

Pervious in Practice

Methods, materials, mixtures



PIP 1 – Guide to Specifying Pervious Concrete

Background

Recommendations and specifications for pervious concrete pavement are published by the American Concrete Institute (ACI) Committee 522. *ACI 522R-10: Report on Pervious Concrete* provides technical information on pervious concrete's application, design methods, materials, properties, mixture proportioning, construction methods, testing and inspection. *ACI 522.1-13: Specification for Pervious Concrete Pavement* 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. Besides these documents, a specifier of pervious concrete should pay attention to general concepts and details.

Compressive Strength

Compressive strength is commonly used for acceptance of conventional concrete. It should be recognized that application and characteristics of pervious concrete are different from those of conventional concrete. An important fact is that the main property of pervious concrete—its permeability—is inversely proportional to strength. There are no standardized procedures to make and test strength specimens of pervious concrete. The methods for conventional concrete do not apply. **It is, therefore, inappropriate to specify compressive strength requirements for pervious concrete or to use such tests as a basis of acceptance.**

Void Content and Density

Considering the primary function of pervious concrete pavements, the important property that should be specified is a target range for void content (such as 15% to 25%). This property is derived from the measured density in accordance with *ASTM C 1688: Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete*. As stated in *ACI 522.1-13*, the tolerance for the specified void content is +/-5%. The pervious concrete mix submittal should document the density of the pervious concrete relative to the void content that complies with the specified requirements. It is also important to recognize that the void content of a pervious concrete mixture is

determined in a density measure using standardized compaction methods. This verifies that the mixture is properly designed to achieve the specified void content. It should not be expected that this void content will be obtained in the constructed pavement, since construction methods will not replicate the standardized compaction in the test. For this purpose, the density and associated void content of a core taken from a test slab is used as the basis for the subsequent acceptance of the constructed pavement.

Importance of Aggregate on Pervious Concrete Mixture Proportions

Proportioning pervious concrete mixtures is different compared to procedures used for conventional concrete.

When developing pervious concrete mixtures, the goal is to obtain a target or design void content that will allow for the infiltration of water. The void content of a pervious concrete mixture will depend on the characteristics of the ingredients, how they are proportioned and how the mixture is consolidated.

More so than when proportioning conventional concrete mixtures, coarse aggregate properties affect the proportions of all other materials in a pervious concrete mixture. The first step in proportioning the mixture is to accurately determine the void content of the aggregate, in accordance with *ASTM C29*, and the aggregate specific gravity. The void content of aggregate that will be used in a pervious concrete mixture will vary, depending on the grading. The density of the aggregate depends on the relative density of the aggregate and the

grading. Because of these variations, it is inappropriate to specify the density of a pervious concrete mixture. Rather, the target void content range of the pervious concrete mixture should be specified. Experience shows that the void content of pervious concrete mixtures that have been successfully used in projects falls within a range of 17%-23% voids.

Cementitious Materials Content and w/cm Ratio

It is common to see a minimum or required quantity of cementitious materials for conventional concrete, possibly

Do's and Don'ts of Specifying Pervious Concrete

Do not specify compressive strength as acceptance criteria.

Do not specify a minimum cement content or water-to-cement ratio.

Do specify target range for void content.

Do specify acceptance of concrete based on its density relative to the approved mix as determined by ASTM C1688.

for the intent of achieving strength or durability. This concept does not apply to pervious concrete. The volume of cementitious paste in a pervious concrete mixture is governed by the voids in the aggregate. An optimum quantity of paste is needed for proper installation and to ensure that the installed pervious concrete pavement achieves its designed permeability. Deficient quantity of paste can result in raveling; excessive paste will adversely impact its permeability. The consistency of the paste is also critical for constructability and final performance of the pavement. This is governed by the water to cementitious materials ratio (w/cm) and is unique for the set of materials being used. In the past, it was not unusual for pervious concrete specifications to call for 600 to 700 pounds of cement per cubic yard. Considerable experience in successful projects have proven that decreasing the cement content and increasing the water volume, while maintaining an optimized paste volume, results in significant improvements in both the installation process and the quality of the finished pavement. Due to variations in local materials, cementitious materials content and water-to-cementitious materials ratio should not be specified. As in conventional concrete, it is common to use supplementary cementitious materials like fly ash, slag cement, silica fume and natural pozzolans to improve the performance of pervious concrete. The use and quantity of these materials should not be restricted in the pervious concrete specification.

NRMCA has developed a mix proportioning spreadsheet-based resource for pervious concrete mixtures that will help the user establish mixture proportions for pervious concrete for a design void content and optimum consistency. This resource includes a guideline that details the pervious concrete mixture proportioning methodology, supported by a research report that provides experimental validation of the mixture proportioning methodology based on testing conducted at the NRMCA Research Laboratory. The resource, NRMCA Publication 2PE002, is available through the e-bookstore at www.nrmca.org.

Admixtures

As with conventional concrete mixtures, pervious concrete utilizes admixtures and to enhance performance and assist in placement. A list of commonly used admixtures would include, but is not limited to:

- Air-entraining admixture (AEA);
- Extended set-control admixtures (ESCA), also known as hydration-controlling admixture (HCA) and set-retarding admixtures;
- Internal curing admixture (ICA);
- Normal, mid-range or high-range water-reducing admixture (MRWR/HRWR);
- Viscosity-modifying admixture (VMA);
- Fibers; and
- Polymers (including latex-based admixtures).

Admixtures are essential to meet the challenges of placement, which range from discharge from the ready mix truck to proper compaction and reducing moisture loss.

Curing

Retaining moisture in newly constructed pervious concrete pavement is essential to its long-term performance and durability. The most important component of pervious concrete durability is proper curing that maintains moisture and temperature. Because of the open void structure and lower initial water content, moisture may rapidly evaporate from the mixture, especially in low humidity or windy conditions. Moisture loss can be compounded when proper curing methods are not used or are delayed.



Internal curing methods can assist in maintaining moisture in pervious concrete and provide additional water for a more complete hydration of the cement. However, even with internal curing methods, surface curing is essential and cannot be optioned out. *ACI 522.1-13* specifies covering the concrete with polyethylene sheeting for 7 days as the curing method to be used, unless otherwise approved by an engineer.

Acceptance Testing

Normal construction inspection practices that base acceptance on slump and cylinder strengths are not meaningful for pervious concrete. The specifier should not reference test methods for conventional concrete, aggregate, masonry, asphalt or other materials to test and evaluate pervious concrete mixtures. There are currently four ASTM test procedures specifically intended for use on pervious concrete. They are:

1. *ASTM C1688: Standard Test Method for Density and Void Content of Freshly Mixed Concrete*
2. *ASTM C1701: Standard Test Method for Infiltration Rate of In-Place Pervious Concrete*
3. *ASTM C1754: Density and Void Content of Hardened Pervious Concrete*
4. *ASTM C1747: Determining Potential Resistance to Degradation of Pervious Concrete by Impact and Abrasion*

Two of these four test methods—*ASTM C 1688* and *ASTM C 1754*—should be included as methods for pervious concrete acceptance.

As part of the submittal, the concrete supplier/contractor should document the density of the proposed pervious concrete mixture that will achieve the specified range for target void content. For acceptance purposes, the density of fresh pervious concrete should be measured in accordance

with *ASTM C1688* from samples obtained at the discharge from the delivery vehicle. Testing frequencies of once per day, or when visual inspection indicates a change in the concrete, are common. Acceptance criterion is $\pm 5 \text{ lb/ft}^3$ (80 kg/m^3) of the target value documented in the submittal.

ACI 522.1-13: Specification for Pervious Concrete Pavement, bases the acceptance of pervious concrete pavements on the construction of test panels at the project site. The test panels should be placed on a sub-grade and subbase prepared as specified, using the material and construction methods that will be used. The pervious concrete mixture is verified to comply with project specifications for target density in accordance with *ASTM C1688*. After seven days, cores are required to be obtained from the test panels, in accordance with *ASTM C 42*, and measured for density in accordance with



ASTM C 1754. The average density of cores from the test panel set the basis for subsequent quality assurance and acceptance testing. The thickness of the cores are also measured for specification compliance. Additionally, the test panels should be inspected for permeability and raveling. If the pavement drains adequately and surface

and edge raveling is not occurring, then the mock-up has passed and should be used as the baseline for acceptance of the remaining installation.

After the project starts, samples of pervious concrete from the delivery vehicle are tested for density in accordance with *ASTM C1688* and the measured density should be within $\pm 5 \text{ lb/ft}^3$ (80 kg/m^3) Cores taken from installed pavement should also



be tested in accordance with *ASTM C 1754*. The resulting measured density should be within $\pm 5\%$ of the average density of cores from the test panel. The installed pavement should be inspected for permeability and raveling.

When the installation and curing is completed, the permeability of the pavement

should be determined at several random locations in accordance with *ASTM C1701*. Measurement locations should be marked or otherwise identified for future measurements. Permeability results should not be used as a basis of acceptance. The measured permeability of the installed pavement can be used to estimate change in permeability under service conditions to determine maintenance and cleaning frequency. The owner should be advised on the results of these measurements and requirements for cleaning and maintenance of pervious concrete systems.

System Design

Proper design of the pavement system is critical. For best results, use pervious concrete to reduce and not to collect runoff.

Curb cuts, grade separation or vegetated swales should be used to isolate sediment sources from the pervious pavement. Pavement designers should not use earth mounds in the

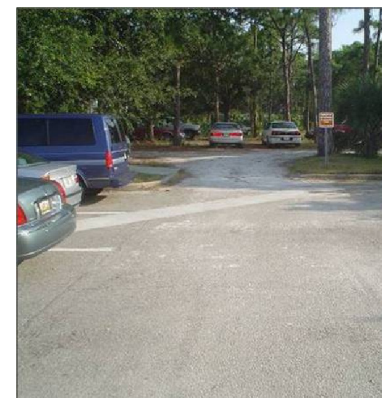


landscape areas. Suggested alternatives are rain gardens or grassy swales for additional stormwater management. Use of light woody ground cover like bark or sawdust, needles or any other vegetation that can migrate onto the pervious pavement is discouraged, as this debris increases the frequency of maintenance and may eventually reduce drainage capacities.

Drainage of stormwater from asphalt pavements and unpaved areas should be directed away from the pervious concrete pavement. Turning traffic scrubs the emulsion off the asphalt pavement and this fine asphalt grit clogs the permeable voids in pervious pavement. This material is very difficult to remove. Additionally, suspended materials in stormwater will reduce the permeability of pervious pavement and increase the frequency of cleaning and maintenance. Adjacent areas that drain to the pavement should be kept seeded and maintained to minimize sediment deposition. Failure to consider these issues, and to implement appropriate preventative measures, will generally require the owner to perform more frequent maintenance and cleaning procedures to maintain the infiltration capacity of the pervious concrete over its service life. Landscape

contractors should be advised of the special precautions required to avoid debris buildup on the pavement surface. Header curbs are curbs that sit flush with the top of pavement and extend below the surface.

This forms a vertical silt barrier and also restricts the lateral movement of water from the detention basin into the base materials of adjacent flexible pavements. It is strongly recommended that header curbs be utilized when pervious concrete is placed adjacent to asphalt pavement.



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. Where pervious concrete is used in combination with asphalt

pavements, signage should emphasize that the pervious concrete surfaces must NEVER be seal coated.

Importance of Maintenance

Pervious concrete pavement serves not only as the surface layer of a stormwater management system, but also as a vital part of a water filtration system. When rain falls, the pervious concrete filters sediments and pollution, and like any filter, it must be inspected regularly and cleaned periodically.

Maintenance of the pervious concrete pavement is the responsibility of the property owner/manager. A Maintenance Plan should be developed to assure proper maintenance procedures are followed. The baseline permeability measured in accordance with *ASTM C1701* after installation can be used as a baseline for establishing requirements for cleaning and maintenance and the frequency needed. Ideally, these measurements should be performed at the locations of the initial measurements. 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, like all stormwater BMP's, consists of monitoring the surface for sediment buildup and removing that buildup as needed, to maintain the pavement's permeability. Owners and property managers should follow good housekeeping practices to prevent accumulation of trash, sediment or other debris on the pervious surface. When proper maintenance techniques are followed, pervious concrete will provide a durable pavement and long-term stormwater management.

The NRMCA has developed the *Pervious Concrete Pavement Maintenance and Operations Guide* to assist property owners and managers in developing and following a maintenance plan. The guide is available at www.perviouspavement.org/downloads/pervious_maintenance_operations_guide.pdf.

Contractor Qualification

It is critical that the selected pervious concrete contractor understands the basic hydrologic and structural function of a pervious concrete pavement system and be able to recognize errors in the design, specification and construction of the system. The contractor should recognize potential problems with the pervious concrete mixture and appropriately advise the concrete supplier of his needs. The contractor should also discuss design and specification issues with the engineer on record.

ACI 522.1-13: Specification for Pervious Concrete Pavement requires that the concrete contractor shall provide evidence of employment of one NRMCA-certified Pervious Concrete Craftsman who must be on site, overseeing each placement crew; or three NRMCA-certified Pervious Concrete Installers who have received hands-on training in the construction of pervious concrete pavements. Certified personnel must be on site, working as members of the placement crew, during all pervious concrete placements. The NRMCA program certifies individuals and not companies. For more information on NRMCA's Pervious Concrete Contractor Certification program, visit www.nrmca.org/Education/Certifications/Pervious_Contractor.htm. If an alternative certification program is submitted, it should be demonstrated to be equivalent to the NRMCA program and administered with an appropriate level of integrity.

References

1. *ACI 522R-10: Report on Pervious Concrete*, American Concrete Institute (ACI), Farmington Hills, MI, www.concrete.org
2. *ACI 522.1-13: Specification for Pervious Concrete Pavement*, American Concrete Institute (ACI), Farmington Hill, MI, www.concrete.org
3. *ASTM C1688: Standard Test Method for Density and Void Content of Freshly Mixed Concrete*, ASTM International, West Conshohocken, PA, www.astm.org
4. *ASTM C1701: Standard Test Method for Infiltration Rate of In-Place Pervious Concrete*, ASTM International, West Conshohocken, PA, www.astm.org
5. *ASTM C1747: Determining Potential Resistance to Degradation of Pervious Concrete by Impact and Abrasion*, ASTM International, West Conshohocken, PA, www.astm.org
6. *ASTM C1754: Density and Void Content of Hardened Pervious Concrete*, ASTM International, West Conshohocken, PA, www.astm.org
7. *NRMCA Pervious Concrete Pavement Maintenance and Operations Guide*, National Ready Mixed Concrete Association (NRMCA), Silver Spring, MD, www.nrmca.org
8. *Pervious Concrete: Guideline to Mixture Proportioning and Research Report*, NRMCA Publication 2PE002, February 2009, National Ready Mixed Concrete Association (NRMCA), Silver Spring, MD, www.nrmca.org

