

# Producing Pervious Pavements

Hints for the engineer, contractor on placement of pervious concrete

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If you flip through the pages of a typical issue of *Concrete International*, you'll see articles about supplementary cementitious materials, high-performance concrete, self-consolidating concrete, vapor retarders, and strength acceptance testing. This article, however, is not typical. It covers a low strength, dry, porous concrete that is so simple, it's complicated. Although its properties may make pervious concrete a tricky material to work with, they can also make it a developer's friend.

One of the key features of pervious concrete is that it can be used to create structurally sound pavement that drains stormwater—thereby reducing runoff and replenishing groundwater supplies. Construction of pervious concrete pavements is different from construction of plain concrete pavements in that the contractor is responsible for an extra level of quality control. Acceptance of the material is not based on strength, smoothness, and thickness but on *porosity*, smoothness, and thickness. Therefore, it takes a different mindset.

Pervious concrete is actually no-fines (or low fines) concrete with a low water-cement ratio and is typically used in low volume applications. Hardened pervious concrete can have a compressive strength ranging from 1000 to 4000 psi (7 to 28 MPa). More important, though, is the void content—pervious concrete pavements have been placed with 15 to 35% void ratios.

Every party involved in the construction of a pervious concrete pavement should keep in mind the functions of the pavement: structural support and stormwater

management. The process starts with proper planning and design in the engineer's office, continues through proper staging and job-site control with the general contractor, and finishes with proper construction by the concrete contractor. This article helps to identify each party's responsibility and identify the keys for their success. However, we will focus primarily on the concrete contractor's role in the success of the pervious pavement.

## WHY PERVIOUS CONCRETE?

In recent years, the engineering and environmental communities have noticed troubling effects caused by development—major changes to stream, lake, and river depths caused by uncontrolled stormwater runoff from developed real estate. Rainwater tends to run off of developed sites (rather than being retained by soil or vegetation), causing stream bank erosion, waterway pollution, and downstream flooding. The government now requires control of stormwater runoff for developed sites.

A typical fix is to use stormwater retention ponds to slow the rate of stormwater discharge from the site. These ponds work well but are costly to the developers as they consume large amounts of valuable real estate. Pervious concrete allows parking areas to be covered with a material that allows stormwater to pass through. This reduces stormwater runoff rates, allows infiltration of the precipitation, and facilitates the recharge of groundwater supplies.

Another common use of pervious concrete pavements is to reduce the impact of development on trees. A pervious concrete pavement allows the transfer of both water and air between the roots and the ground surface. Pervious concrete pavements have been successfully placed inside the drip line of urban trees without adversely affecting their health. To ensure the success of this type of system, it is imperative that the roots of the tree are not damaged during construction operations, especially during earthwork and grading operations.

## TYPICAL SECTIONS

As with plain concrete, pervious concrete may be built on an open-graded base course, or on suitable site soils. In Florida, the material is often placed on the native sandy soils, which allow percolation and infiltration of the stormwater. In other states, where subgrade soils may be clay, the pervious concrete is cast on an open-graded gravel base such as a No. 57 (ASTM C 33)<sup>1</sup> rock (Fig. 1). This allows a large volume of retention under the pavement and provides extra structural support. It is important that the structural support chosen for the pervious pavement not be greatly affected by moisture penetrating lower pavement layers.

## CONSTRUCTION BASICS

As mentioned earlier, construction of a pervious concrete pavement is quite different from ordinary concrete. There are four key elements to the success of a pervious pavement surface:

1. Subgrade preparation—the subgrade should be uniform and properly compacted;
2. Concrete mixing water—the concrete should have the correct amount of water;
3. Concrete compaction/finishing—the concrete should be compacted and finished without excessive effort; and
4. Sufficient curing—curing should be performed in a timely manner and of sufficient duration.

Just like any other pavement system, uniform subgrade compaction is critical for a successful pervious concrete pavement. Further, it is important not to overcompact the subgrade soils. A key design feature of a pervious concrete pavement system is its permeability. The permeability of subgrade soils decreases nonlinearly with increases in density. Thus, if subgrade soils are compacted beyond their design limits, then the infiltration rate of the soil will decrease and the pavement will not drain the desired amount of runoff. The Florida Concrete and Products Association,<sup>2</sup> for example, recommends compaction to only 92 to 96% of the modified Proctor maximum density (ASTM D 1557)<sup>3</sup> for sandy subgrades.

Where this might seem quite soft compared with typical compactive efforts, uniformity is key. For silty or clay soils, the level of compaction will depend on the



**Fig. 1: Pervious concrete can be cast on an open-graded gravel base where subgrade soils are primarily clay**

specifics of the pavement design. Further, care should be taken, in this situation, not to overcompact a soil with swelling potential. As with any concrete pavement, the subgrade should be moistened before concrete placement, and wheel ruts from the concrete trucks should be raked and recompact.

The most complicated skill for a pervious concrete contractor to acquire is judging the proper quantity of mixing water in the fresh, no-fines concrete. This material is sensitive to minor changes in water content, so field adjustment of the fresh mixture is almost always necessary. Having the proper quantity of water in the concrete is critical because too much water causes the pores to collapse, and too little water prevents proper curing of the concrete, which will lead to a premature surface raveling failure. Corrective action for either of these scenarios is removal and replacement of the concrete.

Experienced contractors learn to judge the proper water content in the fresh concrete by visual inspection. Key characteristics to note include the presence of open pore space in the compacted concrete and a light sheen from the free water in the concrete. The concrete supplier should take some responsibility in this as well. Drivers should be trained to understand the basics of pervious concrete.

A pervious concrete pavement may be placed with either fixed forms or a slipform paver. Nevertheless, the simplest approach to placing pervious concrete is to cast it in forms that have a riser strip on the top of each form such that the strikeoff device is actually 3/8 to 1/2 in. (10 to 13 mm) above the final elevation of the pavement. As the concrete leaves the truck, it should be raked to an approximate elevation (Fig. 2). Strikeoff may then be performed by truss screed, roller screed, or straightedge (for small areas). After striking off the concrete, the riser strips are removed and the concrete is rolled to the proper elevation.

Rolling compacts the fresh concrete to provide strong bond between the paste and aggregate and creates a



**Fig. 2:** Concrete should be raked to an approximate elevation as it leaves the truck



**Fig. 4:** The owner may prefer the look of a rounded edge adjacent to a sidewalk



**Fig. 3:** Pervious concrete should be cross-rolled when fresh to smooth it out



**Fig. 5:** Rules about jointing are the same with pervious concrete as with any concrete

smooth riding surface. Caution should be exercised in rolling to prevent excessive force, which would cause the voids to collapse. Test panels, local experience, or both will provide necessary information on proper riser strip thickness and rolling technique. In any case, rolling should be performed immediately after strikeoff. The roller itself should be specially designed to roll pervious concrete in that it is weighted properly, protected from warping, and covers the entire lane width.

It should be noted that it is possible to roll slip-formed pavement; however, if formed properly, the pavement will be adequately compacted and have the necessary surface smoothness. Sod rollers are not practical for rolling pervious concrete in warm climates. Sod rollers require an extended finishing time to achieve a sufficiently flat and smooth surface, which lengthens the time (to greater than 20 min.) before curing may start.

Occasionally, extra steps are necessary to provide the desired finish on pervious concrete. Where ride quality is an issue, the fresh concrete should be cross-rolled to smooth out any flatness deviations (Fig. 3). Additionally, it may be necessary to float the edges of the concrete. It is common to see the rollers not compacting sufficiently

at the edges, so the concrete is hand floated to ensure quality all the way up to the form. Pervious concrete can also be tooled. A rounded edge may be desired, for example, adjacent to a sidewalk (Fig. 4). Each of these steps would be done after the initial rolling, but before jointing.

Jointing pervious concrete pavement follows the same rules as for an unreinforced concrete pavement,<sup>4</sup> with a few exceptions. With less water in the fresh concrete, shrinkage of the hardened material is reduced. Thus, joint spacings may be wider. The rules of jointing geometry, however, remain the same (Fig. 5). Rather than saw cutting, joints in pervious concrete are tooled with a rolling/jointing tool (Fig. 6). This allows joints to be cut in short time, and allows curing to continue uninterrupted.

Proper curing is essential to the structural integrity of a pervious concrete pavement. Curing ensures sufficient hydration of the cement paste to provide the necessary strength in the pavement section. Further, insufficient curing will cause the surface to ravel, in extreme cases, to the full depth of the pavement. Therefore, curing should begin within 20 min. of concrete placement. Plastic sheeting is typically used to retain moisture in the pavement mass for curing (Fig. 7). It should be secured



**Fig. 6:** A rolling/jointing tool may be used on pervious concrete, rather than saw cutting



**Fig. 7:** Plastic sheeting is typically used to retain moisture in the pavement mass for curing

with reinforcement or lumber such that it will be able to stay in place for the full 7-day curing period, in any weather.

As pervious concrete should not be specified by design strength, at no time should acceptance be based on strength. More important to the success of a pervious pavement is void content. Thus, acceptance should be based on the unit weight of the in-place pavement being within 5 lb/ft<sup>3</sup> (80 kg/m<sup>3</sup>) of the design unit weight.

Density (unit weight) is the only field test required for fresh pervious concrete. Slump and air content tests for conventional concrete are not applicable to a no-fines concrete mixture. If the pervious concrete pavement is an element of the site's stormwater management plan, the designer should certify that it is functioning properly through visual observation of its drainage characteristics before opening of the facility.

## TROUBLESHOOTING

One can imagine a number of things going wrong when

placing a concrete pavement. Unfortunately, as with any construction, problems do arise. Minor issues such as light cracking, discoloration, and deviations from flatness can be resolved by a number of means. There are, however, three major construction field problems with pervious concrete that require removal and replacement as the only option to repair the deficiency:

1. Too much water in the concrete mixture;
2. Not enough water in the concrete mixture; and
3. Insufficient curing of the concrete.

The first problem is easy to diagnose, and can usually be caught before the concrete has hardened. If there is too much water in the mixture, the cement paste will fill the voids and seal the surface of the concrete. If the contractor notices this happening with the fresh concrete, the load should be immediately rejected, and the concrete producer notified of the problem. Additionally, the fresh material should be removed before hardening.

If this problem is not noticed until after the concrete has hardened, it will adversely affect the stormwater

## RESPONSIBILITIES

Beyond contract documents and technical specifications, each party involved in building a pervious concrete pavement has several responsibilities to ensure the success of the pavement and storm water management system. These should be discussed in a preconstruction meeting between all of the stakeholders to ensure each party understands the importance of their duties.

### General contractor

- Keep all traffic off pervious concrete until cured.
- Protect pervious concrete pavement from damage during construction.

- Hire only qualified contractors to place pervious concrete.

### Concrete contractor

- Provide proper subgrade.
- Use adequate equipment.
- Cure and protect the concrete for minimum of 7 days.

### Concrete producer

- Provide trained drivers, batch operators, and dispatchers who understand pervious concrete.
- Provide properly batched material.
- Provide material only to qualified finishers.

management features of the pavement. Again, the only way to fix it is to remove the deficient section and replace it with new material.

The second and third problems can look similar in hardened concrete. These issues create symptoms of a raveling surface. In some situations, it will even look like a loose gravel pavement. The difference between the two can be diagnosed by looking at the edge of the pavement.

If there was too little water in the mixture, the pavement will be weak throughout its depth, to the point it can be crumbled by hand. If there was too little curing, only the top will be deficient and the lower half of the pavement will be sound. In either situation, the only remedy is to remove the affected area, to the full depth, and replace it with new concrete.

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Selected for reader interest by the editors.



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