# Producing Pervious Pavements

Hints for the engineer, contractor on placement of pervious concrete

BY MATTHEW OFFENBERG

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)[1] 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,[2] for example, recommends compaction to only 92 to 96% of the modified Proctor maximum density (ASTM D 1557)[3] 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 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 recompacted.

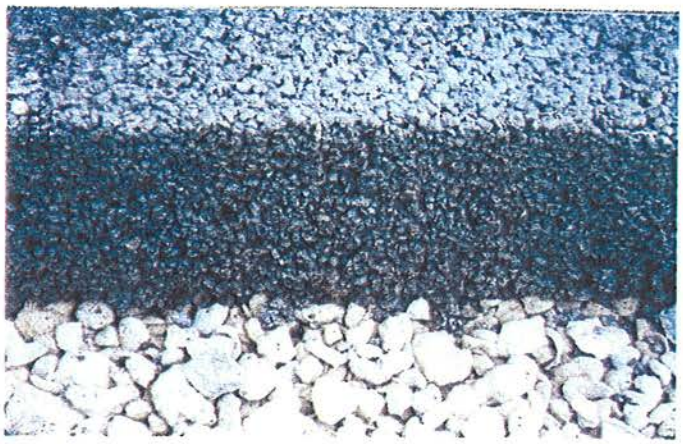

**Fig. 1: Pervious concrete can be cast on an open-graded gravel base where subgrade soils are primarily clay**

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**

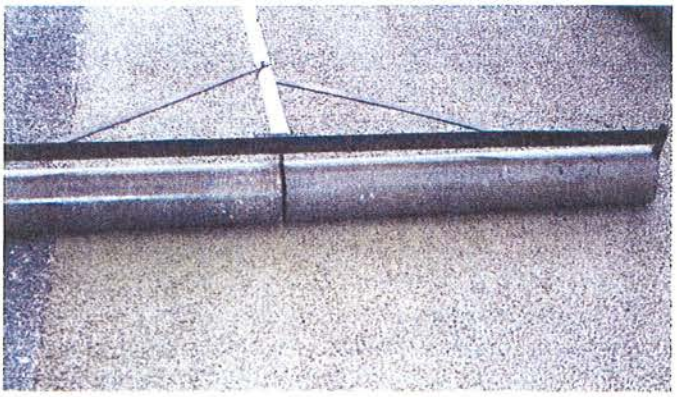

**Fig. 3: Pervious concrete should be cross-rolled when fresh to smooth it out**

**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,[4] 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$^3$ (80 kg/m$^3$) 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.

## References


1. ASTM International, "Standard Specification for Concrete Aggregates (ASTM C 33-99)," W. Conshohocken, PA, 1999, 8 pp.

2. "Pervious Pavement Manual," Florida Concrete and Products Association, Orlando, FL, 1990.

3. ASTM International, "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (ASTM D1557-02e1)," W. Conshohocken, PA.

4. ACI Committee 330, "Guide for Design and Construction of Concrete Parking Lots (ACI 330R-01)," American Concrete Institute Farmington Hills, MI, 2001, 32 pp.


Selected for reader interest by the editors.

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# PERVIOUS CONCRETE PAVEMENT

## PART I - GENERAL

### 1.01 CONTRACT CONDITIONS

Work of this Section is bound by the Contract Conditions and Division 1, bound herewith, in addition to this Specification and accompanying Drawings.

### 1.02 SUMMARY

A. Description

The work of this Section includes Subgrade preparation and installation of Portland Cement Pervious Pavement.

B. Related Sections

1. Section 01300 – Submittals
2. Section 02225 – Excavation, Backfilling and Compacting
3. Section 02233 – Aggregate Base Course
4. Section 03300 – Cast-in-Place Concrete

C. Measurement

No measurement will be made for Work described in this Section, including:

1. Portland cement concrete pervious pavement of the depth specified placed to the lines and grades shown on the Contract Drawings.

2. Extra thickness of pervious pavement, as shown.

5. Concrete joints, joint materials or joint sealant, (saw cutting or by installing pre-manufactured materials) used in the construction of Portland cement pervious concrete pavements.

D. Payment

Portland cement pervious concrete pavement of the depth and type specified, will be paid for as part of the Contract Lump Sum price, which price will be payment in full for furnishing all labor, materials, tools, equipment and incidentals, and doing all Work necessary to complete the Portland cement pervious concrete pavement, as specified, including:
Furnishing or installing curing materials, reinforcing bars or carbon fiber fabric, concrete joints, keyways, thickened edges of concrete at joints, joint material, joint sealant, or sawcutting joints, used in construction of Portland cement pervious pavement.

**1.03 REFERENCES**

A. Annual Book of ASTM Standards, 1997; American Society for Testing and Materials, Philadelphia, PA.

B. Standards of the American Association of State Highway and Transportation Officials (AASHTO).

C. ASTM C 29 "Test for Unit Weight and Voids in Aggregate."

D. ASTM C 33 "Specification for Concrete Aggregates."ASTM C 42 "Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

E. ASTM C 117 "Test Method for Material Finer than 75 µm (No. 200) Sieve in Mineral Aggregates by Washing."

F. ASTM C 140 "Methods of Sampling and Testing Concrete Masonry Units."

G. ASTM C 150 "Specifications for Portland Cement" (Types I or II only).

H. ASTM C 172 "Practice for Sampling Fresh Concrete."

I. ASTM C 260 "Specification for Air-Entraining Admixtures for Concrete."

J. ASTM C 494 "Specification for Chemical Admixtures for Concrete."

K. ASTM C 595 "Specifications for Blended Hydraulic Cements" (Types IP or IS only).

L. ASTM C 618 "Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for use as a Mineral Admixture in Portland Cement Concrete."

M. ASTM C 989 "Specification for Ground Granulated Blast-Furnace Slag for use in Concrete and Mortars."

N. ASTM C 1077 "Practice for Laboratories Testing Concrete and concrete Aggregates for use in Construction and Criteria Laboratory Evaluation."

O. ASTM C 1688 "Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete."

P. ASTM D 448 "Specification for Standard Sizes of coarse Aggregate for Highway Construction.

Q. ASTM D 1557 "Tests for Moisture-Density Relations of Soils and Soil Aggregate Mixtures using 10 Pound Rammer and 18-inch Drop"

R. ASTM E 329 "Standard Recommended Practice for Inspection and Testing Agencies for Concrete, Steel and Bituminous Materials as used in Construction."

S. ASTM C 1701 **"**Standard Test Method for Infiltration Rate of In Place Pervious Concrete

**1.03 SUBMITTALS**

A. See Section 01300- Administrative Requirements, for submittal procedures.

B. Concrete Mix Design:

**1.04 QUALITY ASSURANCE**

A. Perform work of this section in accordance with ACI 522.

B. Follow recommendations of ACI 306R when concreting during cold weather.

C. Use adequate numbers of skilled workmen who are thoroughly trained and experienced in the necessary crafts and who are completely familiar with the specified requirements and the methods needed for proper performance of the work in this section.

## 1.05 CONTRACTOR QUALIFICATIONS

A. The Contractor shall employ no less than one National Ready Mixed Concrete Association (NRMCA) Certified Pervious Concrete Craftsman who must be on site, overseeing each placement crew during all concrete placement, or the Contractor shall employ no less than three NRMCA Certified Pervious Concrete Installers, who shall be on site working as members of each placement crew during all concrete placement unless otherwise specified. Alternative documentation of qualifications shall be permitted when approved by the Architect/Engineer. Prior to award of the contract, the placing contractor shall furnish Owner/Engineer a statement attesting to qualifications and experience and the following:

1. A minimum of 3 completed projects, total square footage to exceed 10,000 sf with addresses.
2. Unit weight acceptance data.
3. In-Situ pavement test results including void content and unit weight.
4. Sample of Product (i.e. core or test panel)

B. If the placing contractor and concrete producer have insufficient experience with Portland Cement pervious concrete pavement (less than 3 successful jobs), the placing contractor shall retain an experienced consultant or NRMCA Certified Pervious Craftsman to monitor production, handling, and placement operations at the contractor's expense.

C. Test Panels: Regardless of qualification, Contractor is to place, joint and cure two test panels, each to be a minimum of 225 sq. ft. at the required project thickness to demonstrate to the Architect's and Owner's satisfaction that in-place unit weights can be achieved and a satisfactory pavement can be installed at the site location.

D. Test panels may be placed at any of the specified Portland Cement pervious locations on the project or at another test site.
Test panels shall be tested for thickness in accordance with ASTM C 1688 Density and Void Content of Freshly Mixed Pervious Concrete and for core unit weight in accordance with ASTM C 1754.

E. Satisfactory performance of the test panels will be determined by:

1. Compacted thickness no less than ¼" of specified thickness.

2. Void Structure: 17% minimum; 23% maximum.

3. Unit weight plus or minus 5 pcf of the design unit weight.

4. If measured void structure falls below 13% or if measured thickness is greater than ¼" less than the specified thickness of if measured weight falls less than 5 pcf below unit weight, the test panel shall be removed at the contractor's expense and disposed of in an approved landfill.

E. If the test panel meets the above-mentioned requirements, it can be left in-place and included in the completed work.

## 1.06 PROJECT CONDITIONS

A. Protection of Existing Improvements

1. Protect adjacent work from splashing of paving materials. Remove all stains from exposed surfaces of paving, structures, and grounds. Remove all waste and spillage.

2. Do not damage or disturb existing improvements or vegetation. Provide suitable Protection where required before starting work and maintain protection throughout the course of the work.

3. Restore damaged improvements, including existing paving on or adjacent to the site that has been damaged as a result of construction work, to their original condition or repair as directed to the satisfaction of the Owner, and authority having jurisdiction at no additional cost.

B. Safety and Traffic Control

1. Notify and cooperate with local authorities and other organizations having Jurisdiction when construction work will interfere with existing roads and traffic.

2. Provide temporary barriers, signs, warning lights, flagmen, and other protections As required to assure the safety of persons and vehicles around the construction area and to organize the smooth flow of traffic.

C. Weather Limitations

Do not place Portland cement pervious concrete pavement mixtures when the ambient temperature is 40 degrees Fahrenheit or lower, unless otherwise permitted in writing by the Engineer.

**1.07 PRE PAVING CONFERENCE**

A pre-paving conference with the engineer shall be held two (2) days prior to beginning placing the pervious concrete. The contractor shall have the pervious concrete consultant, ready mix supplier, the foreman and the entire concrete crew that will form and place the concrete in attendance at this meeting.

## PART 2 - PRODUCTS

**2.01 CONCRETE MIX DESIGN**

Contractor shall furnish a proposed mix design with proportions of materials prior to commencement of work. The data shall include unit weights determined in accordance with ASTM C 1688.

## 2.02 STORMWATER STORAGE/INFILTRATION BEDS

1. Coarse aggregates shall meet the size and grading requirements as defined in Standard Sizes of Coarse Aggregate, Table 4, AASHTO Specifications, Part I, 13th Ed., 1982, or later, unless otherwise specified.

2. Coarse aggregate for groundwater recharge bed shall be 2-1/2" to 1-1/2" uniformly graded Crushed coarse aggregate, with a wash loss of no more than 0.5%, AASHTO size number 2 per Table 4, AASHTO Specifications, Part I, 13th Ed., 1982, or later.

3. Choker base course aggregate for groundwater recharge bed shall be 1" to 3/8" uniformly graded, crushed coarse aggregate, or approved equal, AASHTO Specifications, Part I, 13th Ed., 1982, or later.

3. Filter fabric shall be Propex PERC™ Pervious Concrete Infiltration Fabric or approved equal.

5. Impervious liner – shall be Permalon, PLY-X 150, or approved equal.

## 2.03 PORTLAND CEMENT PERVIOUS CONCRETE

1. Cement:

   Portland Cement Type I or II conforming to ASTM C 150 or Portland Cement Type IP or IS conforming to ASTM C 595. Slag or Flyash may be used as part of the total cementitious content.

2. Aggregate:

   Use #9 (1/4") Washed, crushed coarse aggregate with a minimum void content per ASTM C29 of 40%. If other gradation of aggregate are to be used, submit data on proposed material to owner for approval.

3. Admixtures:

   The following admixtures may be used as needed:
   a) Type A/F Water Reducing – ASTM C 494.
   b) Air Entraining Agent – ASTM C 260.
      May be used to improve resistance to freeze/thaw cycles.
   c) A viscosity modifier.
      Used to reduce paste drain down caused by using a dirty aggregate
   d) Buckeye Cellulose fibers for residential and lightweight commercial applications
      Dosed at the rate of 3# per cubic yard
   e) Forta macro-synthetic fibers for heavy duty commercial applications
      Dosed at the rate of 5# per yard

The following admixtures shall be used:

a) A hydration stabilizer that also meets the requirements of ASTM C 494 Type B Retarding or Type D Water Reducing/Retarding admixtures.
This stabilizer suspends cement hydration by forming a protective barrier around the cementitious particles, which delays the particles initial set.

b) HydroMax® Internal Curing Admixture
Dosed at the rate of 1.5 oz/cwt of total cementitious material.
Should reduce the amount of cementitious material needed as well as the need for a viscosity modifier.

4. Water: Potable water shall be used.

5. Proportions:

a. Cement Content: For pavements subjected to vehicular traffic loading, the total cementitious material shall not be less than 480 lbs. per cu. yd. For other pavement areas not subject to vehicular traffic loading, the total cementitious material shall not be less than 450 lbs. per cu. yd.

b. Aggregate Content: the volume of aggregate per cu. yd. shall be equal to 27 cu. ft. when calculated as a function of the unit weight determined in accordance with ASTM C 1688.

An aggregate/cement ratio range of 4:1 to 4.5:1.

A unit weight range of 105 lbs/cu. ft. to 140 lbs/cu. ft. per ASTM C 1688.

Voids of 17% to 23%.

c. Admixtures: Shall be used in accordance with the manufacturer's instructions and recommendations.

d) Mix Water: Mix water shall be such that the cement paste displays a wet metallic sheen without causing the paste to flow from the aggregate. (Mix water yielding a cement paste with a dull-dry appearance has insufficient water for hydration).

Water cement ratios can range from 0.30 to 0.38.

Insufficient water results in inconsistency in the mix and poor bond strength. High water content results in the paste sealing the void system primarily at the bottom and poor surface bond.

## PART 3 – EXECUTION

Owner shall be notified at least 24 hours prior to all recharge be and pervious paving work

### 3.01 INSTALLATION

1. SUBGRADE PREPARATION

   a) Existing subgrade under bed areas shall NOT be compacted or subject to excessive construction equipment traffic prior to stone bed placement.
   b) Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material shall be removed with light equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake or equivalent and light tractor.
   c) Bring subgrade of stone recharge bed to line, grade, and elevations required.
   d) Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction before the placing of stone.

2. RECHARGE BED INSTALLATION

   a) Upon completion of subgrade work, the Architect shall be notified and shall inspect at his discretion before proceeding with recharge bed installation.
   b) Filter fabric, pipe, and recharge bed aggregate shall be placed immediately after approval of subgrade preparation. Any accumulation of debris or sediment which has taken place after approval of subgrade shall be removed prior to installation of filter fabric at no extra cost to the Owner.
   c) Place PERC™ filter fabric in accordance with manufacturer's standards and recommendations. Adjacent strips of filter fabric shall overlap a minimum of sixteen inches (16"). Secure fabric at least two feet (2') outside of bed and take steps necessary to prevent any runoff or sediment from entering the storage bed. Place impervious liner over geo-textile extending six feet (6') beyond toe of slope face at building face, secure as recommended by manufacturer.
   d) Install coarse aggregate in 6 inch maximum lifts. Lightly compact each layer with equipment, keeping equipment movement over storage bed subgrades to a minimum. Install aggregate to grades required on the drawings.
   e) Install 1" thick choker base course size #57 (AASHTO) aggregate evenly over surface of stone bed, sufficient to allow placement of pavement, and notify Engineer for approval.
   f) Following placement of bed aggregate, the filter fabric shall be folded back along all bed edges to protect from sediment washout along bed edges. At least a two foot (2") strip shall be used to protect beds from adjacent bare soil. This edge strip shall remain in place until all bare soils contiguous to beds are stabilized and vegetated. In addition, hay bales shall be placed at the toe of slopes which may be adjacent to beds to further prevent sediment from washing into beds during site development. As the site is fully stabilized, excess filter fabric along the bed edges can be cut back to gravel edge.

## 3.02 PORTLAND CEMENT PERVIOUS PAVEMENT CONCRETE MIXING, HAULING AND PLACING:

1) Mix Time: Central mixed concrete shall be mixed for a minimum of one minute after introduction of all materials into mixer. Truck mixers shall be operated at the speed designated as mixing speed by the manufacturer for 75 to 100 revolutions of the drum.
   b) If a central mixed batch plant is used, the mixer must be rinsed out prior to loading pervious materials if a normal concrete mix was previously batched.
2. Transportation: The Portland Cement aggregate mixture may be transported by ready mix trucks or dump trucks or mixed on site and should be used within one (1) hour of the introduction of mix water, unless otherwise approved by an engineer. This time can be increased to 180 minutes when utilizing the hydration stabilizer specified above at the proper dosage rate, unless otherwise approved by an engineer.
3. Each truck should not haul more than two (2) loads before being cycled to another type concrete, unless delivered by dump truck or if a stabilizing hydration agent is used in the pervious concrete mix design or if field experience proves that there is no significant concrete buildup in concrete mixer after delivery.
4. Prior to placing concrete, the subbase shall be soaked and in a wet condition (no ponding of water) at time of placement. Failure to provide a moist subbase will result in a reduction in strength of the pavement.
5. Discharge shall be a continuous operation and shall be completed as quickly as possible.
   a) if consolidation occurs during concrete discharge, placement shall be halted and wet concrete removed (this may happen towards the end of some loads).
6. Concrete shall be deposited as close to its final position as practicable and such that fresh concrete enters the mass of previously placed concrete. The practice of discharging onto subgrade and pulling or shoveling to final placement is not allowed.
7. Placing and Finishing Equipment: Unless otherwise approved by the Owner or Engineer in writing, the Contractor shall provide mechanical equipment of either slipform or form riding with a following compactive unit that will provide a minimum of 10 psi vertical force.
8. The pervious concrete pavement will be placed to the required cross section and shall not deviate more than +/- 3/8 inch in 10 feet from profile grade.
9. If placing equipment does not provide the minimum specified vertical force, a full width roller or other full width compaction device that provides sufficient compactive effort shall be used immediately following the strike-off operation.
10. Strike off the pervious concrete 1/2" to 3/4" above the final grade prior to compaction, if needed, by using either slip-form, form riding vibrating screed, form riding aluminum roller screed or laser screed. Strike off may be done by hand for sidewalks. Care must be taken to avoid filling voids in the concrete.
11. If vibration, internal or surface applied, is used, it shall be shut off immediately when forward progress is halted for any reason.
12. The Contractor will be restricted to pavement placement widths of a maximum of fifteen (15’) feet unless the Contractor can demonstrate competence to provide pavement placement widths greater than the maximum specified to the satisfaction of the Owner.

## 3.03 CURING

1. Curing procedures shall begin immediately following all finishing operations if PerviouShield™ liquid spray on curing compound/densifier is used.
2. Curing procedures shall be complete within 20 minutes after the final placement operations if polyethylene sheeting is used.

   The pavement surface shall be covered with a minimum .31 mil thick polyethylene sheet (painters plastic) or other approved covering material prior to final cross rolling of the surface and then covered with a layer of four to six (4 – 6) mil thick polyethylene sheeting. Prior to covering, an evaporative reducer shall be sprayed above the surface when required due to ambient conditions (high temperature, high wind, and low humidity). The cover shall overlap all exposed edges and shall be secured (without using dirt or stone) to prevent dislocation due to winds or adjacent traffic conditions.
3. Cure Time: Portland Cement Type I, II, or IS – 7 days minimum.
4. No truck traffic shall be allowed for 10 days (no passenger car/light trucks for 7 days and no pedestrian traffic for 24 hours).

## 3.04 JOINTING

1. Control (contraction) joints shall be installed as indicated by plans. They shall be installed at a depth of the 1/ 3 to 1/4 the thickness of the pavement.
2. These joints can be installed in the plastic concrete or saw cut.
   a) If saw cut, the procedure should begin as soon as the pavement has hardened sufficiently to prevent raveling and uncontrolled cracking (normally after curing), minimum of 24 hours after placement.
   b) Possible complications from saw cutting include:
   a. Removal of plastic to perform saw cutting will cause pervious concrete to hydrate too quickly (Not a concern if PerviouShield™ is used). If plastic is removed to accommodate saw cutting, re-hydrating of pervious concrete is required.
   b. Walking on pervious concrete too early can damage concrete surface
3. Transverse constructions joints shall be installed whenever placing is suspended a sufficient length of time that concrete may begin to harden.
4. Isolation (expansion) joints should be used in structure widths exceeding thirty (30) feet or at seventy five (75) feet on sidewalks or when pavement is abutting slabs or other adjoining structures.
5. Expansion joint material shall be K-form screed rail or approved equal.
5. To reduce raveling, if transverse or isolation joints are used, or where pervious concrete meets impervious pavement, extra compaction may be necessary.
6. Additional installation specifications for the pervious concrete provided by the material source and engineer shall be followed strictly.

## 3.05 PORTLAND CEMENT PERVIOUS PAVEMENT CONCRETE TESTING, INSPECTION, AND ACCEPTANCE

1. The owner will retain an independent testing laboratory.
2. The testing laboratory shall conform to the applicable requirements of ASTM E 329 "Standard Recommended Practice for Inspection and Testing Agencies for Concrete, Steel, and Bituminous Materials as Used in Construction" and ASTM C 1077 "Standard Practice for Testing Concrete and Concrete Aggregates for use in Construction, and Criteria for Laboratory Evaluation" and shall be inspected and accredited by the Construction Materials Engineering Council, Inc. or by an equivalent recognized national authority.
3. The Agent of the testing laboratory performing field sampling and testing of concrete shall be certified by the American Concrete Institute as a Concrete Field Testing Technician Grade I, or by a recognized state or national authority for an equivalent level of competence.
4. Testing and Acceptance:

    a) A minimum of 1 gradation test of the subgrade is required every 5000 square feet to determine percent passing the No. 200 sieve per ASTM C 117.
    b) A minimum of one test for each load of pervious concrete in accordance with ASTM C 1688 to verify unit weight shall be conducted. Delivered unit weights are to be determined in accordance with ASTM C 1688 using a 0.25 cubic foot cylindrical metal measure. The measure is to be filled and compacted in accordance with ASTM C 1688. The unit weight of the **delivered concrete** shall be +/- 2.5 pcf of the accepted design unit weight.
    c) It is highly recommended that unit weight testing per ASTM C 1688 be performed on every load of concrete to assure uniformity through the project.
    d) Test panels shall have two cores taken from each panel in accordance to ASTM C 42 at a minimum of seven (7) days after placement of the pervious concrete. The cores shall be measured for thickness, void content and unit weight in accordance with ASTM C1754. Range of satisfactory unit weight values are +/- 5 pcf of the design unit weight.
    e) After a minimum of seven (7) days following each placement, three cores shall be taken in accordance with ASTM C 42. The cores shall be measured for thickness, void content and unit weight determined as described above for test panels. Core holes shall be filled with concrete meeting the pervious design or other concrete material as permitted by the owner.

5. Maintenance: There shall be a maintenance plan submitted by the owner to prevent the clogging of the pervious concrete pavement which shall include periodic testing for flowability by the pervious concrete installer prior to the pervious concrete being opened to service, with flow rates reported in writing to the owner and again at six (6), twelve (12) eighteen (18) and twenty-four (24) months and again report the results in writing to the owner. It is the contractor's responsibility to help the owner to develop a maintenance plan. The owner must have a plan and methods to restore flowability if the flow rate drops below 75% of the original rate. Acceptable methods to restore levels of flowability are either to vacuum or powerwash the pervious concrete sections.

**END OF SECTION**

# Guideline Specifications for Subgrade and Compaction for Portland Cement Pervious Concrete Pavements

January 2010

**FORWARD**

This sample specification for Subgrade and Compaction for Portland Cement Pervious Concrete Pavement is provided as a guideline only. Specific projects will have conditions that may require modifications to this document. It is recommended that an accompanying *'Guideline Specification for Portland Cement Pervious Concrete Pavement'* also be referenced. An additional resource from PSCA entitled '*Recognized Procedures for Achieving Quality Pervious Concrete'* can be a helpful tool for placement and inspection.

Proper preparation of subgrades and compaction is a vital aspect of a successful pervious concrete pavement project to assure proper soils conditions and percolation rates for the given design.

Technical assistance and installation training is available from your local cement and concrete associations. Planning, design, materials and construction information can be provided. The concrete industries of California and Nevada offer you these choices:

- **California Nevada Cement Association**
  - Southern California and Southern Nevada:
    David Akers (858) 437-1445 david.akers@cncement.org
  - Northern California and Northern Nevada:
    Paulette Salisbury (925) 918-0982 paulette.salisbury@cncement.org
- **Concrete Promotion Council of Northern California**
  - Rob Wallace (888) 633-0393 rob@cpcnc.org
- **Southern California Concrete Producers**
  - Larry Maes (626) 441-3107 lmaes@sccpconcrete.com
- **Sierra Nevada Concrete Association - Reno**
  - Contact Paulette Salisbury (925) 918-0982 paulette.salisbury@cncement.org
- **Southern Nevada Concrete and Aggregate Association – Las Vegas**
  - Contact David Akers (858) 437-1445 david.akers@cncement.org

**SECTION 31 00 00**

**SUBGRADES AND COMPACTION FOR PORTLAND CEMENT PERVIOUS CONCRETE PAVEMENT**

## PART 1 GENERAL

### 1.01 Scope of Work:

**A.** The Work to be completed under this contract includes the subgrade and compaction requirements for Portland Cement Pervious Concrete Pavement for streets, parking & pedestrian areas in conformance with the plans and specifications.

**B.** Work in other sections:

Formwork: see "Concrete Formwork" in Division 03

Other Paving: see other sections in Division 33

Inserts of landscape accessories into concrete pavement: see division 32

Drains in concrete pavement: see Division 32

Portland Cement Pervious Concrete Pavement: see Division 33 Section 033729

### 1.02 References:

**A.** American Society for Testing and Materials

**1.** ASTM D 1557 "Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft$^3$)"

**2.** ASTM D 3385 "Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer"

### 1.03 Subgrade and Compaction:

**A.** **Material:** The top 6 inches shall be composed of granular or gravelly soil that is predominantly sandy with no more than a moderate amount of silt or clay. Granular sub-base may be placed over the subgrade.

**B.** **Permeability:** Subgrade shall be determined in accordance with ASTM D3385.

**C.** **Compaction:** Compact sub-grade to a minimum 90% and a maximum 95%. Compaction shall be in accordance with ASTM D 1557.

**D.** **Fill:** If fill material is required to bring the subgrade to final elevation, it shall be clean and free of deleterious materials. It shall be placed in 6-inch maximum layers, and compacted by a mechanical vibratory compactor to a minimum density of 90% and a maximum density of 95% in accordance with ASTM D 1557.

**E.** **Moisture:** The subgrade moisture content shall be 1% - 3% above optimum as determined by ASTM D 1557.

**F.** Verify subgrade preparation, grade, and conduct permeability and density tests for conformance to project requirements.

**END OF SECTION**

***"This guideline specification is intended solely for use by professional personnel who are competent to evaluate the significance and limitations of the information provided and who will accept responsibility for the application of this information. The Pacific Southwest Concrete Alliance, its members firms and employees disclaim any and all responsibility and liability for the accuracy and the application of the information contained in this publication to the full extent permitted by law."***

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# Guideline Specifications for

# Portland Cement Pervious Concrete Pavements

January, 2010

**FORWARD**

This sample specification for Portland Cement Pervious Concrete Pavement is provided as a guideline only. Specific projects will have conditions that may require modifications to this document. It is recommended that an accompanying *'Guideline Specification for Compaction and Subgrade for Portland Cement Pervious Concrete Pavement'* also be referenced. An additional resource from PSCA entitled '*Recognized Procedures for Achieving Quality Pervious Concrete'* can be a helpful tool for placement and inspection.

Pervious concrete pavement does not look or behave like typical concrete pavements. The finished surface is not tight and uniform, but is open and varied. Surface irregularities and minor amounts of surface raveling are normal. Traditional concrete testing procedures for strength and slump are not applicable. Pervious Concrete is tested instead for consistency, void content and thickness; methods which are outlined in this document to help assure a long life, drainable pavement.

Owners, architects and engineers are strongly encouraged to visit locations where pervious concrete pavement has been installed before making the decision to use the material and to use an experienced installer and finisher.

Technical assistance and installation training is available from your local cement and concrete associations. Planning, design, materials and construction information can be provided. The concrete industries of California and Nevada offer you these choices:

- **California Nevada Cement Association**
  - Southern California and Southern Nevada:

    David Akers (858) 437-1445 david.akers@cncement.org
  - Northern California and Northern Nevada:

    Paulette Salisbury (925) 918-0982 paulette.salisbury@cncement.org
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- **Southern Nevada Concrete and Aggregate Association – Las Vegas**
  - Contact David Akers (858) 437-1445 david.akers@cncement.org

**SECTION 033729**

**PORTLAND CEMENT PERVIOUS CONCRETE PAVEMENT**

## PART 1 GENERAL

### 1.01 Scope of Work:

**A.** The Work to be completed under this contract includes the furnishing of all labor, materials and equipment necessary for construction of Portland Cement Pervious Concrete Pavement for streets, parking and pedestrian areas in conformance with the plans and specifications.

**B.** Work in other sections:

Formwork: see "Concrete Formwork" in Division 03

Other Paving: see other sections in Division 33

Inserts of landscape accessories into concrete pavement: see Division 32

Drains in concrete pavement: see Division 32

Subgrades and Compaction: see Division 31

### 1.02 References:

**A.** American Concrete Institute

**1.** Concrete Field Testing Technician Grade I

**B.** American Society for Testing and Materials

**1.** ASTM C 29 "Test for Bulk Density (Unit Weight) and Voids in Aggregate ASTM C33 "Specification for Concrete Aggregates"

**2.** ASTM C 33 "Specification for Concrete Aggregates"

**3.** ASTM C 94 "Specification for Ready-Mixed Concrete"

**4.** ASTM C 150 "Specification for Portland Cement"

**5.** ASTM C 260 "Specification for Air-Entraining Admixtures for Concrete"

**6.** ASTM C 494 "Specification for Chemical Admixtures for Concrete"

**7.** ASTM C 595 "Specification for Blended Hydraulic Cements"

**8.** ASTM C 618 "Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete."

**9.** ASTM C 685 "Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing"

**10.** ASTM C 989 "Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars."

**11.** ASTM C 1438 "Standard Specification for Latex and Powder Modifiers for Hydraulic Cement Concrete and Mortar."

**12.** ASTM C 1602 “Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete”

**13.** ASTM C 1688 “Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete”

**14.** ASTM C 1701/C1701M “Standard Test Method for Infiltration Rate of In Place Pervious Concrete”

**15.** ASTM C 1751 “Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)

**16.** ASTM C 1752 “Standard Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction.”

**17.** ASTM D 994 “Standard Specification for Preformed Expansion Joint Filler for Concrete (Bituminous Type)”

**18.** ASTM E 329 “Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction.”

**C.** National Ready Mixed Concrete Association

**1.** Text Reference for Pervious Concrete Contractor Certification

**1.03 Quality Assurance:**

**A. The Pervious Concrete Subcontractor:**

**1.** Shall submit:

**a.** Evidence of two successful pervious concrete pavement projects including: the project name and address, owner’s name, contact information and size of each project.

**b.** Verification of current NRMCA Certification requirements described below:

**2.** Shall meet, at the time of bidding: **one** of the following criteria for the minimum certification for each placement crew and submit verification of NRMCA Pervious Concrete Certification with the bid.
(http://www.nrmca.org/Education/Certifications/Pervious_Contractor.htm)

a. The pervious concrete subcontractor shall employ no less than one (1) NRMCA Certified Pervious Concrete Craftsman who must be onsite, actively guiding and working with each placement crew during all pervious concrete placement.

b. The pervious concrete subcontractor shall employ no less than three (3) NRMCA Certified Pervious Concrete Installers who must be onsite, actively guiding and working with pervious concrete for projects.

c. The pervious concrete subcontractor shall employ no less than three (3) NRMCA Pervious Concrete technicians and one (1) Pervious Installer who shall be onsite, actively guiding and working with each placement crew during all pervious concrete placement.

B. **Performance:** Upon completion of the initial curing, the pervious concrete shall be tested for initial baseline infiltration in accordance with ASTM C1701. The rate shall be a minimum of 100 inches per hour.

**1.04 Submittals:** Before starting work, submit the following:

**A. Concrete materials**:

**1.** Proposed concrete mixture proportions including all material weights, volumes, density (unit weight), water **/** cementitious ratio, and void content. The mix design shall not specify a compressive or flexural strength.

**2.** Aggregate type, source and gradation**.**

**3.** Cement, fly ash, ground granulated blast-furnace slag and admixture manufacturer certifications

**B. Qualifications**: Evidence of qualifications listed under Quality Assurance.

**C. Project details**: Specific plans, details, schedule, construction procedures and quality control plan.

**D. Test Panel:**

**1.** Construct Test panel(s) to meet requirements of contract documents. Place a minimum one 225 sq. ft panel. Provide joints and curing using materials, equipment, and personnel proposed for the project as described in Section 1.02.B. Coordinate location of test panels with Owner and Architect/Engineer.

**2.** The test panel shall be tested for acceptance in accordance with section 3.08 Quality Control.

**3.** An approved test panel will be used as quality control for the project and may be incorporated into the project if of acceptable quality.

**4.** Remove and legally dispose of all materials used for test panels not approved and all excess materials.

## PART 2 MATERIALS

**2.01 Materials:**

**A. Cement:** Portland cement Type II or V conforming to ASTM C150 or Portland cement Type IP or IS conforming to ASTM C595.

**B. Supplementary Cementitious Materials:**

**1.** Class F Fly Ash: ASTM C618

**2.** Ground Granulated Blast-Furnace Slag: ASTM C989

**C. Chemical Admixtures:**

**1.** Air entraining agents shall comply with ASTM C260.

**2.** Chemical Admixtures shall comply with ASTM C494.

3. Latex bonding agents shall comply with ASTM C1438.

D. **Aggregates:** Coarse Aggregate: ASTM C33. The maximum size and gradation shall meet the project criteria for surface appearance and void content.

E. **Water:** ASTM C 1602.

F. **Isolation Joint Material:** Shall comply with ASTM D994, D1751, or D1752.

**2.02 Mixture Proportions:** The composition of the proposed concrete mixtures shall be submitted to the owner's representative for review and shall comply with the following provisions unless an alternative composition is demonstrated to comply with the project requirements. Conform with all requirements of Authorities Having Jurisdiction (AHJ) for pavements and walkways.

A. **Cementitious Content**: Comply with the approved mix design.

1. Supplementary cementitious content:

a. Fly ash: 25% maximum of the total cementitious material or in accordance with approved mix design.

b. Slag: 40% maximum of the total cementitious material or in accordance with approved mix design.

B. **Water / Cementitious Ratio** Shall range between 0.27 lb/lb and 0.31 lb/lb. or in accordance with approved mix design.

C. **Aggregate Content:** As appropriate for approved mix design.

D. **Admixtures:** Use in accordance with approved mix design.

E. **Mix Water:** as appropriate for approved mix design.

F. **Color:** Pigments to be selected by the architect.

## PART 3 EXECUTION

**3.01 Subgrade**: Verify subgrade preparation, grade, and conduct permeability and density tests for conformance to project requirements and is acceptable for installation of pervious concrete. (See PSCA 'Section 31 Subgrade Guidelines for Pervious Concrete' that accompanies this document.)

**3.02 Recharge Basin (Detention Basin)**: When base material is used under pervious concrete for water recharge, it shall be composed of uniform sized aggregate conforming to ASTM C33, minimum size 6. For minimum void content, refer to civil or geotechnical contract documents.

**3.03 Formwork:** Form materials: any material permitted by AHJ and of sufficient strength and stability to support mechanical equipment without deformation of plan profiles following spreading, strike-off and compaction operations.

**3.04 Mixing and Hauling:**

**A.** **Production:** Pervious concrete shall be manufactured and delivered in accordance with applicable sections of ASTM C 94 or ASTM C 685.

**B.** **Mixing:** Pervious concrete shall be produced in central mixers, transit mixers or in volumetric mixers.

**C.** **Delivery:** Deliver pervious concrete directly from the mixer by means of conveyer as close as possible to final position.

**D.** **Discharge:** Each truckload will be visually inspected for consistency of concrete mixture. Job site water additions are permitted to obtain and maintain the required mix consistency throughout the discharge. Discharge shall be a continuous operation. Concrete shall be deposited as close to its final position as practical and such that discharged concrete is incorporated into previously placed plastic concrete.

**3.05 Placing and Finishing:** Shall comply with the content of the National Ready Mixed Concrete Association's *'Text Reference for Pervious Concrete Contractor Certification'* with the following provisions:

**A**. Internal vibration shall not be permitted. Use mechanical screed equipment. Do not use hand screeds except in confined and small areas. Cross roll compacted concrete to remove any screeding and compaction marks on the concrete surface.

**B**. Compact to the required cross-section and shall not deviate more than ± 3/8 inch in 10 feet from profile grade.

**3.06 Jointing**

**A.** Joints shall be installed at locations and to depths shown on the project plans.

**B.** Control (contraction) joints shall be installed at regular intervals not to exceed 1.5 times the width of the placement or 20 feet, or in accordance with approved joint placement plan. The control joints shall be installed at ¼ the thickness of the pavement but not to exceed 1-1/2". These joints can be installed in the plastic concrete or saw cut after the concrete has hardened. New joints in plastic concrete or recently hardened concrete shall align with joints in older concrete. Joints abutting curbs and other fixed concrete shall be installed within 10 degrees of perpendicular to the older concrete as possible.

**C.** Install joints to match approved sample.

**D.** Transverse construction joints: Install whenever placing is suspended for 20 minutes or whenever concrete is no longer workable.

**E.** Do not dowel longitudinal joints between successive placements.

**F.** Isolation joints: Use when abutting fixed vertical structures. Place isolation material before concrete is placed and to the depth of the pavement section.

**3.07 Curing:**

**A.** Final curing procedures shall begin no later than 20 minutes after the concrete has been discharged from the mixer. The pavement surface shall be covered with a minimum of six (6) mil thick white or clear polyethylene sheet or other approved covering material. In cold weather black plastic may be used to aid in heat retention. The cover shall prevent air infiltration to the fresh concrete and shall overlap all exposed edges and shall be secured to prevent dislocation due to winds or adjacent traffic conditions**.**

**B.** The curing cover shall remain securely in place for a minimum of 7 days. No vehicular traffic shall be permitted on the pavement until curing is complete and no truck traffic shall be permitted for at least 14 days**.**

**3.08 Quality Control:**

**A.** The owner shall employ a testing laboratory that conforms to the requirements of ASTM E329 and ASTM C1077. All personnel engaged in testing shall be certified by the American Concrete Institute as ACI Concrete Field Technicians or equivalent and shall be certified by NRMCA as a Pervious Concrete Technician.

**B.** Prior to each placement, the formed thickness shall be at least the design thickness testing within -0” to +3/4”.

**C.** Plastic concrete shall be sampled in accordance with ASTM C 172 and density (unit weight) measured in accordance with ASTM C 1688. The density (unit weight) of the delivered concrete shall be +/- 5 pcf of the design density (unit weight).

**D.** Plastic void content shall be calculated as per ASTM C1688 Gravimetric Air Determination and compared to the void percentage required by the hydraulic design.

**E.** Upon completion of initial curing, the pervious concrete shall be tested for a baseline infiltration rate using ASTM C1701.

**END OF SECTION**

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**Change No. 244NS (ADHOC041014)**

**201-1.1.6 Pervious Concrete.**

**201-1.1.6.1 General.** Pervious concrete shall consist of portland cement, coarse concrete aggregate, water, and when approved by the Engineer or specified in the Special Provisions, chemical admixtures, fly ash, sand, or reclaimed concrete material.

**201-1.1.6.2 Materials.** Materials shall consist of:

a) ~~Coarse~~ No. 4 concrete aggregate conforming to 200-1.4~~, No. 4 unless otherwise specified in the Special Provisions~~;
b) Sand for Portland Cement Concrete conforming to 200-1.5.3;
c) Type II or Type V ~~Portland~~ portland cement conforming to 201-1.2.1~~, Type II, unless otherwise specified in the Special Provisions~~;
d) Hydration stabilizing (Type B or D), air-entraining, and/or specific performing ~~chemical~~ admixtures conforming to 201-1.2.4;
e) Fly ~~fly~~ ash conforming to 201-1.2.5.3~~, the content shall be less than 25 percent~~, and;
f) Reclaimed ~~reclaimed~~ concrete material conforming to 201-1.2.6.

**201-1.1.6.3 Mix Design.** A mix design shall be submitted ~~to the Engineer for approval~~ in accordance with 2-5.3. The minimum cementitious material content shall be 540 pounds per cubic yard (320kg/m$^3$). The fly ash content shall not be greater than 25 percent of the total weight of cementitious materials.

The mix design shall show the mix identification number and the applicable proportions, weights, and quantities of portland cement, aggregate, water, and ~~where~~ when specified or approved, fly ash, chemical admixtures, sand, and reclaimed concrete material. The mix design submittal shall also include the size and source of all concrete aggregates, ~~aggregate,~~ the type and source of portland cement and fly ash, the brand and designation of chemical admixtures, the percent voids, and the intended type of construction ~~for which the concrete is to be used~~.

~~The minimum cementitious material shall be 630 lbs/yd$^3$ (10 Tonne/m$^3$). The maximum water-to-cementitious ratio shall be 0.30 lb/lb (136 g/g), unless otherwise specified in the Special Provisions. If so specified in the Special Provisions or approved by the Engineer, a hydration stabilizing admixture conforming to ASTM C494 Type B or a Type D admixture may be used. If so specified in the Special Provisions or approved by the Engineer, an air-entraining agent conforming to ASTM C260 may be used.~~

**303-8 ~~Pervious Concrete~~ PERVIOUS CONCRETE.**

**303-8.1 General.** Pervious concrete shall conform to 201-1.1.6. Pervious concrete shall be constructed a minimum of 6 inches (150mm) thick~~,~~ unless otherwise ~~specified in the Special Provisions or~~ shown on the Plans.

**303-8.2 ~~Construction~~ Test Section.** The Contractor shall construct a test section using the same equipment, and placing crew as it proposes to use for the remainder of the pervious concrete work ~~Work~~. The test section shall be a minimum of 225 square feet (~~7m$^2$~~ 21m$^2$) ~~and may be placed non-contiguously~~. ~~The test section will be tested by the Agency in accordance with 211-3.~~ The test section(s) may be incorporated into the Work if so approved by the Engineer. ~~The Engineer shall be notified at least 24 hours in advance of construction of the test section.~~

**303-8.3 Subgrade.** The subgrade shall be compacted to a relative compaction between the minimum specified in the Special Provisions ~~of between 92 and~~ and a maximum of 96 percent. ~~Chemical stabilization is not be permitted.~~ The subgrade shall not be treated or stabilized with portland cement or lime. ~~The subgrade shall have a minimum permeability of 0.5 inch per hour as determined by ASTM D3385.~~

**303-8.4 Forms.** Forms shall conform to 302-6.2. ~~Forms shall be placed to the full-depth thickness of the pervious concrete.~~ Forms shall be placed for the full-depth of the thickness of pervious concrete to be constructed~~. Forms shall be~~ and be capable of supporting mechanical equipment without deformation during or following ~~spreading, strike-off and compaction~~ placement operations.

**303-8.5 Placement.** Prior to placement, plastic pervious concrete shall have a density of +/- 5 pounds per cubic foot (80kg/$m^3$) of that shown on the approved mix design when tested in accordance with ASTM C1688. Unless otherwise specified in the Special Provisions, a minimum of one test per Day of placement will be performed. Placement shall conform to the lines, grades, and cross sections shown on the Plans. Placement operations shall not result in the voids becoming sealed.

Pervious concrete shall be uniformly deposited over the entire formed area. A self-propelled roller screed shall be used for strike-off, spreading, and compaction. Hand-rodding may be used in areas inaccessible to the roller-screed if so approved by the Engineer. Adjacent to the edge of each form, hand tampers shall be used for compaction.

~~Pervious concrete shall be deposited over the entire width of the formed area. The concrete shall be placed and finished by a combination of vibration and consolidation using a vibrating truss screed and rollers such that the result is a coherent, stable mass of interconnected voids. Strike-off by hand-rodding may be allowed in small, constrained areas if so approved by the Engineer. During initial placement and prior to strike-off, pervious concrete shall not be walked on. Combined strikeoff/compaction equipment will be allowed if the compaction force exceeds 10 psi (70 kPa). The compactive force shall be calculated by dividing the weight of the compaction device by the contact area. The contact area for a roller shall be one percent of the total surface area of the roller.~~

~~Immediately after strike-off, the surface shall be consolidated to the cross-section shown on the Plans. Consolidation shall be performed by use of a roller or plate compactor with a vertically applied pressure of 10 psi (70kPa). Hand tampers shall be used to consolidate the pervious concrete along the slab edges immediately adjacent to the forms. The Contractor shall exercise caution during consolidation to insure that the surface voids do not become sealed. Over-consolidation and accumulation of excess paste at the concrete surface will not be allowed.~~

~~When tested in accordance with 302-5.6.2~~ The ~~finished~~ surface shall not deviate more than 3/8 inch (9.5mm) from a 10 foot (3m) straightedge laid on the surface. Surface depressions shall be corrected immediately after compaction ~~consolidation~~ by placing fresh pervious concrete in the depressions and compacting using a hand tamper.

After compaction, the surface shall be protected from rapid evaporation by water fogging, covering with 1 mil polyethylene sheeting, or the application of a chemical evaporation retardant approved by the Engineer.~~After consolidation the surface shall be immediately water fogged until curing material is applied.~~

**303-8.6 ~~Weakened-Plane~~ Joints**.

**303-8.6.1 ~~General.~~ Weakened-Plane Joints.**

**303-8.6.1.1 General.** Weakened-plane joints shall be constructed at the locations shown on the Plans or at regular intervals not to exceed two times the width of the placement or ~~40~~ 15 feet

(4.6~~12~~m) on-center, whichever is less. Joints shall be constructed to a depth of 1/4 of the thickness, ~~of the pervious concrete with~~ or a minimum ~~depth~~ of 1-1/2 inches (~~38~~ 37.5mm), whichever is greater.

~~Transverse construction joints shall be installed constructed whenever placing placement is suspended for more than 20 minutes.~~

**303-8.6.1.2 Construction Methods**. Unless otherwise specified, ~~W~~weakened-plane joints ~~may~~ shall be constructed by one of the following methods ~~as specified in the Special Provisions~~:

a) Rolling with a small roller to which a beveled fin has been attached around the circumference immediately after compaction and prior to curing. ~~Weakened-plane joints shall be constructed in fresh concrete and shall be formed by rolling a small roller to which a beveled fin has been attached around the circumference. Such joints are constructed immediately after compaction and prior to curing.~~

b) Saw cutting as soon as the pervious concrete can be saw cut without causing raveling along the joint edges. ~~Weakened-plane joints shall be constructed by saw cutting. Saw cut joints shall be constructed as soon as the concrete can be saw-cut without raveling the joint edge.~~ Only the area occupied by the concrete saw shall be uncovered and exposed. Immediately after sawing each joint, the exposed area shall be ~~heavily misted~~ fogged with water and re-covered in accordance with 302-8.7.

**303-8.6.2 Transverse Construction Joints.** Transverse construction joints shall be constructed whenever placement is suspended for more than 20 minutes.

**303-8.7 Curing**. Curing shall consist of covering the surface and, as necessary, the application of water. Curing shall begin within 20 minutes of placement. The surface shall be securely covered with polyethylene sheeting having a minimum thickness of 6 mils (150µm). The cover shall be checked daily to verify that it has not been displaced or damaged, and that condensation is evident underneath the sheeting. Damaged sheeting shall be repaired. Displaced sheeting shall be replaced. When there is no observable condensation, 1.5 gallons of water per square yard (5.7L/$m^2$) shall be applied to the surface.~~Curing procedures shall begin within 20 minutes of concrete placement or 15 minutes when the wind is in excess of 5 miles per hour (8 kilometers per hour). When the wind is in excess of 5 miles per hour (8 kilometers per hour), evaporation retardant and curing compound or water fogging shall be used. The surface is then securely covered securely with polyethylene sheeting. Evaporation retardants, polyethylene sheeting and curing compound shall conform to 201-4. Polyethylene sheeting shall have a minimum thickness of 6 mils (152µm). The cover shall remain securely in-place for a minimum of 7 days.~~

**303-8.8 Acceptance.** Acceptance will be based on conformance to the Specifications. Pervious concrete shall have a consistent, uniform surface with no visible excess cement paste, tears, or gouges. Roller-constructed joints shall have smooth, rounded, and uniformly compacted edges. Saw cut joints shall not contain cement paste or dust nor exhibit evidence of spalling. Unless otherwise specified in the Special Provisions, pervious concrete shall have a minimum infiltration rate of 100 inches per hour (2540mm/hr) when tested in accordance with ASTM C1701.~~Pervious concrete shall have an infiltration rate of a minimum of 100 inches per hour (254 cm/hr) or as specified in the Special Provisions, when tested in accordance with 211-3.~~

**303-8.9 Measurement. ~~and Payment.~~** ~~Payment for pervious concrete shall be made at the Contract Unit Price per square foot (square meter) or cubic yard (cubic meter) basis as shown on the Bid.~~ Pervious concrete will be measured by the square foot ($m^2$) for each thickness shown on the Plans, or by the cubic yard ($m^3$).

**303-8.10 Payment.** Payment for pervious concrete will be made at the Contract Unit Price per square foot ($m^2$) for each thickness shown on the Plans, or per cubic yard ($m^3$), as shown in the Bid.

ACI 522.1-08

# Specification for Pervious Concrete Pavement

An ACI Standard

Reported by ACI Committee 522

American Concrete Institute®

First Printing
March 2008

American Concrete Institute®
*Advancing concrete knowledge*

# Specification for Pervious Concrete Pavement

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# Specification for Pervious Concrete Pavement

An ACI Standard

Reported by ACI Committee 522

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*This specification covers materials, preparation, forming, placing, finishing, jointing, curing, and quality control of pervious concrete pavement. Provisions governing testing, evaluation, and acceptance of pervious concrete pavement are included.*

*This reference specification can be made applicable by citing it in Project Specifications. The Architect/Engineer supplements this reference specification as needed by designating or specifying individual project requirements.*

**Keywords:** concrete parking lots; concrete pavements; construction; curing; inspection testing; jointing; pavement; pervious concrete; specifications.

*Units*—Values stated in inch-pound units are to be regarded as standard. Values given in parentheses are mathematical conversions to SI units that are provided for information only, and are not considered standard.

## NOTE TO SPECIFIER

This Specification is incorporated by reference in the Project Specification using the wording in P3 of the Preface and including information from the Mandatory Requirements, Optional Requirements, and Submittals Checklists following the Specification.

## PREFACE

**P1.** ACI Specification 522.1 is intended to be used by reference or incorporation in its entirety in the Project Specification. Do not copy individual Parts, Sections, Articles, or Paragraphs into the Project Specification, because taking them out of context may change their meaning.

**P2.** If Sections or Parts of ACI Specification 522.1 are copied into the Project Specification or any other document, do not refer to them as an ACI specification, because the specification has been altered.

**P3.** A statement such as the following will serve to make ACI Specification 522.1 a part of the Project Specification:

"Work on (Project Title) shall conform to all requirements of ACI 522.1, 'Specification for Pervious Concrete Pavement,' published by the American Concrete Institute, Farmington Hills, Michigan, except as modified by these Contract Documents."

**P4.** Each technical section of ACI Specification 522.1 is written in the three-part section format of the Construction Specifications Institute, as adapted for ACI requirements. The language is imperative and terse.

**P5.** The Specification is written to the Contractor. When a provision of this specification requires action by the Contractor, the verb "shall" is used. If the Contractor is allowed to exercise an option when limited alternatives are available, the phrasing "either...or..." is used. Statements provided in the Specification as information to the Contractor use the verbs "may" or "will." Informational statements typically identify activities or options that "will be taken" or "may be taken" by the Owner or Architect/Engineer.

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## SECTION 1—GENERAL

### 1.1—Scope

**1.1.1** This Specification provides requirements for the construction of pervious concrete pavement.

In case the requirements of this Specification conflict with the Contract Documents, the Contract Documents shall govern.

### 1.2—Definitions

**Architect/Engineer**—the architect, engineer, architectural firm, or engineering firm issuing Contract Documents or administering the Work under Contract Documents, or both.

**Contract Documents**—a set of documents supplied by the Owner to the Contractor as the basis for construction; these documents contain contract forms, contract conditions, specifications, drawings, addenda, and contract changes.

**Contractor**—the person, firm, or entity under contract for construction of the Work.

**early-entry dry-cut saw**—a tool designed to produce joints in concrete commencing 1 to 4 hours after finishing and without raveling the cut edges.

**exposure condition, moderate**—an environment, normally in temperate climate regions, in which concrete will only occasionally be exposed to moisture and will not be saturated before freezing and where no deicing agents or other aggressive chemicals are used.

**exposure condition, severe**—an environment, normally in cold climate regions, in which concrete may be saturated or in almost continuous contact with moisture before freezing, and where deicing agents are used.

**joint, construction**—the surface where two successive placements of concrete meet, across which it may be desirable to achieve bond, and where the first has undergone final set before the next placement.

**joint, contraction**—formed, sawed, or tooled groove in a concrete structure to create a weakened plane to regulate the location of cracking resulting from the dimensional change of different parts of the structure.

**joint, isolation**—a normally vertical interface allowing relative movement without transferring sufficient tension, compression, or traction forces to negatively affect the performance of a structure or pavement.

**Owner**—the corporation, association, partnership, individual, public body, or authority for whom the Work is constructed.

**panel**—a concrete element that is relatively thin with respect to other dimensions and is bordered by joints or edges.

**pavement, pervious**—a pavement comprising material with sufficient continuous voids to allow water to pass from the surface to the underlying layers.

**permitted**—accepted or acceptable to the Architect/Engineer, usually pertaining to a request by Contractor, or when specified in Contract Documents.

**Project Drawings**—graphic presentation of project requirements.

**Project Specification**—the written document that details requirements for the Work in accordance with service parameters and other specific criteria.

**reference standards**—standardized mandatory language documents of a technical society, organization, or association, including the building codes of local or state authorities, which are referenced in the Contract Documents.

**subbase**—a layer in a pavement system between the subgrade and the base course, or between the subgrade and a portland-cement concrete pavement.

**subgrade**—the soil prepared and compacted to support a structure or a pavement system.

**submittal**—document or material provided to the Architect/Engineer for review or acceptance.

**Work**—the entire construction or separately identifiable parts thereof required to be furnished under Contact Documents.

## 1.3—Referenced standards

**1.3.1** Standards of ACI and ASTM referred to in this specification are listed with serial designation including year of adoption or revision, and are part of this specification.

**1.3.1.1** *ACI standards*

| | |
|---|---|
| 306.1-90 | Standard Specification for Cold Weather Concreting |

**1.3.1.2** *ASTM standards*

| | |
|---|---|
| C29/C29M-97(2003) | Standard Test Method for Bulk Density (Unit Weight) and Voids in Aggregate |
| C42/C42M-04 | Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete |
| C94/C94M-07 | Standard Specification for Ready-Mixed Concrete |
| C138/C138M-01a | Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete |
| C140-06 | Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units |
| C172-04 | Standard Practice for Sampling Freshly Mixed Concrete |
| C174/C174M-06 | Standard Test Method for Measuring Thickness of Concrete Elements Using Drilled Concrete Cores |
| C979-05 | Standard Specification for Pigments for Integrally Colored Concrete |
| C1077-06 | Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation |
| D994-98(2003) | Standard Specification for Preformed Expansion Joint Filler for Concrete (Bituminous Type) |
| D1751-04 | Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types) |
| D1752-04a | Standard Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction |
| D3385-03 | Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer |
| D3665-06 | Standard Practice for Random Sampling of Construction Materials |
| E329-06a | Standard Specification for Agencies Engaged in Construction Inspection and/or Testing |

## 1.4—Standards-producing organizations

Abbreviations for and complete names and addresses of organizations issuing documents referred to in this specification are listed:

American Concrete Institute (ACI)
P.O. Box 9094
Farmington Hills, MI 48333-9094
www.concrete.org

ASTM International (ASTM)
100 Barr Harbor Drive
West Conshohocken, PA 19428
www.astm.org

National Ready Mixed Concrete Association (NRMCA)
900 Spring Street
Silver Spring, MD 20910
www.nrmca.org

## 1.5—Submittals

**1.5.1** Contractor shall submit drawings and documentation as required in this specification for acceptance by the Architect/Engineer.

**1.5.2** Obtain written acceptance of submittals before using the materials or methods requiring acceptance.

**1.5.3** *Responsibility of Contractor*—Before construction, submit to Architect/Engineer:

**1.5.3.1** Qualifications of Contractor related to construction of pervious concrete pavements.

**1.5.3.2** Proposed concrete mixture proportions and density.

**1.5.3.3** When required by the Architect/Engineer, in-place pavement test results from previous Work, completed in the last 12 months, including design void content, density, and concrete mixture proportions.

**1.5.3.4** Two test panels, as described in 1.6.2, placed, jointed, and cured; each a minimum of 225 $ft^2$ (20.9 $m^2$) and having the required thickness defined by Contract Documents.

## 1.6—Quality control

**1.6.1** *General*—Test and inspect concrete materials and operations as Work progresses as described in 1.6.5. Failure to detect defective Work or material early will not prevent rejection if a defect is discovered later, nor shall it constitute final acceptance.

**1.6.1.1** *Contractor qualification*—The Contractor shall employ no less than one National Ready Mixed Concrete Association (NRMCA) certified pervious concrete craftsman who must be on site, overseeing each placement crew during all concrete placement, or the Contractor shall employ no less than three NRMCA certified Pervious Concrete Installers, who shall be on site working as members of each placement crew during all concrete placement, or the Contractor shall employ no less than five NRMCA certified Pervious Concrete Technicians, who shall be on site working as members of each placement crew during all concrete placement unless otherwise specified. Alternative documentation of qualifications shall be permitted when approved by the Architect/Engineer.

**1.6.2** *Test panels*—Test panels shall be placed using the mixture proportions, materials, and equipment as proposed for the project. Test panels, if acceptable, may be incorporated

into the project. Test density of fresh concrete for the test panels in accordance with ASTM C138/C138M following the consolidation procedures described in ASTM C29/C29M, Jigging Procedure. Core hardened concrete for the test panels in accordance with ASTM C42/C42M, test thickness in accordance with ASTM C174/C174M, and test density in accordance with ASTM C140, Paragraph 9.3.

**1.6.2.1** Fresh density shall be within ±5 lb/ft$^3$ (80 kg/m$^3$) of the specified fresh density.

**1.6.2.2** Tolerance for thickness and density reported as the average of three cores of each test panel shall be as follows:

**1.6.2.2.a** The average compacted thickness shall not be more than 1/4 in. (6 mm) less than the specified thickness, with no single core exceeding 1/2 in. (13 mm) less than the specified thickness; nor shall the average compacted thickness be more than 1-1/2 in. (38 mm) more than the specified thickness.

**1.6.2.3** When a test panel is outside one or more of the limits of 1.6.2.1 and 1.6.2.2, the test panel shall be rejected, removed, and replaced at the Contractor's expense.

**1.6.2.4** When the test panel complies with 1.6.2.1 and 1.6.2.2, the panel may be left in place and included in the completed Work.

**1.6.3** *Testing agencies*—Agencies that perform testing services on concrete materials shall meet the requirements of ASTM C1077. Agencies inspecting the Work shall meet the requirements of ASTM E329. Testing agencies performing the testing shall be accepted by Architect/Engineer before performing any Work.

**1.6.3.1** Field tests of concrete required in 1.6.4 shall be performed by an individual certified as both an NRMCA Certified Pervious Concrete Technician or equivalent and an ACI Concrete Field Testing Technician—Grade 1 or equivalent.

**1.6.4** *Testing responsibilities of Contractor*

**1.6.4.1** Advise the Architect/Engineer at least 48 hours before concrete placement.

**1.6.5** *Testing*

**1.6.5.1** Obtain a minimum 1 ft$^3$ (28 L) sample for acceptance tests in accordance with ASTM C172. Measure a minimum of one density test during each day's placement in accordance with C138/C138M following the consolidation procedures described in ASTM C29/C29M, Jigging Procedure. Determine density using a minimum 0.25 ft$^3$ (0.007 m$^3$) cylindrical metal measure. Fill and compact the measure in accordance with ASTM C29/C29M, Jigging Procedure.

**1.6.5.1.a** Fresh density shall be within ±5 lb/ft$^3$ (80 kg/m$^3$) of the specified fresh density.

**1.6.5.2** Remove three cores from each lot of 5000 ft$^2$ (450 m$^2$), in accordance with ASTM C42/C42M, not less than 7 days after placement of the pervious concrete. Cores shall be a minimum nominal 4 in. (100 mm) diameter. Select three locations in accordance with ASTM D3665. Measure the cores for thickness (ASTM C42/C42M) and density (ASTM C140). After thickness determination, trim and measure the cores for density in the saturated condition as described in Paragraph 9.3, Saturation, of ASTM C140. Immerse the trimmed cores in water for 24 hours, drain for 1 minute, remove surface water with a damp cloth, then weigh immediately.

**1.6.5.2.1** Tolerance for thickness and density reported as the average of three cores of each lot shall be as follows:

**1.6.5.2.1.a** The compacted thickness shall not be more than 1/4 in. (6 mm) less than the specified thickness, with no single core exceeding 1/2 in. (13 mm) less than the specified thickness; nor shall the average compacted thickness be more than 1-1/2 in. (38 mm) more than the specified thickness.

**1.6.5.2.1.b** Hardened density shall be within ±5% of the approved hardened density from the test panels.

**1.6.5.2.2** When a lot is outside one or more of the limits of 1.6.5.2.1, the lot shall be subject to rejection, removed, and replaced at the Contractor's expense unless accepted by the Owner.

**1.6.5.3** Core holes shall be filled with concrete or preblended grout.

## SECTION 2—PRODUCTS

### 2.1—Subbase

Coarse aggregates shall meet the size and grading requirements of Contract Documents.

### 2.2—Pervious concrete

Comply with ASTM C94/C94M and the following requirements:

**2.2.1** *Aggregates*—Nominal maximum aggregate size shall not exceed 1/3 of the specified pavement thickness.

**2.2.2** *Admixtures*—Chemical admixtures that facilitate the production and placement of pervious concrete shall be permitted. The use of such admixtures shall be notified to the Architect/Engineer.

**2.2.3** *Fibers*—The use of fibers in pervious concrete mixtures is permitted when approved by the Architect/Engineer.

**2.2.4** *Pigments*—Use pigments complying with ASTM C979 if specified in Contract Documents.

### 2.3—Isolation joint material

**2.3.1** For isolation joint materials, comply with ASTM D994, D1751, or D1752.

### 2.4—Forms

**2.4.1** Make forms with steel, wood, or other material that is sufficiently rigid to maintain specified tolerances, and capable of supporting concrete and mechanical concrete placing equipment.

**2.4.2** Forms shall be clean and free of debris of any kind, rust, and hardened concrete.

## SECTION 3—EXECUTION

### 3.1—Subgrade preparation

**3.1.1** Prepare subgrade as specified in Contract Documents.

**3.1.2** Construct subgrade to ensure that the required pavement thickness is obtained in all locations.

**3.1.3** Keep all traffic off of the subgrade during construction to the maximum extent practical. Regrade and recompact

subgrade disturbed by concrete delivery vehicles or other construction traffic, as needed.

**3.1.4** Compact the material added to obtain final subgrade elevation.

**3.1.5** Determine subgrade permeability in accordance with ASTM D3385 before concrete placement. Confirm that subgrade permeability meets requirements of Contract Documents.

## 3.2—Subbase

**3.2.1** Use only when specified in Contract Documents. Where used, prepare subbase in accordance with Contract Documents.

## 3.3—Setting formwork

**3.3.1** Set, align, and brace forms so that the hardened pavement meets the tolerances specified in 3.9.

**3.3.2** Apply form release agent to the form face, which will be in contact with concrete, immediately before placing concrete.

**3.3.3** The vertical face of previously placed concrete may be used as a form.

**3.3.3.1** Protect previously placed pavement from damage.

**3.3.3.2** Do not apply form release agent to previously placed concrete.

**3.3.4** Placement width shall be as specified in Contract Documents. Concrete placement width shall not exceed 20 ft (6 m) unless otherwise specified.

## 3.4—Batching, mixing, and delivery

**3.4.1** Batch and mix in compliance with ASTM C94/C94M except that discharge shall be completed within 60 minutes of the introduction of mixture water to the cement. Increase time to 90 minutes when using an extended set control admixture. Water addition is permitted at the point of discharge.

## 3.5—Placing and finishing fixed-form pavement

**3.5.1** Deposit concrete either directly from the transporting equipment or by conveyor onto the prewetted subgrade or subbase, unless otherwise specified.

**3.5.2** Do not place concrete on frozen subgrade or subbase.

**3.5.3** Deposit concrete between the forms to an approximately uniform height.

**3.5.4** Spread the concrete using a come-along, short-handle, square-ended shovel, or rake.

**3.5.5** Do not allow foot traffic on the fresh concrete.

**3.5.6** Strike off concrete between forms using a form-riding paving machine or vibrating screed. Other strike-off devices may be used when accepted.

**3.5.7** Do not use steel trowels or power finishing equipment.

**3.5.8** Finish the pavement to the elevations and thickness specified in Contract Documents and meet the requirements of 3.9.

## 3.6—Placing and finishing slipform pavement

**3.6.1** Slipform equipment is permitted.

**3.6.2** Deposit and finish concrete in accordance with 3.5, except 3.5.4 and 3.5.6.

## 3.7—Final surface texture

**3.7.1** Compact fresh concrete to stay within the requirements of 3.9.

**3.7.2** Compact the concrete along the slab edges with hand tools.

**3.7.3** Compact concrete to a dense, pervious surface.

## 3.8—Edging

**3.8.1** Edge top surface to a radius of not less than 1/4 in. (6 mm).

## 3.9—Tolerances

**3.9.1** Construct pavement to comply with the following tolerances:

Elevation: +3/4 in. (+19 mm), –0 in. (–0 mm)

Thickness: +1-1/2 in., –1/4 in. (+38 mm, –6 mm)

Contraction joint depth: +1/4 in. (6 mm), –0 in. (–0 mm)

**3.9.1.1** Mechanically sweep pavement before testing for compliance with tolerances.

## 3.10—Curing

**3.10.1** Begin curing within 20 minutes of concrete discharge unless longer working time is accepted by the Architect/Engineer.

**3.10.2** Completely cover the pavement surface with a minimum 6 mil (0.15 mm) thick polyethylene sheet. Cut sheeting to a minimum of a full placement width.

**3.10.3** Cover all exposed edges of pavement with polyethylene sheet.

**3.10.4** Secure curing cover material without using dirt.

**3.10.5** Cure pavement for a minimum of 7 uninterrupted days, unless otherwise specified.

## 3.11—Hot- and cold-weather construction

**3.11.1** When hot weather is anticipated, submit detailed procedures for the production, transportation, placement, protection, curing, and temperature monitoring of concrete during hot weather.

**3.11.2** In cold weather, comply with ACI 306.1, recording concrete temperature no less than twice per 24-hour period.

## 3.12—Jointing

**3.12.1** Unless otherwise specified, construct joints at the locations, depths, and with horizontal dimensions indicated in Contract Documents.

**3.12.2** When jointing requirements are not indicated on the Project Drawings, submit drawings describing proposed jointing in accordance with 1.4 and the requirements of 3.12.2.1 through 3.12.2.9. Do not proceed with Work until the jointing requirements are accepted by the Architect/Engineer.

**3.12.2.1** Indicate locations of contraction joints, construction joints, and isolation joints. Spacing between contraction joints shall not exceed 20 ft (6 m).

**3.12.2.2** The larger horizontal dimension of a slab panel shall not exceed 125% of the smaller dimension.

**3.12.2.3** The angle between two intersecting joints shall be between 80 and 100 degrees, as specified in Contract Documents.

**3.12.2.4** Joints shall intersect pavement free edges at 90-degree angles and shall extend straight for a minimum of 1-1/2 ft (0.5 m) from the pavement edge where possible.

**3.12.2.5** Align joints of adjacent pavement panels.

**3.12.2.6** Align joints in attached or adjacent curbs within 1/4 in. (6 mm) of joints in pavement.

**3.12.2.7** Contraction joint depth shall be 1/4 to 1/3 of the pavement thickness. Minimum joint width for saw-cutting is 1/8 in. (3 mm). When using an early-entry dry-cut saw, the depth of the cut shall be at least 1 in. (25 mm).

**3.12.2.8** Use isolation joints only where pavement abuts fixed objects, such as buildings, foundations, and manholes.

**3.12.2.9** Extend isolation joints through the full depth of the pavement. Fill the entire isolation joint with isolation joint material.

**3.12.3** Create contraction joints by one of the following methods:

**3.12.3.1** Tool contraction joints to the specified depth and width in fresh concrete immediately after the concrete is compacted.

**3.12.3.2** Sawcut concrete after concrete has hardened sufficiently to prevent aggregate from being dislodged and soon enough to control pavement cracking. To minimize drying, ensure that curing materials are removed only as needed to make cuts.

## 3.13—Opening to traffic

**3.13.1** Do not open the pavement to vehicular traffic until the concrete has cured for at least 7 uninterrupted days and until the pavement is accepted by the Architect/Engineer for opening to traffic.

## FOREWORD TO CHECKLISTS

**F1.** This Foreword is included for explanatory purposes only; it does not form a part of Specification ACI 522.1.

**F2.** ACI Specification 522.1 may be referenced by the Specifier in the Project Specification for any building project, together with supplementary requirements for the specific project. Responsibilities for project participants must be defined in the Project Specification. The ACI specification cannot and does not address responsibilities for any project participant other than the Contractor.

**F3.** Checklists do not form a part of ACI Specification 522.1. Checklists assist the Specifier in selecting and specifying project requirements in the Project Specification.

**F4.** The Specifier shall make adjustments to the needs of a particular project by reviewing each of the items in the checklists and including the items the Specifier selects as mandatory requirements in the Project Specification.

**F5.** The Mandatory Requirements Checklist indicates Work requirements regarding specific qualities, procedures, materials, and performance criteria that are not defined in ACI Specification 522.1.

**F6.** The Optional Requirements Checklist identifies Specifier choices and alternatives. The checklists identify the Sections, Parts, and Articles of the reference specification and the action required or available to the Specifier.

**F7.** The Submittals Checklist identifies Specifier choices for information or data to be provided by Contractor before, during, or after construction.

**F8.** *Recommended references*—Documents and publications that are referenced in the checklists of ACI Specification 522.1 are listed. These references provide guidance to the Specifier and are not considered to be part of ACI Specification 522.1.

*American Concrete Institute*

305R Hot Weather Concreting

306R Cold Weather Concreting

## MANDATORY REQUIREMENTS CHECKLIST

| Section/Part/Article | Notes to Specifier |
|---|---|
| 1.6 | Review for compliance with Project Specifications. Designate responsibility for quality control inspection and testing. |
| 2.2.1 | Specify nominal maximum aggregate size. |
| 3.1 | Specify subgrade preparation and permeability requirements in appropriate section of Contract Documents. |
| 3.5.8 | Specify final surface elevations and pavement thicknesses in Contract Documents. |
| 3.12.1 | Specify joint locations, depths, and dimensions on Project Drawings. |

## OPTIONAL REQUIREMENTS CHECKLIST

| Section/Part/Article | Notes to Specifier |
|---|---|
| 1.6.1.1 | Specify other Contractor qualifications:<br>Contractor may provide written and photographic evidence of project experience and proficiency in successfully completing pervious concrete pavement construction, and submit evidence of completion of nationally recognized pervious concrete craftsman certification program.<br><br>If the Contractor has insufficient experience with pervious concrete pavement (less than three successful jobs), the Contractor shall retain an experienced consultant to monitor production, handling, and placement operations at the Contractor's expense. The selection of the consultant shall be subject to the acceptance of the Architect/Engineer. |
| 2.1 | Specify coarse aggregate size and grading requirements. |
| 3.2 | Specify the type of subbase in Contract Documents, when required. |
| 3.3.4 | Specify acceptable placement width. |
| 3.5 | Specify if other methods of conveying are permitted. |
| 3.5.6 | Specify if other methods of strike-off are permitted. |
| 3.10.1 | If longer working time is required or permitted, specify maximum time. |
| 3.10.5 | Specify duration of curing. |
| 3.12.2.3 | Specify acceptable angle between joints. |

## SUBMITTALS CHECKLIST

| Section/Part/Article | Submittal items and notes to Specifier |
|---|---|
| 1.6.1.1 | Review and accept NRMCA certification documents from contractor or qualifications alternative to NRMCA certification documenting proficiency and experience in constructing pervious concrete pavements. |
| 3.11.1 | When required, verify execution plan from Contractor where applicable. Refer to ACI 305R. |
| 3.11.2 | When required, verify execution plan from Contractor where applicable. Refer to ACI 306R. |
| 3.12.2 | When required, verify jointing requirements submitted by Contractor, where applicable. |
| 3.12.2.1 | Review and accept drawings from Contractor describing joint requirements and spacing. |
| 3.12.2.8 | When required, verify jointing details submitted by Contractor, where applicable. |

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*Advancing concrete knowledge*

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- Spring and fall conventions to facilitate the work of its committees.
- Educational seminars that disseminate reliable information on concrete.
- Certification programs for personnel employed within the concrete industry.
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# Specification for Pervious Concrete Pavement

The AMERICAN CONCRETE INSTITUTE

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# Pervious Concrete Pavement Maintenance and Operations Guide

## NRMCA Pervious Concrete Pavement Maintenance and Operations Guide

Pervious concrete pavement is a Portland cement-based, rigid permeable pavement that serves not only as the surface layer of a stormwater management system, but also as a vital part of a water filtration system. Beneath the pervious concrete is the second layer of the stormwater system, the base rock, which is an open-graded, stone layer that is used for temporary stormwater detention. When rain falls, the pervious concrete allows on-site infiltration of stormwater. It also filters sediments and pollution from stormwater deposited on the pavement surface.

Because this permeable surface is a filter, like any filter it must be cleaned periodically. Cleaning is performed by vacuuming to remove sediments that have accumulated. The frequency of the vacuuming is directly related to the amount of sediment that the surface receives over time.

## The following chart can serve as a *minimal recommendation* for scheduled maintenance:

| ACTIVITY | SCHEDULE |
|---|---|
| Avoid sealing or repaving with impervious materials. In particular, never use asphalt or other tar-type sealers on pervious concrete. | N/A |
| Visually inspect pervious pavement area to ensure that it:<br>• is clean of debris<br>• de-waters between storms<br>• is clean of sediments | Monthly |
| • Maintain upland and adjacent grassy areas.<br>• Seed upland and adjacent bare areas.<br>• Keep the pervious pavement surface free of sediment by blowing, sweeping or vacuuming.<br>• Excessive water flow carrying debris toward the pavement should be diverted. | As needed |
| Inspect the pervious pavement surface for deterioration or spalling. | Annually |

## Pervious Concrete Maintenance: Plan and Practice

Maintenance of the pervious concrete pavement is the responsibility of the property owner/manager. The Maintenance Plan should be developed to assure proper maintenance procedures are followed. After the first year of operation, the plan should be reviewed and, if necessary, revised to reflect the actual results of that first period of service. When ownership of the property is transferred, the maintenance plan must be transferred as well.

In general, maintenance of pervious concrete pavement consists of monitoring the surface for sediment buildup, and removing that buildup as needed, to maintain the pavement's permeability. Owners/property managers should follow good housekeeping practices to prevent accumulation of trash, sediment or other debris on the pervious surface. Drainage of all unpaved areas should be directed away from the pervious concrete pavement. If areas are allowed to drain onto the pavement, suspended materials may wash into the void structure of the pervious pavement and reduce the porosity and compromise its service life. Adjacent areas that do drain to the pavement should be kept seeded and maintained to minimize sediment deposition which may increase the frequency of cleaning of the pervious surface. Landscape contractors should be advised of the special precautions required to avoid debris buildup on the pavement surface. Additionally, it is recommended that informational signage be posted to identify the pervious pavement as being part of a stormwater management system and that particular care should be taken to maintain its peak performance.

The first step in creating a maintenance plan is to develop a baseline infiltration rate for your pervious concrete system. ASTM C1701: Standard Test Method for Infiltration Rate of In-Place Pervious Concrete, is the procedure used to determine the infiltration rate of pervious concrete. Performing an initial ASTM C1701 test for a baseline is best done the day that the plastic curing is removed. The pavement has not been in service yet, so this initial baseline measurement will document the optimal performance of the pavement, as constructed, for stormwater management. ASTM C1701 requires three test procedures to be performed for every 25,000 square feet and an average taken of the three tests. This will be the baseline for comparison of all future tests. The original testing locations should be marked or noted in the maintenance log so that future tests can be run at the same locations. A change in the infiltration rate with service will determine the appropriate frequency of maintenance.

**There are three levels of pervious concrete pavement maintenance:**

1. **Routine Maintenance:** Should include visual inspection of the pervious pavement to ensure that it is clean of debris and sediments, and that it will dewater between storms. Routine maintenance cleaning procedures would include blowing (with leaf blower or similar equipment), truck-sweeping and/or dry vacuuming. Routine maintenance may help prevent more stubborn clogging by keeping sediment from becoming ground deep into the pavement's void structure. This routine maintenance should be performed as needed (at least monthly) to keep the entire pervious concrete area clean. Visually inspect the pavement periodically during or immediately following a rain event. Ponding or puddles are signs that it is time to clean the pavement. In some areas, moss growth can be an issue. Moss can be controlled by sprinkling baking soda on the surface, followed by a dry vacuuming within a few weeks. Additionally, moss growth can be retarded/eliminated with lime water applications. Since this pavement is designed to infiltrate water, any surface treatment must be evaluated for environmental impacts to ground water.
2. **Periodic Maintenance:** In areas that see freezing temperatures, it is a good practice to perform periodic maintenance just before winter to insure that the pervious concrete voids are clean and free of non-compressible materials that may inhibit draining and, therefore, could contribute to freeze-thaw damage. Additionally, periodic maintenance may be required following winter to remove any anti-skid materials that may have been used. Proper cleaning procedures would include pressure washing and/or vacuuming the area with either a dry vacuum or a regenerative vacuum sweeper. Care should be taken to avoid extremely high pressures with a pressure washer, as this can degrade the bonding cement paste and increase raveling. Cleaning equipment should allow for the debris to be bagged and removed from the unit so it can be weighed.

## A maintenance log should be completed that records the following:

- Date of service
- Name of individual/company performing service
- Type of maintenance performed
- Amount (lbs.) and type(s) of sediment/debris/other material removed as result of cleaning
- General observations and record of pavement condition
- Name/signature of individual completing the inspection
- Additionally, if ASTM C1701 is performed, the test results and locations should be included in the report. (A sample Maintenance Log is included on page 7 of this guide).

Additionally, if ASTM C1701 was performed, the test results and locations should be included in the report. (A sample Maintenance Log is included on page 7 of this guide).

Routine and periodic maintenance is essential with the goal of avoiding renovation/rehabilitation.

3. **Deep Cleaning/Unclogging:** Over time, deep cleaning/unclogging of pervious concrete pavement may become necessary, particularly if routine and periodic maintenance is not performed. If a pervious concrete pavement system is not periodically cleaned, the void structure system will become clogged with debris over time. Typically, an average infiltration rate decrease of 25% from the initial value, or an infiltration rate less than 100 inches per hour, triggers the need for deep cleaning/unclogging. Neglected projects that had never been cleaned and are completely clogged should be restored to a drainage rate of 100-200 inches per hour, per ASTM C1701, by using specialized cleaning equipment.

***ASTM C1701: Standard Test Method for Infiltration Rate of In-Place Pervious Concrete***

*Cleaning pervious concrete can maintain and/or restore its original permeability*

Deep cleaning/unclogging is best accomplished by simultaneous pressure washing and vacuuming. Several equipment manufacturers have developed pressure washing/vacuum systems that have proven to rehabilitate the pore structure of pervious pavement. For best results, follow the equipment manufacturer's recommendations. As with the periodic maintenance procedures, when cleaning/unclogging is performed, a maintenance log should be completed and filed with the owner/property manager.

Use of Chemicals to clean pervious concrete should be done with extreme caution to prevent damage to the aquifer, the biological organisms within the pervious system, or the pervious concrete pavement itself.

# Winter Maintenance

***This is a critical aspect of owning a Pervious Concrete Pavement. Improper winter maintenance has been responsible for many failures of Pervious Concrete Pavement Surfaces.***

Freeze-thaw resistance of pervious concrete depends on its saturation level at the time of freezing. When the large voids are saturated, complete freezing can cause severe damage to the pervious concrete pavement. Field observations have shown that, due to its rapid draining characteristics, a properly maintained pervious concrete pavement will rarely be fully saturated.

Winter maintenance issues affect pervious concrete the same as standard concrete. Deicing chemicals should not be used on any type of concrete in the first year. Concrete that is not properly cured is more susceptible to damage from deicing chemicals. Because concrete takes longer to cure in lower temperatures, when it is placed late in the year, such as late fall or early winter, it may be more susceptible to damage due to the use of deicing chemicals. As with conventional concrete, applying a penetrating sealer to the pervious concrete can improve its performance in freezing weather. Use a penetrating sealer manufactured specifically for concrete. **Concrete penetrating sealer should not be confused with impermeable sealers such as asphalt seal coats.**

**The following recommendations should be followed:**

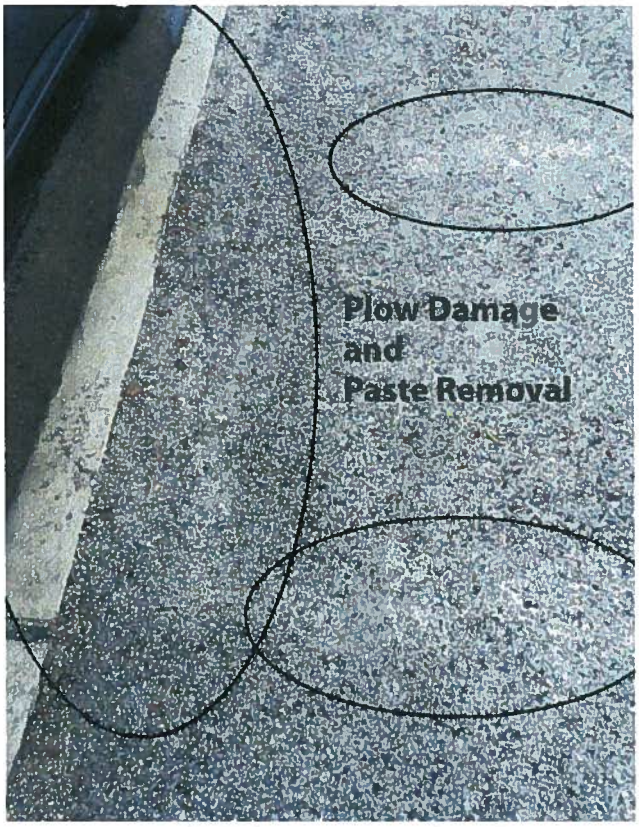
- Anti-icing pre-treatments should never be used on pervious concrete pavements. If these products are used on adjacent pavements, care should be taken to prevent the adjacent runoff from infiltrating the pervious concrete.
- Deicers containing magnesium chloride, calcium magnesium acetate or potassium acetate should ***never*** be used on pervious concrete pavement.
- Deicing agents that contain fertilizer ingredients such as Ammonium Sulfate and Ammonium Nitrate cause chemical deterioration to any Portland cement-based concrete pavement and should ***never*** be used.
- Calcium Chloride impregnated sand can be used for deicing pavements ***after*** the first year.
- Coarse sand (minimum 1/8"), or small crushed aggregate (1/4 – 10, or similar gradation) can be used as an anti-skid material with the understanding that vacuum cleaning will be performed after the winter season. **Fine sands such as masonry sand or play sand should NOT be used on pervious concrete pavements!**
- Snow plowing can be performed with trucks mounted with plows, but the plow should be fitted with a polyurethane cutting edge. Use of snow blowers may be a better alternative to plowing, if available. Snow removal should not be performed using front end loaders or skid loaders by either scooping or back dragging. Note that snow plowing may result in striations on the concrete surface. These striations are merely aesthetic and will often disappear over time.

The number one concern of property facilities managers is liability. Facilities managers instruct their maintenance personnel to salt and plow when snow begins to lay on the surface. In many cases, that minimal amount of snow will melt when the sun comes out or when temperatures even slightly rise. Once the snow melts, it infiltrates into the pervious concrete and does not refreeze on the surface, as it would on an impervious surface. Additionally, studies show that the ground beneath the pervious concrete system is less susceptible to freezing due to the insulating properties of the air space in the aggregate base. This is very beneficial to the facilities managers who are concerned about safety factors and liability.

Pervious concrete should ***never*** be used as a storage area to pile snow from other areas unless it has been specifically designed as a snowshelf, with special consideration for resistance to deicing chemicals, water quality issues and additional maintenance as requisite. The snow that has been plowed from other surfaces may be full of debris that will clog the pervious concrete voids. Additionally, the plowed snow will most likely have a very high salt or anti-skid content.

**An Ounce of Prevention...**

The best maintenance practice is prevention. Keeping the pavement clean, and within design specifications, is the owner's responsibility. When proper maintenance techniques are followed, pervious concrete will provide a durable pavement and long-term stormwater management.




**For more information, go to www.pervious pavement.org**

## References:

American Concrete Institute (ACI), 2010. ***Pervious Concrete (522R-10),*** Farmington Hills, MI.

National Ready Mixed Concrete Association (NRMCA), ***Text Reference for Pervious Concrete Contractor Certification,*** NRMCA Publication #2PPCRT. Silver Spring, MD.

Tennis, P. D., Leming, M. L. and Akers, D. J. 2004. ***Pervious Concrete Pavements.*** Portland Cement Association (PCA), Skokie, IL

Watershed Management Institute (WMI). 1997. ***Operation, Maintenance, and Management of Stormwater Management Systems.*** Prepared for US Environmental Protection Agency, Office of Water, Washington, DC.

## Pervious Concrete Maintenance Log

**Site Name and Location:** _____

**Initial ASTM C1701 Test Results:** _____ **Inches / Hour**

| Date of Inspection | Observations/ Pavement Condition | ASTM C1701 Performed? | ASTM C1701 Results | Type of Maintenance Performed | Type and Amount of Debris/Sediment Removed | Maintenance Performed By: | Name/Signature of Inspector |
|---|---|---|---|---|---|---|---|
| | | Yes ☐<br>No ☐ | Before Maintenance<br>☐ IN/HR<br>After Maintenance<br>☐ IN/HR | | | | |
| | | Yes ☐<br>No ☐ | Before Maintenance<br>☐ IN/HR<br>After Maintenance<br>☐ IN/HR | | | | |
| | | Yes ☐<br>No ☐ | Before Maintenance<br>☐ IN/HR<br>After Maintenance<br>☐ IN/HR | | | | |
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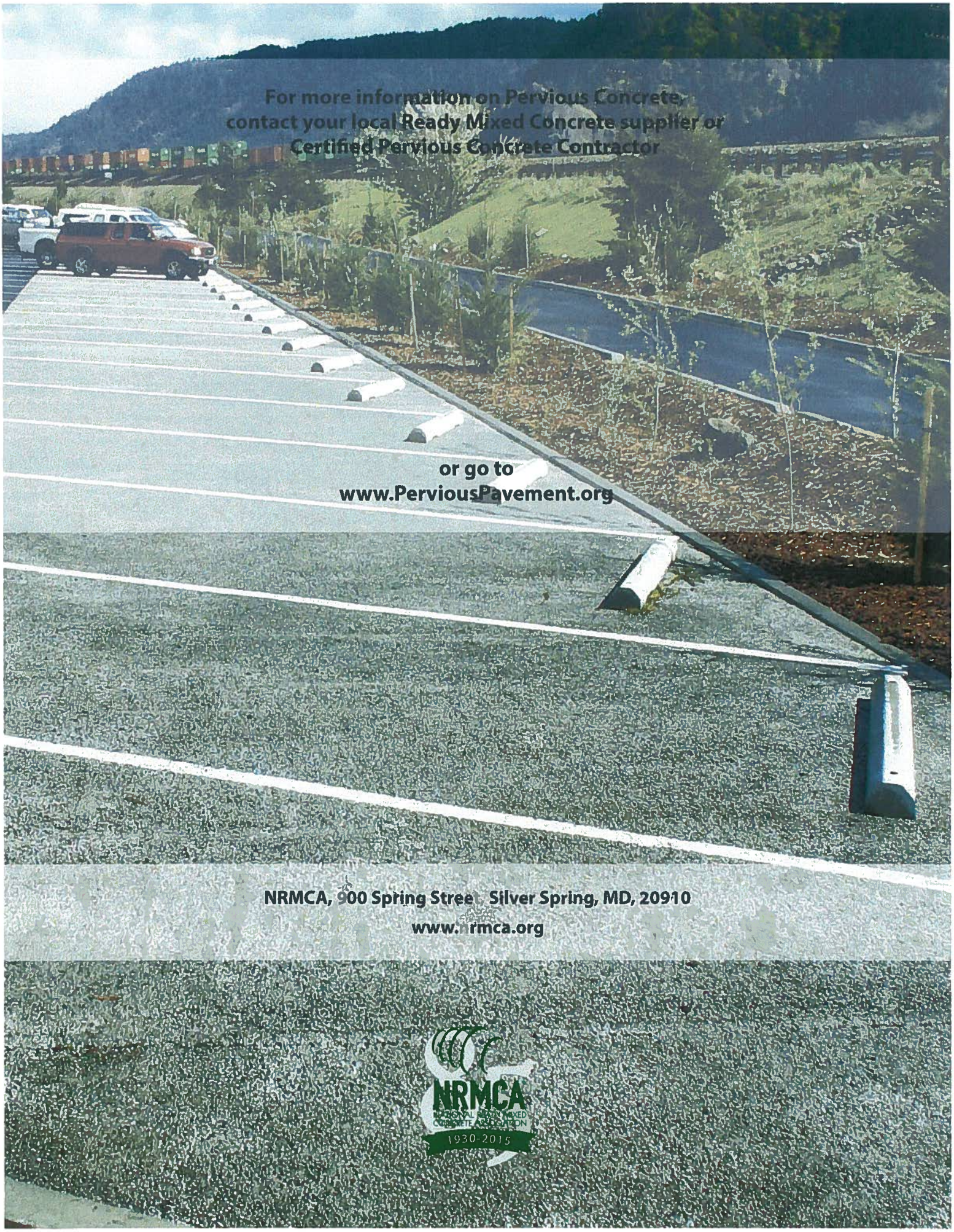

For more information on Pervious Concrete, contact your local Ready Mixed Concrete supplier or Certified Pervious Concrete Contractor

or go to
www.PerviousPavement.org

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