Construction and Materials*
- Protecting the slab from external moisture, even though he has completed all the concrete work and is no longer at the site
- Water-vapor emissions from the slab, even though the general contractor followed specification requirements by placing a granular layer over a vapor retarder
- Delays in completion of the project due to these problems

Sound familiar? On this project, the floor contractor returned at his own expense to grind the slabs and minimize curl. Luckily, he was able to convince the design team that the other issues were not his responsibility.

All of these issues should be resolved with the general contractor, design team and owner *before* the slab is placed. Concrete subcontractors should be held responsible for flatness and levelness within the time frame designated by ACI tolerance standards, but not longer. General contractors should be responsible for protecting the slab from external moisture. Only they can coordinate and direct the services of the roofer, excavator and other subcontractors who can help to minimize moisture infiltration. And, unlike the concrete subcontractor, the general is on the project from start to finish.

Concrete subcontractors need to resolve these issues at prepour planning meetings. If they don't, they had better be prepared for the phone call telling them they're responsible for fixing problems caused by rainwater infiltration. To avoid that call, add the items discussed here to your prepour conference checklist.

Editor's note

Discussions, pro and con, for differing vapor-retarder installation options are also given in ASTM E 1643, *Standard Practice for Installation of Water Vapor Retarders Used in Contact with Earth or Granular Fill under Concrete Slabs.*

References

1. T. Anderson and H. Roper, "Influence of an Impervious Membrane Beneath Concrete Slabs on Grade," Concrete Symposium, Brisbane, Australia, 1977, p. 51.

2. ACI 302.1R-96, *Guide for Concrete Floor and Slab Construction*, American Concrete Institute, Farmington Hills, Mich., February 1997.

3. Raymond S. Rollings, "Retail-Grocery — Floor Failure," *Journal of the Performance of Constructed Facilities,* American Society of Civil Engineers, Reston, Va., May 1995.

4. Herman G. Protze, III, "Construction of Concrete Slabs-On-Grade: Moisture Emission Problems," *Solving Moisture-Related Problems with Slabs-On-Grade,* Seminar 24-63, World of Concrete 1997.

5. Bruce A. Suprenant, "Moisture Movement through Concrete Slabs," *Concrete Construction*, November 1997, pp. 879-885.

PUBLICATION #C980427