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Tech Brief

Permeable Concrete Pavements

This Tech Brief presents an overview of two types of permeable concrete pavement systems and their use. Information is provided on the structural and hydrological design, factors for successful construction and maintenance, and the performance of these systems.

BACKGROUND

Permeable pavements originated in Europe some 45 years ago. They initially started as various forms of open aggregate or grass pavements to promote water infiltration instead of runoff. They were reinforced with a variety of cell structures formed using concrete or plastic materials to enhance their load carrying capacity. Permeable pavements surfaced with cast-in-place concrete typically are referred to as “pervious concrete pavement” [FHWA 2012]. Permeable pavements surfaced with interlocking concrete block pavers are referred to as “permeable interlocking concrete pavement” (PICP) [Hein et al. 2015]. Other less used products include precast pervious concrete panels and paving stone units manufactured with open-graded aggregate. Figures 1 and 2 show examples of pervious concrete pavement and PICP.

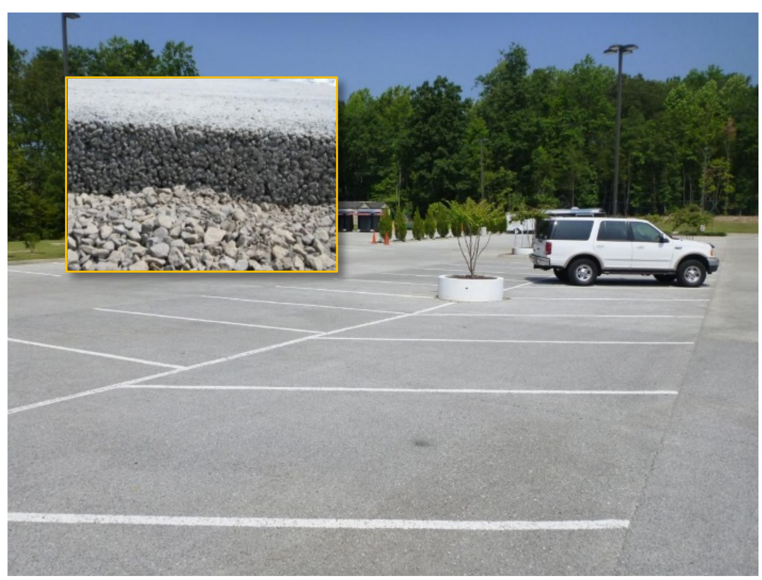

Figure 1. *Photo. Pervious concrete pavement – Williamsburg, Virginia*

U.S. Department of Transportation
Federal Highway Administration

__Figure 2.__ Photo. Permeable interlocking concrete pavement – Hilton Head, South Carolina

Figure 3 illustrates typical permeable pavement cross sections. As shown, permeable pavement systems consist of a surface of open-graded aggregate concrete or segmental concrete paving units with joints or openings that allow water to flow freely into an open-graded aggregate base/subbase reservoir. Water is collected and stored in the reservoir before it leaves the pavement structure. Figure 3b shows a partial infiltration design with drainage to accommodate some water that does not enter low infiltration soils.

Permeable pavements over high infiltration subgrade soils may not require underdrains, and these are called full infiltration designs (figure 3a). Other designs over expansive or fill soils or close to buildings may enclose the pavement structure with geomembrane (impermeable liner). An outlet pipe provides temporary storage and outflow control. This design approach can also be used for water harvesting. The use of a geomembrane to restrict infiltration into the soil subgrade is often called a low infiltration design (figure 3c). When stormwater is infiltrated through the system, the water is filtered, and suspended particles within the water are captured and held within the bedding and aggregate layers.

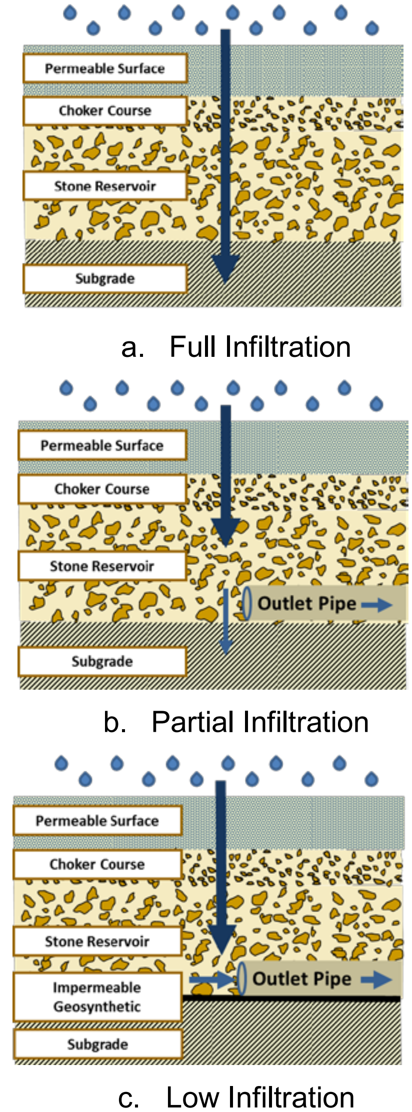

__Figure 3.__ Illustration. Typical permeable pavement cross section

Permeable pavements are an effective method for reducing stormwater runoff and pollutants from urbanized areas and can function well with minimal maintenance. Design pollutant removal efficiencies are on the order of 85 percent for total suspended solids, 35 percent for phosphorus, and 30 percent for nitrogen [Borst et al. 2010, Brattebo & Booth 2003, Collins et al. 2008, TRCA 2008]. Permeable pavement systems do not typically remove dissolved forms of chemicals, salts, metals, or nutrients.

Ecologically, excessive temperatures are another form of water pollution [Wardynski et al. 2013]. During the warmer months, urban environments enrich stormwater with thermal energy. Heat from rooftops and pavements is transferred to stormwater during a runoff event and conveyed to the receiving waters (creeks, rivers, lakes, etc.).

This process can create sharp and rapid increases in water temperature downstream that are harmful, and sometimes toxic, to aquatic organisms. Water retained in the reservoir layers of a permeable pavement can be cooled down prior to its discharge. Water that infiltrates becomes part of the groundwater supply in the water cycle, further promoting natural temperature balancing.

The design of permeable pavement requires a balance in providing a structurally sufficient pavement to withstand traffic loading while achieving stormwater management/hydrologic design goals. High-quality construction techniques and proper maintenance of permeable pavements are critical to their longevity. Permeable pavements are not suitable for every application, but with the proper design, construction, and maintenance, they provide a low-impact, green alternative that is worth considering. They may be more cost-effective than conventional pavements by conserving land use (by not requiring runoff detention facilities) and by reducing drainage infrastructure.

Specialized installation is important for pervious concrete to attain a highly interconnected void content with strong inter-particle binding. Typically, pervious concrete has little or no fine aggregate and has just enough cementitious paste to coat the coarse aggregate particles while preserving the interconnectivity of the voids. A water-to-cementitious materials (w/cm) ratio of 0.28 to 0.40 with a void content of 15 to 25 percent is common. The addition of a small amount of fine aggregate reduces the void content but can increase the strength, allowing higher traffic loads. Additives for pervious concrete include fibers to improve strength, water reducers to improve strength and workability, hydration-controlling admixtures to improve working time, and viscosity-modifying admixtures to improve flow and discharge from concrete supply vehicles. The construction and placement of pervious concrete requires special attention to details such as cement hydration and compaction of the mixture to ensure the long-term durability of the pavement.

Conventional interlocking concrete pavement consists of high-strength impermeable concrete blocks laid over a sand bedding course with sand-filled joints. This type of system is not very permeable. To make it permeable, both the sand bedding and joint filler for PICPs is replaced with a stone chip material that provides both friction to prevent block movement and permeability to allow the infiltration of water.

The American Concrete Paving Association (ACPA) and Interlocking Concrete Pavement Institute (ICPI) have published guidance for the design, construction, and maintenance of permeable concrete pavements (figure 4). The American Concrete Institute (ACI) and the American Society for Testing and Materials (ASTM) have published test methods for permeable concrete pavement placement. In addition, the American Society of Civil Engineers (ASCE) is expected to publish a new standard guideline for the design, construction, and maintenance of permeable concrete pavements in 2016.

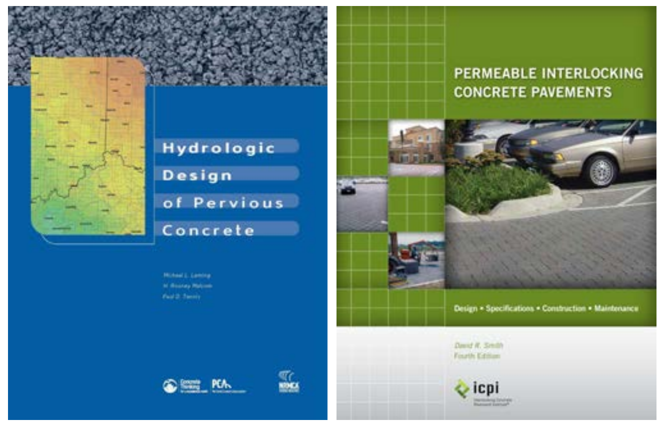

Figure 4. *Photos. Permeable pavements guides*

DESIGN

The design of permeable pavements takes into account two design components: the structural design to withstand the anticipated traffic loading and the hydrologic design to achieve stormwater management goals.

Structural Design

The most common structural analysis procedure for PICP follows the requirements of the American Association of State Highway and Transportation Officials (AASHTO) Guide for Design of Pavement Structures as modified by ICPI for their Permeable Design Pro software [AASHTO 1993, ICPI 2016].

The AASHTO pavement structural design method is summarized using the following equation (figure 5):

$$\mathrm{LogW} = Z_R \times S_0 + 9.36 \times \log(SN+1) - 0.20 + \frac{\log\left[\frac{p_i - p_t}{p_i - 1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log(M_R) - 8.07$$

Figure 5. *Equation. AASHTO pavement structural design equation*

A brief description of the key pavement structural design elements and typical values for PICP is provided below:

W The AASHTO design procedure characterizes traffic loads in terms of equivalent single axle loads (ESALs). One ESAL represents the application of a single 18,000-lb (80-kN) axle load. Permeable pavements in North America typically have been designed for applications not exceeding about 1 million ESALs [Smith 2011].

Z_R The design reliability level (factor of safety) takes into account the probability that the pavement as designed may not provide satisfactory service during the intended period of service. Critical facilities typically are assigned reliability factors of 95 percent or higher. Low traffic volume roadways and less critical facilities may be assigned reliability values of 75 percent or less.

S_0 The overall standard deviation takes into account the variability associated with design and construction inputs, including variability and material properties, subgrade, traffic, and environmental exposure. For PICP, a standard deviation of 0.44 is appropriate.

SN The structural number of the pavement calculated as the sum product of the structural layer coefficient, a_i, and the layer thickness, d_i.

a_i The layer coefficient is a measure of the strength of an individual layer i. Paver and bedding materials used for PICP are in the range of 0.2 to 0.3 and 0.06 to 0.09 for open-graded base and subbase materials, respectively.

d_i Thickness for individual layer i.

p_i This is the initial serviceability of the as-constructed pavement. An initial serviceability of 4.2 would be considered reasonable for PICP.

p_t The terminal serviceability of the pavement, or the point in time at which rehabilitation of the pavement would be considered necessary to keep it in a serviceable condition. A value of 2.5 would be considered reasonable for PICP.

M_R The characterization of the subgrade is a factor for both the structural design and the infiltration of water into the subgrade (if the goal of the permeable pavement design is to infiltrate water into the subgrade). The design M_R value will depend on the soil properties and its moisture condition. The relationship between soil permeability and in-place soil density achieved during construction is necessary to establish a relationship between subgrade infiltration capability and the structural capacity necessary to support the design traffic.

Pervious concrete structural design is based on the StreetPave system as modified by the ACPA for their PerviousPave software [ACPA 2016]. This procedure uses fatigue of the pervious concrete as the primary failure mode for the pavement. The fatigue damage for the pavement is shown in the following equation (figure 6):

$$FDtotal = FDsingle + FDtandem + FDtridem$$

Figure 6. *Equation. Total fatigue damage*

where:

FD_{total} = total fatigue damage, %

FD_{single} = fatigue damage from single axle loads, %

FD_{tandem} = fatigue damage from tandem axle loads, %

FD_{tridem} = fatigue damage from tridem axle loads, %

Fatigue damage for each axle type is determined using Miner's damage hypothesis [Miner 1945] shown in the equation below (figure 7):

$$FD = \frac{n}{N_f}$$

Figure 7. *Equation. Miner's damage equation*

where:

n = number of load applications

N_f = allowable applications before failure

The number of load applications is determined using the same traffic analysis as outlined in the AASHTO design procedure, except the heavy vehicles are divided into the number of single, tandem, and tridem axle load categories. The total allowable applications to failure can be estimated using the following equation (figure 8):

$$logN_f = \left[\frac{-SR^{-10.24}\log(1-P)}{0.0112}\right]^{0.217}$$

Figure 8. *Equation. Total allowable applications to failure*

where:

N_f = allowable applications before failure

SR = stress ratio, %

The stress ratio is a function of flexural strength and the equivalent stress, which is a function of load weight. The higher the number of load repetitions, the lower the stress ratio. For load repetitions of 100 axle loads, the stress ratio would be in the order of 0.8. For load repetitions greater than 1 million, the stress ratio is 0.5.

The probability of failure is calculated using the following equation (figure 9):

$$P = 1 - R * \frac{SC}{50}$$

Figure 9. *Equation. Probability of failure*

where:

P = probability of failure, %

R = reliability, %

SC = percent slabs cracked at the end of the design life (assumed at 15%)

The stress ratio is the stress divided by the strength of the material as shown in the following equation (figure 10):

$$SR = \frac{\sigma_{eq}}{MR}$$

Figure 10. *Equation. Stress ratio*

where:

SR = stress ratio, %

σ_{eq} = equivalent stress, psi (MPa)

MR = flexural strength of the concrete, psi (MPa)

The flexural strength of typical conventional concrete pavement ranges from about 650 to 945 psi (4.5 to 6.5 MPa). The flexural strength of pervious concrete typically ranges from about 290 to 435 psi (2 to 3 MPa).

Hydrologic Design

The approach used for the hydrologic design of permeable pavements depends on the goals of a specific project. Hydrologic design goals may take a number of forms, including:

- **Stormwater volume control** – Maintain, or improve upon, pre-development stormwater discharge conditions.
- **Water quality** – Meet minimum volume capture or sizing criteria (e.g., capture first 1 inch [25 mm] of rainfall) over the contributing drainage area to accommodate first flush and/or contaminant removal efficiencies (e.g., 80 percent total suspended solids removal).
- **Water thermal characteristics** – Maintain, or improve upon, pre-development temperature of surface or groundwater discharging to the receiving body.
- **Flood/peak flow control** – Retain or detain specific design storms (e.g., 100-year, 24-hour duration storm event) to prevent downstream erosion or capacity limitations with existing stormwater infrastructure.
- **Downstream erosion control** – Eliminate or minimize downstream erosion potential by limiting critical discharge or reducing outflow volumes.
- **Infiltration/recharge targets** – Maintain or increase groundwater recharge rates to prescribed targets or thresholds in order to maintain pre-development water budget requirements.
- **Ecosystem and habitat** – Maintain the existing hydrologic regime, including surface and groundwater interactions and shallow base flow necessary to maintain significant vegetation communities, wetlands, and aquatic habitat.

There are several stormwater models that could be used to complete the hydrologic design for permeable pavements. Depending on the hydrologic design goals, appropriate models may include the following:

Simple volumetric runoff estimation methods – These models generate an estimated runoff volume for a specified design storm depth but do not assign a hydrograph “shape” to this runoff volume. Examples include the Natural Resources Conservation Service (NRCS) Curve Number method [USDA 1986], the volumetric runoff coefficient method, and others.

Event-based hydrograph estimation methods – These models generate an estimated runoff hydrograph for a specified design storm. Examples include the Watershed Hydrology Program (WinTR-20), Small Watershed Hydrology (Win TR-55), Santa Barbara Unit Hydrograph (SBUH), HEC-1 Flood Hydrograph Package, HydroCAD Stormwater Modeling (HydroCAD), ICPI Permeable Design Pro, and others.

Continuous simulation modelling programs – These models generate long-term runoff hydrographs from multiple storms based on a real observed continuous rainfall record and other hydrologic inputs; many also have the capability to route the hydrograph through stormwater management facilities that conduct continuous analysis of transient inflows, outflows, and storage levels. Examples include the U.S. Environmental Protection Agency Stormwater Management Model (SWMM), the Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS), Source Loading and Management Model for Windows (WinSLAMM), Integrated Design Evaluation and Assessment of Loadings (IDEAL), and others.

Design Optimization

Figure 11 is a flowchart illustrating the process to optimize the design of a permeable pavement. The following sections discuss the components of this process.

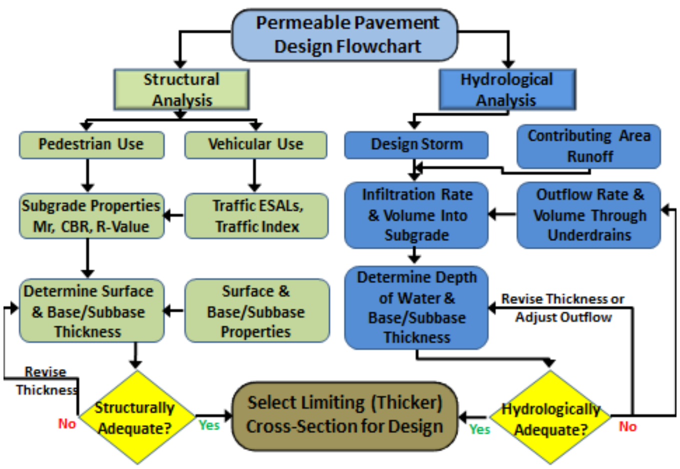

Figure 11. *Permeable pavement design flowchart (Hein & Smith 2011)*

Cold Climate Design and Frost Considerations

In northern climates, freeze-thaw is one of the principal causes of pavement damage. Guidance for pavement design typically includes the use of a coarse stone reservoir that acts a capillary barrier, thereby preventing the wicking of moisture either from an infiltration reservoir or from the subgrade into the pavement subbase. The use of thickened pavement subbase, well drained subbase materials, and sub-drains has been shown to effectively limit freeze-thaw damage [Henderson & Tighe 2011].

Detail Design

Geometrics – Longitudinal grades < 5 percent.

Subgrade infiltration – Determine the subgrade soil permeability by testing in situ. Permeability determination should include a single or double ring infiltrometer or in situ falling head permeability tests (using a lined borehole). Percolation tests using an unlined borehole or a test pit percolation test (often used for the design of septic drain fields) are not recommended because they can overestimate soil infiltration rates. Further details on permeability testing methods are provided in ASTM D5126.

Pervious concrete – Thicknesses of 5 to 8 inches (125 to 200 mm) are made permeable by removing the fine materials from the aggregate gradation. Ensure uniform density and compaction during construction and include mixture design modification additives such as natural or synthetic fibers to improve durability, as pervious concrete is weaker and more susceptible to raveling than conventional concrete.

Permeable interlocking concrete pavers – The paving units themselves are not permeable. Permeability is achieved by spacing the pavers a set distance from each other and filling the space with a permeable aggregate. The standard paver thickness for vehicular traffic is 3 1/8 inches (80 mm). Thicker, 4-inch (100-mm) pavers are used for heavy-duty applications such as ports and intermodal pavers. Pavers require lateral support to ensure that the units act as a system to transfer loading.

Aggregate layers – Aggregates should be angular, hard, durable, clean, low in fines content, and graded for maximum storage capacity (high porosity). Stone reservoir aggregates typically have a maximum size in the order of 3 inches (75 mm). This large gradation is difficult to fine-grade for the pavement surface, so another layer (base layer) is typically placed on top of the stone reservoir layer. The base layer is graded finer, with a maximum aggregate size of 1 1/2 inches (40 mm). The selection of the gradation of the base layer should be checked using choking criteria to reduce the risk of aggregate movement between the base and the stone reservoir layer. The choking criteria also apply to the use of a bedding course of stone chip with a maximum aggregate size of 3/8 inches (9.5 mm), which is provided between the pavers and the open-graded base layer.

Erosion protection – The erodibility of adjacent native soils should be assessed to determine the potential for erosion. Increased erosion protection through the use of erosion blankets, rip rap, granular sealing, placement of drainage gaps, etc. may be required.

Subgrade Compaction – To facilitate water infiltration, guidelines published by State stormwater agencies for the construction of permeable pavement generally recommend not compacting the subgrade. Although an uncompacted subgrade benefits water infiltration, it tends to consolidate when saturated under vehicular loading, causing settlement or other damage to the pavement structure. Therefore, the design may need to balance infiltration against compaction.

Expansive soils – In general, permeable pavements are not recommended for subgrade soils that are susceptible to swelling and/or heaving such as silt, fine sands, and high-plasticity clays. Ensuring rapid drainage of water from the stone reservoir and through the use of an impermeable liner can help mitigate these effects.

Geosynthetics – Impermeable liners may be used to prevent washouts and frost heaving, or for expansion of moisture-sensitive subgrade soils. Impermeable liners typically consist of heavy-duty polyethylene. Geotextiles should conform to subsurface drainage requirements in AASHTO M-288, Geotextiles for Highway Applications [AASHTO 2006]. Geotextile strength properties should conform to Class 1 (highest strength) if exposed to severe installation conditions with greater potential for geotextile damage.

Underdrains – It is considered best practice to install underdrains for all permeable pavement applications and connect to a positive outlet away from the pavement structure. Longitudinal underdrains should be placed below the bottom of the stone reservoir elevation to ensure that they are protected during construction and ensure that complete drainage can be provided if needed. The amount of water stored in the stone reservoir for infiltration can be controlled by the elevation at which the underdrains begin to discharge to surface water.

Edge restraints – Edge restraints are required for all PICP and typically are included for pervious concrete as well. For roadway applications, edge restraints should consist of concrete curbing.

Slopes – Permeable pavements can be designed for sloped surfaces. Subgrades can be bermed and piped to control down-slope flows and encourage infiltration through the use of check dams. The design for sloped systems should ensure that water cannot surge from below and exit the surface of the pavement. For low-infiltration designs, flows can be slowed with check dams or baffles, allowing some filtering through the aggregate base/subbase prior to discharge though piping systems. The flow barriers for check dams and baffles can be concrete, geotextile-wrapped aggregate dams or transverse trenches excavated into the subgrade. Figure 12 shows an example of a flow barrier.

Figure 12. *Aggregate and impermeable liner flow barrier*

Urban design features – The complete cross section of the pavement is usually underlain by granular materials. These materials need to be protected from erosion by providing them with a hard surface. Subsurface water flow typically is directed to longitudinal subdrains connected to the storm drain system. Other urban design features, such as curbs, gutters, safety barriers, retaining walls, and noise barrier walls, may also be included in the design.

Supplementary surface drainage features – The permeable pavement may not have sufficient surface permeability to infiltrate water from major storm events. In these cases, supplementary surface drainage features such as curb cutouts may be provided in the design to direct water from the pavement surface to other stormwater features.

Adjacent buildings and other pavements – Permeable pavements may be constructed adjacent to buildings or conventional pavements with dense-graded bases. Building foundations should be protected from water infiltration by sloping the permeable pavement away from the building, protecting the building foundation by waterproofing or installing an impermeable liner vertically against the foundation wall or conventional pavement and along the nearest sides and bottom of the permeable pavement.

Monitoring well – For large-scale applications and demonstration projects, the permeable pavement should include a vertical perforated pipe, 4 to 6 inches (100 to 150 mm) in diameter, that serves as an observation well. The bottom of the pipe can penetrate the subgrade and be protected and supported during base/subbase filling and compaction. The pipe should be located near the permeable pavement system low point at least 3 ft (1 m) away from the edge of the permeable pavement.

CONSTRUCTION

The construction of permeable pavements is similar to the construction of a pavement incorporating an open-graded drainage layer. Care must be taken during construction to prevent damage and contamination of the permeable pavement system. A preconstruction meeting is highly recommended to identify sequencing and controls to reduce the potential for clogging of the permeable pavement surface as well as the other unique construction considerations for permeable pavement:

Up-gradient surfaces that may contribute run-on to the permeable pavement during construction should be stabilized or the permeable pavement should be protected by using silt fences.

Due to the diversity of activities taking place during roadway construction, protecting the permeable pavement materials from contamination is critical; contamination of these materials could potentially result in subsequent migration of contaminants to surface water and/or groundwater.

Double washing of aggregates may be necessary to ensure a fines content of less than 2 percent.

Compaction of the subgrade is necessary to support the design traffic, and it would not be practical to limit compaction of the subgrade directly below a permeable pavement.

Specific locations should be identified as construction access points so that travel of equipment across the permeable pavement is avoided.

Underground utilities should be protected from damage due to construction activities. As the permeable pavement infiltrates water into the subgrade, it may be necessary to protect some utilities from water damage, such as water intrusion and/or preferential flow of infiltrated water through utility trenches. Utility companies should be contacted to determine if the utilities require special attention.

MAINTENANCE

Proper and timely maintenance is critical for permeable pavement systems. The surface of the permeable pavement should be properly maintained to provide a durable and safe driving surface, as well as to minimize the clogging potential. The ability of the system to effectively infiltrate water can be affected by pavement use and maintenance practices. Extensive use of winter sanding and biomass loading from surrounding vegetation (trees, grass, weeds, etc.) can substantially reduce system infiltration and should be avoided where possible.

In the past, conventional wisdom held that regular preventive maintenance activities such as vacuum sweeping could help maintain system permeability. In areas where permeability was reduced by sanding, permeability can be restored by more aggressive maintenance practices, such as power washing and regenerative air vacuuming.

Preventive Maintenance

Preventive maintenance will help to ensure the long-term durability of the pavement. Key activities include:

- Inspect and monitor the integrity and function of the permeable pavement.
- Permeability checks should be completed using standard infiltration tests (ASTM C1701-09 for pervious concrete and ASTM C1781-13 for PICP).
- Visual inspection of clogging and durability.
- Inspect permeable pavements after major rain events to ensure pavement structural integrity and surface infiltration.
- Perform vacuum sweeping at regular intervals in high-risk areas, such as areas where sources of sediment or organic debris are higher and where the ratio of tributary to pervious area is high. It is recommended that vacuum sweeping be performed twice per year, or more often in areas subject to higher concentrations and deposition rates of dust and debris, biomass loading, etc. [Henderson & Tighe 2011].
- Restore any joint filler loss for PICP.
- Properly maintain upstream drainage pathways and landscaping to minimize additional water and run-on of sediment and debris.

- Inspect and clean all outlet structures to ensure positive water flow from the pavement.
- Provide inspection ports and regularly monitor drainage rates of the stone reservoir to identify if clogging of underlying soils or outlet structures has occurred; remedy to avoid damage associated with extended ponding.
- Eliminate the use of sand for winter maintenance activities.
- Clearing snow completely after every storm is recommended. Special plow blades can be used but are not necessary. Raised plow blades are not recommended, and any bouncing movement of the vehicle may result in damage to the permeable pavement surface.
- Limit the use of winter deicing chemicals for sensitive vegetation areas, sensitive receiving waters, or for pavements designed to capture and reuse water. See Winter Maintenance Considerations section below.

Winter Maintenance Considerations

Properly designed permeable surfaces can be resistant to freeze-thaw related damage [Henderson & Tighe 2011]. Due to the higher porosity of the surface material, winter deicing chemicals are rarely required. Sanding operations should be avoided, as the sand can lead to increased clogging. Deicing chemicals should be used moderately.

After snow plowing operations, snow may remain in the open voids of the surfaces temporarily. Studies have shown that heat stored within the permeable pavement will assist in melting the snow trapped in the open pore structure immediately following snow plowing operations [Delatte et al. 2007]. In cold climates, snow plows may cause abrasion of the surface. Snow plow damage may be reduced by using wide blades and minimizing back-blading [Kevern 2010].

Permeability Restoration

The permeability of these pavements will be reduced over time due to clogging. Permeability may be restored through:

- Restorative vacuum sweeping using specialized, full vacuum street cleaning equipment.
- Power washing the pavement. However, this should be considered a “last resort” in maintaining the surface course, as it may break up and drive contaminants from the surface and upper layers of the stone reservoir deeper in the pavement, resulting in a reduction in the service life of the overall pavement.

If the observed performance of the pavement indicates a significant reduction in permeability from the last inspection, complete infiltration testing in accordance with local or project-specific requirements is warranted. In the absence of site-specific requirements, use the simplified infiltration test, chapter 18 of the North Carolina Department of Environment and Natural Resources best management practices [NCDENR 2012] with the representative dewatering times for simplified infiltration testing:

- Newly installed/recently maintained: <30 seconds.
- Acceptable—continue preventative maintenance: 30-60 seconds.
- Partially clogged—restorative maintenance should be scheduled: 60-90 seconds.
- Clogged—requires restorative maintenance immediately: >90 seconds.

PERFORMANCE

The performance of a permeable pavement system is usually governed by its ability to infiltrate and treat stormwater. Most permeable pavements are constructed on pathways, parking areas, and low-volume roadways and do not tend to receive heavy, frequent traffic.

As the pavement ages, it may be necessary to treat localized areas to restore the pavement surface condition. This may include removal and replacement of pervious concrete or pavers, leveling or addition of new aggregate materials, removal and replacement of jointing material, etc. Edge restraints should be inspected to ensure that they are performing their required function. Outlet drains and observation wells should be inspected to confirm continued drainage from the pavement structure. Areas up-slope of the permeable pavement should be examined for potential sources of contaminants that may reduce system permeability.

A maintenance plan should be developed and followed. The plan should include documentation of key design features of the system, operational constraints (e.g., restrict use of winter sand, maintain overflow and outflow features, monitor observation wells), inspection schedules and checklists, maintenance procedures, rehabilitation activities and timing, and other such factors. Personnel responsible for the maintenance and operation of the permeable pavement should be identified and provided with the maintenance plan. The maintenance plan should be reviewed and modified based on actual use and operation of the facility.

The structural design life (performance period) of a permeable pavement is the length of time until it is no longer able to satisfy the performance requirements. Structural rehabilitation typically addresses shear failure of the bedding, base, subbase, or subgrade soils, often indicated by surface deformation (rutting) from wheel loads for PICP or cracking of the pervious concrete. At the end of the structural design life, some settlement, rutting, cracked pervious concrete, some damaged pavers, loss of jointing material, and/or edge restraint damage can be expected. These distresses can be addressed by removing and replacing the damaged areas to cost-effectively extend the service life of the pavement.

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