5.4.8 Permeable Pavement

Variations: permeable interlocking pavers, concrete grid pavers, plastic reinforced grid pavers.

Description: Permeable pavements are alternative paving surfaces that allow stormwater runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated. Porous paving systems have several design variants. The four major categories are: 1) pervious concrete; 2) modular block systems; 3) porous asphalt and 4) grass and gravel pavers. All have a similar structure, consisting of a surface pavement layer, an underlying stone aggregate reservoir layer and a filter layer or fabric installed on the bottom.

Key Design Criteria:

- **Contributing area**: External drainage area should generally not exceed twice the surface area of the permeable pavement.
- **Pavement slope**: ≤ 6%

Site Constraints:

- **Hotspots**: Not suitable
- **High loading situation**: Not intended to treat sites with high sediment or trash/debris loads.
- **Water table**: min. 2 feet
- **Setbacks from**:
  - Water supply well: min. 100 feet
  - Septic systems: min. 50 feet min.
  - Dry or wet utility lines: min. 5 feet down-gradient.
- **Soil**: No constraint, except soil C or D usually requires an underdrain.
- **Limitations**: It should not be used for high speed road

Maintenance:

- Inspect the surface of the pavement for evidence of sediment deposition, organic debris, staining or ponding that may indicate surface clogging.
- Vacuum sweeping regularly
- Inspect the structural integrity of the pavement surface,
- Check inlets, pretreatment cells and any flow diversion structures for sediment buildup
- Inspect the condition of the observation well

Advantages:

- Can increase aesthetic value
- Provides water quality treatment
- Dual use for pavement structure and stormwater management
- Meet partial or full storage requirements for local stormwater detention standards
- Retrofit existing developed areas, especially highly impervious areas

Disadvantages:

- Cost
- Maintenance
- Limited to low traffic areas with limited structural loading
- Potential issues with handicap access
- Infiltration can be limited by underlying soil property
- Not effective on steep slopes

Design Checklist:

- Check feasibility for site
- Check permeable pavement sizing guidance and make sure there is an adequate footprint (can be split to multiple areas)
- Calculate design volume
- Design Permeable Pavement in accordance with design criteria and typical details
- Submit plans
1. Design

1.1 Application

1.1.1 Types

The pavement course should be selected based on the project’s budget and desired appearance as well as the types of loadings that will be applied to the permeable pavement. Designers may propose other types of pavement courses but they will be responsible for showing that their proposed design will function well both hydraulically and structurally in both short and long term. See Table 1 for a summary of the most commonly used pavement courses and some of the pros and cons of each.

Table 1: Types of permeable pavement.

<table>
<thead>
<tr>
<th>Permeable Interlocking Concrete Pavers (PICP)</th>
<th>PICPs are a type of unit paver system that maintains drainage through gaps between the pavers filled with small, uniformly graded gravel. The pavers are bedded on a gravel layer that provides uniform support and drainage. <strong>Pros:</strong> Well suited for plazas, patios, small parking areas, parking stalls and residential streets. PICP is easy to renovate if it becomes clogged. As compared to PC and PA, PICP is easier and less costly to renovate if it becomes clogged. The Interlocking Concrete Pavement Institute offers a PICP Specialist Certification program for contractors. <strong>Cons:</strong> PICP often has the highest initial cost for materials and installation. The regular maintenance of PICP is more expensive than PC and PA because of the need to refill the gravel after street sweeping and the greater occurrence of weeds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pervious Concrete (PC)</td>
<td>PC is produced by reducing the fines in a conventional concrete mix to maintain interconnected void space for drainage. Pervious concrete has a coarser appearance than standard concrete. <strong>Pros:</strong> PC is the most structurally sound permeable course, making it a good choice for travel lanes or larger vehicles in addition to parking areas, patios and residential streets. The regular maintenance costs are lower than PICP and CGP. PC has a design guide, construction specification and a contractor certification program managed by independent organizations (American Concrete Institute and National Ready Mixed Concrete Association). <strong>Cons:</strong> Mixing and installation must be done correctly or the PC will not function properly. It may be difficult to restore permeability to the PC after a significant loss of initial permeability without removing it and installing a new course.</td>
</tr>
</tbody>
</table>

Parking lot of St. John Lutheran church, Knoxville, TN (Source: SMART Center)

Hallsdale PUD parking lot, Powell, TN (Source: SMART Center)
| Pervious Asphalt (PA) | Porous asphalt is very similar to standard asphalt except that the fines have been removed to maintain interconnected void space. PA may not be approved unless the designer shows that the design provides equal or better performance than PICP and PC.

**Pros:** May be more economical in initial cost than PC for large scale operations (greater than 100,000 square feet).

**Cons:** PA does not offer the structural strength of PC and it has a much shorter design life, typically less than 15 years. There are also concerns about unknowingly using asphalt sealants or overlays that would eliminate the permeability of the PA. Mixing and installation must be done correctly or the PA will not function properly. |

| Concrete Grid Pavers (CGP) | CGPs are an “older cousin” to PICPs and have relatively larger open areas that are filled with gravel, sand, or even a loamy sand top soil. CGPs may not be approved for vehicular loads unless the designer shows that the design provides equal or better performance than PICP and PC.

**Pros:** CGP is a somewhat less expensive paver option than PICP.

**Cons:** The vast majority of sites observed exhibited problems with waviness (differential settling) or clogging caused by soil and vegetation in the grids (or both). CGP should only be used for non-travel purposes or occasional use (fire lanes, police cut through lanes, etc). |

| Plastic Turf Reinforcing Grid (PTRG) | PTRG, also called geocells, consist of flexible plastic interlocking units that allow for infiltration through large gaps filled with gravel or topsoil planted with turf grass. PTRG is well suited to provide for emergency vehicle access over lawn areas. For other uses, PTRG may not be approved unless the designer shows that the design provides equal or better performance than PICP and PC.

**Pros:** Reduces expenses and maximizes lawn area.

**Cons:** PTRG has less structural strength than the other pavement course options, especially if used under wet conditions. Also, the use of soil and vegetation between the grids makes it prone to clogging. |
Table 2: Comparative properties of 3 major permeable pavement types.

<table>
<thead>
<tr>
<th>Design Factor</th>
<th>Porous Concrete (PC)</th>
<th>Pervious Asphalt (PA)</th>
<th>Permeable interlocking concrete pavers (PICP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale of application</td>
<td>Small and large scale paving applications</td>
<td>Small and large scale paving applications</td>
<td>Micro, Small and large scale paving applications</td>
</tr>
<tr>
<td>Pavement thickness(^1)</td>
<td>5 to 8 inches</td>
<td>3 to 4 inches</td>
<td>3 inches(^1,8)</td>
</tr>
<tr>
<td>Bedding layer(^1,8)</td>
<td>None</td>
<td>2 inches of No. 8 stone</td>
<td>2 inches of No. 8 stone over 3 to 4 inches of No. 57</td>
</tr>
<tr>
<td>Construction properties(^2,8)</td>
<td>Cast in place, seven day cure, must be covered</td>
<td>Cast in place, 24 hour cure</td>
<td>No cure period; manual or mechanical installation of pre-manufactured units, over 5000 sf/day per machine</td>
</tr>
<tr>
<td>Design permeability(^4)</td>
<td>10 feet/day</td>
<td>6 feet/day</td>
<td>2 feet/day</td>
</tr>
<tr>
<td>Construction cost(^5)</td>
<td>$2.00 to $6.50/sq. ft.</td>
<td>$0.50 to $1.00/sq. ft.</td>
<td>$5.00 to $10.00/sq. ft.</td>
</tr>
<tr>
<td>Min. batch size</td>
<td>500 sq. ft.</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Longevity(^6)</td>
<td>20 to 30 years</td>
<td>15 to 20 years</td>
<td>20 to 30 years</td>
</tr>
<tr>
<td>Overflow</td>
<td>Drop inlet or overflow edge</td>
<td>Drop inlet or overflow edge</td>
<td>Surface, drop inlet or overflow edge</td>
</tr>
<tr>
<td>Temperature reduction</td>
<td>Cooling in the reservoir layer</td>
<td>Cooling in the reservoir layer</td>
<td>Cooling at the pavement surface &amp; reservoir layer</td>
</tr>
<tr>
<td>Colors/texture</td>
<td>Limited range of colors and textures</td>
<td>Black or dark grey color</td>
<td>Wide range of colors, textures, and patterns</td>
</tr>
<tr>
<td>Traffic bearing capacity(^7)</td>
<td>Can handle all traffic loads, with appropriate bedding layer design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface clogging</td>
<td>Replace paved areas or install drop inlet</td>
<td>Replace paved areas or install drop inlet</td>
<td>Replace permeable stone jointing materials</td>
</tr>
<tr>
<td>Other issues</td>
<td>Avoid seal coating</td>
<td></td>
<td>Snowplow damage</td>
</tr>
<tr>
<td>Design reference</td>
<td>American Concrete Institute # 522.1.08</td>
<td>Jackson (2007); NVRA (2008)</td>
<td>Smith (2006); ICPI (2008)</td>
</tr>
</tbody>
</table>

1 Individual designs may depart from these typical cross-sections, due to site, traffic and design conditions.
2 Reservoir storage may be augmented by corrugated metal pipes, plastic arch pipe, or plastic lattice blocks.
3 ICPI (2008)
4 NVRA (2008)
5 WERF 2005 as updated by NVRA (2008)
6 Based on pavement being maintained properly, Resurfacing or rehabilitation may be needed after the indicated period.
7 Depends primarily on on-site geotechnical considerations and structural design computations.
8 Stone sizes correspond to ASTM D 448: Standard Classification for Sizes of Aggregate for Road and Bridge Construction.
1.1.2 Design Scales
Permeable pavement can be installed at the following three scales:

1. **Micro-Scale Pavements**, which applies to converting impervious surfaces to permeable ones on small lots and redevelopment projects, where the installations may range from 250 to 1000 square feet in total area. Where redevelopment or retrofitting of existing impervious areas results in a larger foot-print of permeable pavers (small-scale or large-scale, as described below), the designer should implement the Load Bearing, Observation Well, Underdrain, Soil Test, and Building Setback criteria associated with the applicable scale.

2. **Small-scale pavement** applications treat portions of a site between 1000 and 10,000 square feet in area, and include areas that only occasionally receive heavy vehicular traffic.

3. **Large scale pavement** applications exceed 10,000 square feet in area and typically are installed within portions of a parking lot.

### Table 3: Three design scales for permeable pavement.

<table>
<thead>
<tr>
<th>Design Factor</th>
<th>Micro-Scale Pavement</th>
<th>Small-Scale Pavement</th>
<th>Large-Scale Pavement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impervious area treated</td>
<td>250 to 1000 sq. ft.</td>
<td>1000 to 10,000 sq. ft.</td>
<td>More than 10,000 sq. ft.</td>
</tr>
<tr>
<td>Typical Applications</td>
<td>Driveways, Walkways, Court Yards, Plazas, Individual Sidewalks</td>
<td>Sidewalk Network, Fire Lanes, Road Shoulders, Spill-Over Parking, Plazas</td>
<td>Parking Lots with more than 40 spaces, Low Speed Residential Streets</td>
</tr>
<tr>
<td>Most Suitable Pavement</td>
<td>PICP, PTRG, PRP, and CGP</td>
<td>PA, PC, PICP, and CGP</td>
<td>PA, PC and PICP</td>
</tr>
<tr>
<td>Load Bearing Capacity</td>
<td>Foot traffic Light vehicles</td>
<td>Light vehicles</td>
<td>Heavy vehicles (moving &amp; parked)</td>
</tr>
<tr>
<td>Reservoir Size</td>
<td>No</td>
<td>Yes, impervious cover up to twice the permeable pavement area may be accepted as long as sediment source controls and/or pretreatment is used</td>
<td></td>
</tr>
<tr>
<td>Observation Well</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Underdrain</td>
<td>Rare</td>
<td>Depends on the soils</td>
<td>Back-up underdrain</td>
</tr>
<tr>
<td>Required Soil Tests</td>
<td>One per practice</td>
<td>Two per practice</td>
<td>One per 5000 sq. ft of proposed practice</td>
</tr>
<tr>
<td>Building Setbacks</td>
<td>5 feet down-gradient 25 feet up-gradient</td>
<td>10 feet down-gradient 50 feet up-gradient</td>
<td>25 feet down-gradient 100 feet up-gradient</td>
</tr>
</tbody>
</table>

Regardless of the design scale of the permeable pavement installation, the designer should carefully consider the expected traffic load at the proposed site and the consequent structural requirements of the pavement system. Sites with heavy traffic loads will require a thick aggregate base and, in the case of porous asphalt and pervious concrete, may require the addition of an admixture for strength or a specific bedding design. In contrast, most micro-scale applications should have little or no traffic flow to contend with.
1.2 Major Design Elements

Table 4: Pervious Pavement Design Elements.

<table>
<thead>
<tr>
<th>Available Space</th>
<th>A prime advantage of permeable pavement is that it does not normally require additional space at a new development or redevelopment site, which can be important for tight sites or areas where land prices are high.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soils</td>
<td>Soil conditions do not constrain the use of permeable pavement, although they do determine whether an underdrain is needed. Impermeable soils in Hydrologic Soil Groups (HSG) C or D usually require an underdrain, whereas HSG A and B soils often do not. In addition, permeable pavement should never be situated above fill soils unless designed with an impermeable liner and underdrain. If the proposed permeable pavement area is designed to infiltrate runoff without under drains, it must have a minimum infiltration rate of 0.5 inches per hour. Initially, projected soil infiltration rates can be estimated from USDA-NRCS soil data, but they must be confirmed by an on-site infiltration measurement. Native soils must have silt/clay content less than 40% and clay content less than 20%. Designers should also evaluate existing soil properties during initial site layout, and seek to configure the site to conserve and protect the soils with the greatest recharge and infiltration rates. In particular, areas of HSG A or B soils shown on NRCS soil surveys should be considered as primary locations for all types of infiltration.</td>
</tr>
<tr>
<td>External Drainage Area</td>
<td>Any external drainage area contributing runoff to permeable pavement should generally not exceed twice the surface area of the permeable pavement, and it should be as close to 100% impervious as possible. Some field experience has shown that an up gradient drainage area (even if it is impervious) can contribute particulates to the permeable pavement and lead to clogging (Hirschman, et al., 2009). Therefore, careful sediment source control and/or a pre-treatment strip or sump (e.g., stone or gravel) should be used to control sediment run-on to the permeable pavement section.</td>
</tr>
<tr>
<td>Pavement Slope</td>
<td>The surface of the permeable pavement must have a slope of ≤ 6%. The surface of the subgrade must have a slope of ≤ 0.5%. Terraces and baffles may be installed to achieve flat subgrades under sloping pavement surfaces.</td>
</tr>
<tr>
<td>Water Table</td>
<td>A high groundwater table may cause runoff to pond at the bottom of the permeable pavement system. Therefore, a minimum vertical distance of 2 feet must be provided between the bottom of the permeable pavement installation (i.e., the bottom invert of the reservoir layer) and the seasonal high water table.</td>
</tr>
<tr>
<td>Design Storm</td>
<td>Permeable pavement must be designed to treat the Runoff Reduction Volume and to provide safe conveyance of the 10-year, 24-hour storm event via infiltration, bypass or detention and release.</td>
</tr>
<tr>
<td>Setbacks</td>
<td>Permeable pavement should not be hydraulically connected to structure foundations, in order to avoid harmful seepage. Setbacks to structures and roads vary, based on the scale of the permeable pavement installation (see Table 3). At a minimum, small- and large-scale pavement applications should be located a minimum horizontal distance of 100 feet from any water supply well, 50 feet from septic systems, and at least 5 feet down-gradient from dry or wet utility lines. Setbacks can be reduced at the discretion of the local program authority for designs that use underdrains and/or liners.</td>
</tr>
</tbody>
</table>
### Installation

For PICP, CGP, PRTG, and PRP, follow manufacturer recommendations and industry standards to ensure lasting effectiveness. Some of the manufacturer requirements that must be considered include designing the bedding course and specifying jointing materials. Any manufacturer requirements should be implemented in addition to (and NOT instead of) the design requirements in this manual.

For PC and PA, it is crucial to specify the proper mix design. For pervious concrete, the mix design shall be in accordance with the latest version of ACI 522.1 Specification for Pervious Concrete. If installing PC or PICP, it is preferable to use contractors that are certified and use the applicable design guides.

### Subgrade

A washed aggregate base must be used. The surface of the subgrade must be scarified, ripped or trenched to maintain the pre-construction subgrade infiltration rate.

The subgrade for the permeable pavement must be graded in the dry. The aggregate base and permeable course should be completed as soon as possible to reduce the chance of compaction of the subgrade.

### Run On

Permeable pavement may be designed to receive runoff from adjacent impervious surfaces such as roofs and conventional pavement (if the soils are adequate). The design must provide storage for the runoff volume, and there must be a well-designed distribution system.

Runoff from adjoining pervious areas, such as grassed slopes and landscaping, must be prevented by grading the landscape away from the site except for instances when draining pervious areas to pavement is unavoidable, such as parking lot islands.

### Installation

Permeable pavement must not be installed until the upslope and adjoining areas are stabilized. After installations, barriers must be installed to prevent construction traffic from driving on the pavement.

### Hydraulic Head

The elevation difference needed for permeable pavement to function properly is generally nominal, although 2 to 4 feet of head may be needed to drive flows through underdrains. Flat terrain may affect proper drainage of permeable pavement designs, so underdrains should have a minimum 0.5% slope.

### Observation Well

A minimum of one observation well shall be provided at the low point in the system unless the subgrade is terraced; in that case, there shall be one well for each terrace.

### Edge Restraints

Edge restraints must be provided around the perimeter of permeable pavement systems (except for pervious concrete) as well as anywhere permeable pavement (of any type) is adjacent to conventional pavement.

### Maintenance

The property owner should clearly understand the unique maintenance responsibilities inherent with permeable pavement, particularly for parking lot applications. The owner should be capable of performing routine and long-term actions (e.g., vacuum sweeping) to maintain the pavement’s hydrologic functions, and avoid future practices (e.g., winter sanding, seal coating or repaving) that diminish or eliminate them.

### High Loading Situations

Permeable pavement is not intended to treat sites with high sediment or trash/debris loads, since such loads will cause the practice to clog and fail.

### Hotspot

Infiltration of runoff from designated hotspots is highly restricted or prohibited.

### High Speed Roads

Permeable pavement should not be used for high speed roads, although it has been successfully applied for low speed residential streets, parking lanes and roadway shoulders.

### Floodplains

Permeable Pavement should be constructed outside the limits of the 100-year floodplain, unless a waiver is obtained from the local authority.

### Signage

Permeable pavement signage must be clearly and permanently posted to prevent use by inappropriate vehicles, and the deposition and storage of particulate matter (except for single family residences, where signage is optional).
1.3 Calculations

1.3.1 Structural Design

If permeable pavement will be used in a parking lot or other setting that involves vehicles, the pavement surface must be able to support the maximum anticipated traffic load. The structural design process will vary according to the type of pavement selected, and the manufacturer’s specific recommendations should be consulted. The thickness of the permeable pavement and reservoir layer must be sized to support structural loads and to temporarily store the design storm volume (e.g., the runoff reduction, channel protection, and/or flood control volumes). On most new development and redevelopment sites, the structural support requirements will dictate the depth of the underlying stone reservoir.

The structural design of permeable pavements involves consideration of four main site elements:
- Total traffic
- In-situ soil strength
- Environmental elements
- Bedding and Reservoir layer design

The resulting structural requirements may include, but are not limited to, the thickness of the pavement, filter, and reservoir layer. Designers should note that if the underlying soils have a low California Bearing Ratio (CBR) (less than 4%), they may need to be compacted to at least 95% of the Standard Proctor Density, which generally rules out their use for infiltration. Designers should determine structural design requirements by consulting transportation design guidance sources, such as the following:

TDOT Roadway Design Guidelines (REV. August 8, 2014)
http://www.tdot.state.tn.us/chief_Engineer/assistant_engineer_design/design/DesGuide.htm

http://www.transportation.org/

http://www.transportation.org/

1.3.2 Hydraulic Design

Permeable pavement is typically sized to store the complete runoff reduction volume or another design storm volume in the reservoir layer. Modeling has shown that this simplified sizing rule approximates an 80% average rainfall volume removal for subsurface soil infiltration rates up to one inch per hour. More conservative values are given because both local and national experience has shown that clogging of the permeable material can be an issue, especially with larger contributing areas carrying significant soil materials onto the permeable surface.

The infiltration rate typically will be less than the flow rate through the pavement, so that some underground reservoir storage will usually be required. Designers should initially assume that there is no outflow through underdrains, to determine the depth of the reservoir layer, assuming runoff fully infiltrates into the underlying soil.

Design recommendations:
- For design purposes, the native soil infiltration rate (i) should be the field-tested soil infiltration rate divided by a factor of safety of 2. The minimum acceptable native soil infiltration rate is 0.5 inches/hr.
- The porosity (n) for No. 57 stone = 0.40
- Max. drain time for the reservoir layer should be not less than 48 or more than 72 hours.

1.3.2.1 Runoff Volume

The first step in designing permeable pavement SCM is to identify the size of the CDA. Once the CDA is identified, the soil and cover type(s) must then be identified to determine the net runoff volume for the appropriate design storm. Using the cover type(s) to determine the CN for the CDA, the net runoff volume
can be calculated from the regionally-specific design storm using Tennessee Runoff Reduction Assessment Tool (TNRRAT). This net runoff volume (or some smaller fraction if another practice will be used to handle the remaining volume) is the target volume to be handled by the Pervious Pavement SCM.

1.3.2.2 Practice Dimensions
Sizing the practice dimension can be done using the TNRRAT, otherwise manual calculation needs to be used.

Ponding time (T)
An infiltrating permeable pavement system shall be capable of infiltrating the rainfall depth associated with the Runoff Reduction Volume within 48 to 72 hours. The equation for estimating ponding time is provided below.

Equation 1: Ponding Time (T)

\[ T = \frac{P(1 + R)}{24 \times SF \times i} \]

Where:
- **T** = Ponding time (days)
- **P** = Depth of the design storm (inches)
- **R** = Aa/Ap, the ratio of the CDA to the permeable pavement area (between 0 and 1)
- **SF** = Safety factor (0.2)
- **i** = Measured in-situ soil infiltration rate (in/hr)

If the ponding time exceeds 72 hours, then the designer can reduce the amount of CDA that drains to the permeable pavement and see if this decreases ponding time to less than 72 hours. Otherwise, the site requires a detention system. It shall be designed to detain the stormwater for a 48 to 72 hour period.

Equation 2: Aggregate Depth for the Runoff Reduction Volume (RRV)
The aggregate depth shall be determined based on the assumption that no infiltration occurs during the design storm. The formula for RRV is as follows:

\[ RRV = \frac{P(1 + R)}{n} \]

Where:
- **RRV** = Depth of aggregate needed to treat the runoff reduction volume (inches)
- **P** = Rainfall depth for the design storm (inches)
- **R** = Aa/Ap, the ratio of the CDA to the permeable pavement area (between 0 and 1)
- **n** = porosity of reservoir layer (0.4)

Please note that the bedding layer of aggregate in a PICP system may not be used to provide storage for the runoff reduction volume.

Equation 3: Design for Safe Conveyance of the 10-year, 24-hour Storm
Permeable pavement designs shall include a mechanism for safely conveying the 10-year, 24-hour storm, which may be accomplished through infiltration, bypass, or detention. The permeable pavement can also be designed to meet local requirements for peak attenuation and volume control for larger storms using the same design process described below for the 10-year, 24-hour storm.

\[ D_{10} = \frac{P_{10}(1 + R) - d \times i \times SF}{n} \]
Where:

\[ D_{10} = \text{Aggregate depth to infiltrate the 10-year, 24-hour storm (inches)} \]
\[ P_{10} = \text{Rainfall depth for the 10-year, 24-hour storm (inches)} \]
\[ R = \frac{Aa}{Ap}, \text{the ratio of the CDA to the permeable pavement area (between 0 and 1)} \]
\[ d = \text{Storm duration (24 hours)} \]
\[ i = \text{Soil infiltration rate (in./hr)} \]
\[ SF = \text{Safety factor (0.2)} \]
\[ n = \text{Porosity of reservoir layer (0.4)} \]

1.4 Design Criteria

1.4.1 Soil Infiltration Rate Testing

To design a permeable pavement system without an underdrain, the measured infiltration rate of subsoils must be 0.5 inch per hour or greater. A minimum of one test must be taken per 1,000 sq. ft. of planned permeable pavement surface area. In most cases, a single soil test is sufficient for micro-scale and small-scale applications. At least one soil boring must be taken to confirm the underlying soil properties at the depth where infiltration is designed to occur (i.e., to ensure that the depth to water table, depth to bedrock, or karst is defined). Soil infiltration testing should be conducted within any confining layers that are found within 4 feet of the bottom of a proposed permeable pavement system.

1.4.2 Drainage System and Pre-treatment

Pretreatment for most permeable pavement applications is not necessary, since the surface acts as pretreatment to the reservoir layer below. Additional pretreatment may be appropriate if the pavement receives run-on from an adjacent pervious or impervious area. For example, a gravel filter strip can be used to trap coarse sediment particles before they reach the permeable pavement surface, in order to prevent premature clogging.

To avoid pavement clogging, pervious areas (such as lawns and landscaping) on the site may not drain to permeable pavement except for instances when this is unavoidable, such as parking lot islands. The site plan must show pervious areas graded to flow away from the pavement or include conveyances to route runoff from pervious surfaces elsewhere. These conveyances should be designed for non-erosive flow during the 10-year, 24-hour storm event or the local conveyance design standard, whichever is larger.
Impervious areas are allowed to drain to the permeable pavement with proper design of the pavement system per this chapter. Examples of areas that may be easily diverted onto the permeable pavement include: travel lanes in parking lots, sidewalks, and roof drains. Roof leaders may be directed to the permeable pavement surface, but it is the designer’s responsibility to ensure that these leaders are of a sufficient number and spacing to prevent nuisance flooding. It is recommended that no more than 1000 square feet of impervious area drain to a single point. The additional built-upon area (BUA) draining to the pavement may not exceed the area of the pavement itself (in other words, a maximum 1:1 ratio pavement area to other BUA).

### 1.4.3 Type of Surface Pavement
The type of pavement should be selected based on a review of the factors in Table 1, and designed according to the product manufacturer’s recommendations.

### 1.4.4 Sub-base Reservoir Layer
The thickness of the reservoir layer is determined by RRV and D10 (see Equations 2 and 3). A professional should be consulted regarding the suitability of the soil subgrade.

- The reservoir below the permeable pavement surface should be composed of clean, washed stone aggregate and sized for both the storm event to be treated and the structural requirements of the expected traffic loading.
- The storage layer may consist of clean washed No. 57 stone, although No. 2 stone is preferred because it provides additional storage and structural stability.
- The bottom of the reservoir layer should be completely flat (less than 0.5% slope) so that runoff will be able to infiltrate evenly through the entire surface. A flat subgrade is needed to provide optimal storage capacity within the aggregate base. Terraces and baffles or graded berms can be used in the subgrade design to store stormwater at different elevations so that it can be treated. See Figure 4 for a schematic of how terraces and baffles can be configured in the subgrade. The plan set should include a separate subsurface (subgrade) grading plan, especially for sites with baffles/berms/terrace/bays/cells.
1.4.5 Internal Geometry and Drawdowns

- **Elevated Underdrain.** To promote greater runoff reduction for permeable pavement located on marginal soils, an elevated underdrain should be installed with a stone jacket that creates a 12 to 18 inch deep storage layer below the underdrain invert.

- **Rapid Drawdown.** When possible, permeable pavement should be designed so that the target runoff reduction volume stays in the reservoir layer for at least 48 hours before being discharged through an underdrain.

- **Conservative Infiltration Rates.** Designers should always decrease the measured infiltration rate by a factor of 2 during design, to approximate long term infiltration rates.

1.4.6 Underdrains

The use of underdrains is recommended when there is a reasonable potential for infiltration rates to decrease over time, when underlying soils have an infiltration rate of less than 1/2-inch per hour, or when soils must be compacted to achieve a desired Proctor density. Underdrains can also be used to manage extreme storm events to keep detained stormwater from backing up into the permeable pavement.

- An underdrain(s) should be placed within the reservoir and encased in 8 to 12 inches of clean, washed stone.

- An underdrain(s) can also be installed and capped at a downstream structure as an option for future use if maintenance observations indicate a reduction in the soil permeability.

- Underdrains should be used in accordance with the following:
  - Minimum 0.5% slope
  - Located 20 feet or less from the next pipe when using multiple pipes
  - Perforated schedule 40 PVC pipe (corrugated HDPE may be used for smaller load-bearing applications), with 3/8-inch perforations at 6 inches on center
  - Encased in a layer of clean, washed No.57 stone
  - Include an adjustable outlet control design such as an orifice and weir wall housed within an adjacent manhole or other structure that is easily accessed for maintenance and inspections
  - Outlet control design should ensure that the stone reservoir drains slowly (recommended > 48 hours); however, it must completely drain within 72 hours.
Infiltration designs can be fitted with an underdrain(s) and capped at the downstream structure as an option for future use if maintenance observations indicate a reduction in the soil permeability.

- Underdrain cleanouts should be provided if the pavement surface area exceeds 1,000 ft².

- Underdrains must be used in locations in which bedrock is encountered less than 2 feet beneath the planned invert of the reservoir layer.

1.4.7 Conveyance and Overflow

Permeable pavement designs should include methods to convey larger storms of 10-yr, 24 hour to the storm drain system. The following is a list of methods that can be used to accomplish this:

- Place a perforated pipe horizontally near the top of the reservoir layer to pass excess flows after water has filled the base. The placement and/or design should be such that the incoming runoff is not captured (e.g., placing the perforations on the underside only).

- Increase the thickness of the top of the reservoir layer by as much as 6 inches (i.e., create freeboard). The design computations used to size the reservoir layer often assume that no freeboard is present.

- Create underground detention within the reservoir layer of the permeable pavement system. Reservoir storage may be augmented by corrugated metal pipes, plastic or concrete arch structures, etc.

- Set the storm drain inlets flush with the elevation of the permeable pavement surface to effectively convey excess stormwater runoff past the system (typically in remote areas). The design should also make allowances for relief of unacceptable ponding depths during larger rainfall events.

- Route excess flows to another detention or conveyance system that is designed for the management of extreme event flows. Figures 5 through 9 detail possibilities of safe conveyance of the 10-year, 24 hour storm.

![Figure 5: Infiltrate the 10-yr, 24-hr storm (Source: NCSU-BAE).](image-url)
Figure 6: Detail via underdrain with upturned elbow (Source: NCSU-BAE).

Figure 7: Bypass via subsurface openings in manhole structures (Source: NCSU-BAE).

Figure 8: Bypass via catch basin (PC & PA only) (Source: NCSU-BAE).
1.4.8 Observation Well

Observations wells measure the elevation of standing water at the subgrade of the permeable pavement system. They are required for all commercial applications and for any residential system exceeding 10,000 square feet. If the subgrade is not terraced, then the observation well should be placed at the lower end of the subgrade slope. If the subgrade is terraced, then one observation well should be built into the lower end of each terrace.

Observation wells should be fitted with a cap installed flush with the pavement surface to facilitate quarterly inspection and maintenance. Observations of the water depth throughout the estimated ponding time (T) provide an indication of how well the water is infiltrating.

The observation well should be placed near the center of the pavement and shall consist of a rigid 4 to 6 inch perforated PVC pipe. This should be capped flush with or below the top of pavement elevation and fitted with a screw or flange type cover.

1.4.9 Infiltration Sump

The infiltration sump consists of the same stone material as the reservoir layer. The depth of this layer is sized so that the Runoff Reduction Volume of the sump can infiltrate into the subsoil in a 48 to 72 hour period. The bottom of infiltration sump must be at least 2 feet above the seasonally high water table. The inclusion of an infiltration sump is not permitted for designs with an impermeable liner. In fill soil locations, geotechnical investigations are required to determine if the use of an infiltration sump is permissible.
1.4.10 Filter Fabric (optional)
Filter fabric is another option to protect the bottom of the reservoir layer from intrusion by underlying soils, although some practitioners recommend avoiding the use of filter fabric beneath Permeable Pavements since it may become a future plane of clogging within the system. Designers should evaluate the paving application and refer to AASHTO M288-06 for an appropriate fabric specification. AASHTO M288-06 covers six geotextile applications: Subsurface Drainage, Separation, Stabilization, Permanent Erosion Control, Sediment Control and Paving Fabrics. However, AASHTO M288-06 is not a design guideline. It is the engineer’s responsibility to choose a geotextile for the application that takes into consideration site-specific soil and water conditions. Fabrics for use under permeable pavement should at a minimum meet criterion for Survivability Classes (1) and (2).

1.4.11 Bottom of the Reservoir Layer Protection
There are two options to protect the bottom of the reservoir layer from intrusion by underlying soils. The first method involves covering the bottom with nonwoven, polypropylene geotextile that is permeable, although some practitioners recommend avoiding the use of filter fabric since it may become a future plane of clogging within the system. Permeable filter fabric is still recommended to protect the excavated sides of the reservoir layer, in order to prevent soil piping. The second method is to form a barrier of choker stone and sand. In this case, underlying native soils should be separated from reservoir base/subgrade layer by a thin 2 to 4 inch layer of clean, washed, choker stone (ASTM D 448 No. 8 stone) covered by a layer of 6 to 8 inches of course sand.

1.4.12 Impermeable Liner
This material should be used where deemed necessary by a geotechnical investigation; such as in fill applications, karst, adjacent to building foundations, etc. Use a thirty mil (minimum) PVC Geomembrane liner covered by 8 to 12 oz./sq. yd. non-woven geotextile.

1.4.13 Curb/Edge Restraints and Intersections of Permeable and Impermeable Pavements

Figure 11: Edge restraint (Source: NCDENR).

Edge restraints are an essential element to the structural longevity of a PICP pavement system. Without edge restraints, pavers can “unravel” over time, resulting in movement of pavers. As pavers move, the joints open and unit pavers become damaged. PC pavement systems provide adequate structural edge support and do not require perimeter edge restraints.

Concrete edge restraints (cast-in place or precast curbs) are recommended. Flexible, plastic or metal edging supported with spikes is not recommended for vehicular use. Edge restraints must:
• Extend below the frost line.
• Be flush with the pavement or somewhat higher than the pavement surface. Edge restraints that are higher than the pavement surface help keep the stormwater on the pavement and prevent stormwater run-on from clogging the permeable pavement.

Figure 12: Examples of perimeter edge restraints (Source: NCDENR).

At intersections between permeable pavement and conventional concrete, a geomembrane barrier should be provided to contain the stormwater under the permeable pavement and protect the subgrade under the conventional concrete. There should be a seam between the pavement surfaces for maintenance purposes.

At intersections between permeable pavement and conventional asphalt, a concrete curb that extends below the frost line should be provided to protect the subgrade under the conventional asphalt. The concrete curb will also provide a larger separation between the pavement courses, which will be helpful when the conventional asphalt is resurfaced.

In addition to concrete edge restraints, it is important to consider the boundary between permeable and conventional pavement. The design will differ depending on whether the permeable pavement is adjacent to conventional concrete or conventional asphalt as shown in Figure 13.

Figure 13: Detail of separation between permeable and conventional pavement (Source: NCDENR).
1.4.14 Signage

Because permeable pavements will be maintained and managed differently than traditional pavements, signage at permeable pavement installations is required. This will promote its prolonged effectiveness and prevent conventional pavement management from damaging the system.

Figure 14 is an example of a sign for a permeable pavement system. The design is based on a 24 by 18 inch standard size for sign production. Even though this graphic is in color, color images are not required. Large permeable pavement applications may require numerous signs.

1.4.15 Material Specifications

Permeable pavement material specifications vary according to the specific pavement product selected. Table 5 describes general material specifications for the component structures installed beneath the permeable pavement. Note that the size of stone materials used in the reservoir and filter layers may differ depending whether the system is PC, PA or PICP (see Table 2). A general comparison of different permeable pavements is provided in Table 6, but designers should consult manufacturer’s technical specifications for specific criteria and guidance.

![Permeable Pavement Signage](Source: NCDENR)

**Table 5: Material Specifications for Underneath the Pavement Surface.**

<table>
<thead>
<tr>
<th>Material</th>
<th>Specification</th>
<th>Notes</th>
</tr>
</thead>
</table>
| Bedding Layer | **PC:** None  
**PA:** 2 in. depth of No. 8 stone  
**PICP:** 2 in. depth of No. 8 stone, over 3 to 4 inches of No. 57 | ASTM D448 size No. 8 stone (e.g. 3/8 to 3/16 inch in size). Should be double-washed and clean and free of all fines. |
| Reservoir Layer | **PC:** No. 57 stone  
**PA:** No. 2 stone  
**PICP:** No. 57 stone | ASTM D448 size No. 57 stone (e.g. 1 1/2 to 1/2 inch in size); No. 2 Stone (e.g. 3 inch to 3/4 inch in size). Depth is based on the pavement structural and hydraulic requirements. Should be double-washed and clean and free of all fines. |
| Underdrain | Use 4 to 6 inch diameter perforated PVC (AASHTO M 252) pipe, with 3/8-inch perforations at 6 inches on center; each underdrain installed at a minimum 0.5% slope located 20 feet or less from the next pipe (or equivalent corrugated HDPE may be used for smaller load-bearing applications). Perforated pipe installed for the full length of the permeable pavement cell, and non-perforated pipe, as needed, is used to connect with the storm drain system. T’s and Y’s installed as needed, depending on the underdrain configuration. Extend cleanout pipes to the surface with vented caps at the Ts and Ys. | |
| Filter Layer | The underlying native soils should be separated from the stone reservoir by a thin, 2 to 4 inch layer of choker stone (e.g. No. 8) covered by a 6 to 8 inch layer of coarse sand (e.g. ASTM C 33, 0.02-0.04 inch). | The sand should be placed between the stone reservoir and the choker stone, which should be placed on top of the underlying native soils. |
### Filter Fabric (optional)
Use a needled, non-woven, polypropylene geotextile with Grab Tensile Strength equal to or greater than 120 lbs (ASTM D4632), with a Mullen Burst Strength equal to or greater than 225 lbs./sq. in. (ASTM D3786), with a Flow Rate greater than 125 gpm/sq. ft. (ASTM D4491), and an Apparent Opening Size (AOS) equivalent to a US # 70 or # 80 sieve (ASTM D4751). The geotextile AOS selection is based on the percent passing the No. 200 sieve in “A” Soil subgrade, using FHWA or AASHTO selection criteria.

### Impermeable Liner
Use a thirty mil (minimum) PVC Geomembrane liner covered by 8 to 12 oz./sq. yd.2 non-woven geotextile. NOTE: THIS IS USED ONLY FOR KARST REGIONS.

### Observation Well
Use a perforated 4 to 6 inch vertical PVC pipe (AASHTO M 252) with a lockable cap, installed flush with the surface.

<table>
<thead>
<tr>
<th>Material</th>
<th>Specification</th>
<th>Notes</th>
</tr>
</thead>
</table>
| **Permeable Interlocking Concrete Pavers** | Surface open area: 5% to 15%  
Thickness: 3.125 inches for vehicles  
Compressive strength: 55 Mpa  
Open void fill media: aggregate | Must conform to ASTM C936 specifications.  
Reservoir Layer required to support the structural load. |
| **Concrete Grid Pavers**          | Open void content: 20% to 50%  
Thickness: 3.5 inches  
Compressive strength: 35 Mpa  
Open void fill media: aggregate, topsoil and grass, coarse sand | Must conform to ASTM C1319 specifications.  
Reservoir layer required to support the structural load. |
| **Plastic Reinforced Grid Pavers** | Void content: depends on fill material  
Compressive strength: varies, depending on fill material  
Open void fill media: aggregate, topsoil and grass, coarse sand | Reservoir layer required to support the structural load. |
| **Pervious Concrete**             | Void content: 15% to 25%  
Thickness: typically 4 to 8 inches  
Compressive strength: 2.8 to 28 Mpa  
Open void fill media: None | May not require a reservoir layer to support the structural load, but a layer may be included to increase the storage or infiltration. |
| **Porous Asphalt**                | Void content: 15% to 20 ‰.  
Thickness: typically 3 to 7 in. (depending on traffic load)  
Open void fill media: None | Reservoir layer required to support the structural load. |
1.5 Typical Details

Figure 15: Cross section of a basic permeable pavement design (Source: WVDEP).

Figure 16: Cross section of a basic permeable pavement design with infiltration sump (Source: WVDEP).

2. Construction

Experience has shown that proper installation is absolutely critical to the effective operation of a permeable pavement system.

2.1 Necessary Erosion & Sediment Controls

- All permeable pavement areas should be fully protected from sediment intrusion by silt fence or construction fencing, particularly if they are intended to infiltrate runoff.
- Permeable pavement areas should remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment. Permeable pavement areas should be clearly marked on all construction documents and grading plans. To prevent soil compaction, heavy vehicular and foot traffic should be kept out of permeable pavement areas during and immediately after construction.
- During construction, care should be taken to avoid tracking sediments onto any permeable pavement surface to avoid clogging.
- Any area of the site intended ultimately to be a permeable pavement area should generally not be used as the site of a temporary sediment basin. Where locating a sediment basin on an area intended for permeable pavement is unavoidable, the invert of the sediment basin must be a minimum of 2 feet above the final design elevation of the bottom of the aggregate reservoir course. All sediment deposits in the excavated area should be carefully removed prior to installing the subbase, base and surface materials.
2.2. Permeable Pavement Construction Sequence

The following is a typical construction sequence to properly install permeable pavement, which may need to be modified to depending on whether Porous Asphalt (PA), Pervious Concrete (PC) or Interlocking Paver (IP) designs are employed.

**Step 1: Stabilize drainage area**

Construction of the permeable pavement shall only begin after the entire contributing drainage area has been stabilized. The proposed site should be checked for existing utilities prior to any excavation. Do not install the system in rain or snow, and do not install frozen bedding materials.

**Step 2: Install temporary erosion and sediment control**

As noted above, temporary erosion and sediment controls are needed during installation to divert stormwater away from the permeable pavement area until it is completed. Special protection measures such as erosion control fabrics may be needed to protect vulnerable side slopes from erosion during the excavation process. The proposed permeable pavement area must be kept free from sediment during the entire construction process. Construction materials that are contaminated by sediments must be removed and replaced with clean materials.

**Step 3: Excavate the pavement area**

Where possible, excavators or backhoes should work from the sides to excavate the reservoir layer to its appropriate design depth and dimensions. For micro-scale and small-scale pavement applications, excavating equipment should have arms with adequate extension so they do not have to work inside the footprint of the permeable pavement area (to avoid compaction).

Contractors can utilize a cell construction approach, whereby the proposed permeable pavement area is split into 500 to 1000 sq. ft. temporary cells with a 10 to 15 foot earth bridge in between, so that cells can be excavated from the side. Excavated material should be placed away from the open excavation so as to not jeopardize the stability of the side walls.

The final subgrade slope may not exceed 0.5%.

**Step 4: Scarified the native soil**

The native soils along the bottom and sides of the permeable pavement system should be scarified or tilled to a depth of 6 to 9 inches prior to the placement of the filter layer or filter fabric. In large scale paving applications with weak soils, the soil subgrade may need to be compacted to 95% of the Standard Proctor Density to achieve the desired load-bearing capacity. (NOTE: This effectively eliminates the infiltration function of the installation, and it must be addressed during hydrologic design.)

To rip the subgrade, use a subsoil ripper to make parallel rips six to nine inches deep spaced three feet apart along the length of the permeable pavement excavation. In silty or clayey soils, clean coarse sand must be poured over the ripped surface to keep it free-flowing (Brown and Hunt 2010).

An alternative to ripping is trenching. If trenching is chosen, then parallel trenches 12 inches wide by 12 inches deep shall be made along the length of the permeable pavement excavation. Excavate trenches every 6 feet (measured from center to center of each trench) and fill with ½ inch of clean course sand and 11.5 inches of #57 stone aggregate (Brown and Hunt 2010).
Step 5: Install filter fabric
Filter fabric should be installed on the bottom and the sides of the reservoir layer. In some cases, an alternative filter layer may be warranted. Filter fabric strips should overlap down-slope by a minimum of 2 feet, and be secured a minimum of 4 feet beyond the edge of the excavation. Where the filter layer extends beyond the edge of the pavement (to convey runoff to the reservoir layer), install an additional layer of filter fabric 1 foot below the surface to prevent sediments from entering into the reservoir layer. Excess filter fabric should not be trimmed until the site is fully stabilized.

Step 6: Install the underdrain and observation well
Provide a minimum of 2 inches of aggregate above and below the underdrains. The underdrains should slope down towards the outlet at a grade of 0.5% or steeper. The up-gradient end of underdrains in the reservoir layer should be capped. Where an underdrain pipe is connected to a structure, there shall be no perforations within 1 foot of the structure. Ensure that there are no perforations in clean-outs and observation wells within 1 foot of the surface.

Step 7: Place aggregate base
Moisten and spread 6-inch lifts of the appropriate clean, washed stone aggregate (usually No. 2 or No. 57 stone). Place at least 4 inches of additional aggregate above the underdrain, and then compact it using a vibratory roller in static mode until there is no visible movement of the aggregate. Do not crush the aggregate with the roller.

Step 8: Install curb restraints and pavement barriers
Edge restraints and barriers between permeable and impervious pavement shall be installed per design. Before moving on to the next step, be certain that the design and installation are consistent.

Step 9: Install the bedding layer
Install the desired depth of the bedding layer, depending on the type of pavement, as follows:

- **Pervious Concrete:** No bedding layer is used.
- **Porous Asphalt:** The bedding layer for porous asphalt pavement consists of 2 inches of clean, washed ASTM D 448 No.8 stone. The filter course must be leveled and pressed (choked) into the reservoir base with at least four (4) passes of a 10-ton steel drum static roller.
- **Interlocking Pavers:** The bedding layer for open-jointed pavement blocks should consist 2 inches of washed ASTM D 448 No.8 stone over 3 to 4 inches of No. 57. The thickness of the bedding layer is to be based on the block manufacturer’s recommendation or that of a qualified professional.
Step 10: Install pavement
Paving materials shall be installed in accordance with manufacturer or industry specifications for the particular type of pavement.

Step 11: Protect the pavement through project completion
It is preferable to have the permeable pavement installed at the end of the site construction timeline. If that is not possible, it is important to protect the permeable pavement through project completion. This may be done by:

- Route construction access through other portions of the site so that no construction traffic passes through the permeable pavement site. Install barriers or fences as needed.
- If this is not possible, protect the pavement per the construction documents. Protection techniques that may be specified include mats, plastic sheeting, barriers to limit access, or moving the stabilized construction entrance.
- Schedule street sweeping during and after construction to prevent sediment from accumulating on the pavement.

2.3 Construction Inspection
Inspections before, during and after construction are needed to ensure that permeable pavement is built in accordance with these specifications. Use detailed inspection checklists that require sign-offs by qualified individuals at critical stages of construction, to ensure that the contractor’s interpretation of the plan is consistent with the designer’s intent. Some common pitfalls can be avoided by careful construction supervision that focuses on the following key aspects of permeable pavement installation:

- Store materials in a protected area to keep them free from mud, dirt, and other foreign materials.
- The contributing drainage area should be stabilized prior to directing water to the permeable pavement area.
- Check the aggregate material to confirm that it is clean and washed, meets specifications and is installed to the correct depth.
- Check elevations (e.g., the invert of the underdrain, inverts for the inflow and outflow points, etc.) and the surface slope.
- Make sure the permeable pavement surface is even, runoff evenly spreads across it, and the storage bed drains within 48 to 72 hours.
- Ensure that caps are placed on the upstream (but not the downstream) ends of the underdrains.
- Inspect the pretreatment structures (if applicable) to make sure they are properly installed and working effectively.
• Once the final construction inspection has been completed, log the GPS coordinates for each facility and submit them for entry into the local BMP maintenance tracking database.

It may be advisable to divert the runoff from the first few runoff-producing storms away from larger permeable pavement applications, particularly when up-gradient conventional asphalt areas drain to the permeable pavement. This can help reduce the input of fine particles that are often produced shortly after conventional asphalt is laid down.

### 2.4 As-Built Requirements

After installation, an appropriately licensed professional in Tennessee must perform a final as-built inspection and certification that includes:

- Ensuring that the installation remains in good condition and the surface is free of fines.
- Checking that all pervious surfaces are draining away from the pavement and that the overall site is stabilized.
- Verifying that the pavement was installed per the design.
- Preparing the as-built plans that include any changes the underdrains, observation well locations, terrace layouts, aggregate depth or storage structures, any revised calculations, etc.
- Testing the permeability of the pavement surface using an appropriate test such as ASTM C1701 Standard Test Method for Infiltration Rate of In-Place Pervious Concrete.

### 2.5 Special Case Design Adaptations

#### 2.5.1 Karst Terrain

Permeable pavement infiltration and Infiltration Sump Designs are not recommended in any area with a moderate or high risk of sinkhole formation. A geotechnical investigation and recommendations should be reviewed to consider whether an impermeable bottom liner is necessary. In general, small-scale applications of Permeable Pavement (drainage areas not exceeding one-half acre) are preferred in karst areas in order to prevent possible sinkhole formation.

#### 2.5.2 Steep Slopes

Permeable Pavement can be used on sites with steep slopes; provided the paved areas are terraced and maintain maximum slopes. A geotechnical evaluation should also evaluate the need for impermeable liner on the sides of the stone reservoir to minimize saturation of soils adjacent to steep slopes.

#### 2.5.3 Cold Climate and Winter Performance

The prevalence of sanding and salting operations create additional hazards for Permeable Pavement installations. Since the pavement itself is the pretreatment mechanism for the stone reservoir and infiltration design, precautions such as signage near the entrances to the pavement should specifically warn against applying sand or other grit to the pavement.

Research at the University of New Hampshire Stormwater Center (UNHSC) indicates that Permeable Pavement has a higher frictional resistance than standard pavements and therefore requires less sand and/or salt to maintain braking distance and safety. Further, the internal thermal convection of subsurface ground temperatures serves to warm the permeable pavement section faster than regular pavement, thereby minimizing the need to apply chemicals or salt to accelerate melting (Roseen et al., 2006).

Finally, UNHSC research on Permeable Pavement’s durability in cold weather is ongoing with positive results. Properly constructed Permeable Pavements structural durability is comparable to traditional pavement materials (Roseen and Ballestero, 2008). Design variations may include extending the stone reservoir to below the frost line.
2.5.4 Stormwater Retrofitting

Permeable pavement is a versatile retrofitting practice that can be applied in any situation where the existing pavement may require repair or replacement. Considerations include determining if there is enough hydraulic head available to tie underdrains into an existing drainage structure or to daylight.

For more information on retrofitting, see the Center for Watershed Protection’s manual, Urban Stormwater Retrofit Practices (Schueler et al., 2007).

3. Maintenance

3.1 Recommended Maintenance Tasks

Maintenance is a crucial element to ensure the long-term performance of Permeable Pavement. The most frequently cited maintenance problem is surface clogging caused by organic matter and sediment. Periodic street sweeping will remove accumulated sediment and help prevent clogging; however, it is also critical to ensure that surrounding land areas remain stabilized.

One preventative maintenance task for large-scale applications involves vacuum sweeping on a frequency consistent with the use and loadings encountered in the parking lot. Many consider an annual, dry-weather sweeping in the spring months to be important. The contract for sweeping should specify that a vacuum sweeper be used that does not use water spray, since spraying may lead to subsurface clogging.

Table 7: Recommended maintenance tasks for permeable pavement practices (WV, 2012, p:27).

<table>
<thead>
<tr>
<th>Maintenance Tasks</th>
<th>Frequency¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>• For the first 6 months following construction, the practice and CDA should be inspected at least twice after storm events that exceed 1/2 inch of rainfall. Conduct any needed repairs or stabilization.</td>
<td>After installation</td>
</tr>
<tr>
<td>• Mow grass in grid paver applications</td>
<td>At least 1 time every 1-2 months during the growing season</td>
</tr>
<tr>
<td>• Stabilize the CDA to prevent erosion</td>
<td>As needed</td>
</tr>
<tr>
<td>• Remove any soil or sediment deposited on pavement.</td>
<td></td>
</tr>
<tr>
<td>• Replace or repair any necessary pavement surface areas that are degenerating or spalling</td>
<td></td>
</tr>
<tr>
<td>• Vacuum pavement with a standard street sweeper to prevent clogging</td>
<td>2-4 times per year (depending on use)</td>
</tr>
<tr>
<td>• Conduct a maintenance inspection</td>
<td>Annually</td>
</tr>
<tr>
<td>• Spot weeding of grass applications</td>
<td></td>
</tr>
<tr>
<td>• Remove any accumulated sediment in pre-treatment cells and inflow points</td>
<td>Once every 2 to 3 years</td>
</tr>
<tr>
<td>• Conduct maintenance using a regenerative street sweeper</td>
<td>If clogged</td>
</tr>
<tr>
<td>• Replace any necessary joint material</td>
<td></td>
</tr>
</tbody>
</table>

¹ Required frequency of maintenance will depend on pavement use, traffic loads, and surrounding land use
3.2. Winter maintenance

Winter maintenance on permeable pavements is similar to standard pavements, with a few additional considerations:

- Large snow storage piles should be located in adjacent grassy areas so that sediments and pollutants in snowmelt are partially treated before they reach the Permeable Pavement.
- Sand or cinders should not be applied for winter traction over Permeable Pavement or areas of standard (impervious) pavement that drain toward Permeable Pavement, since it will quickly clog the system. If applied, the materials must be removed by vacuuming in the spring.
- When plowing plastic reinforced grid pavements, snow plow blades should be lifted 1/2 inch to 1 inch above the pavement surface to prevent damage to the paving blocks or turf. Porous asphalt, pervious concrete and permeable interlocking concrete pavers can be plowed similar to traditional pavements, using similar equipment and settings.
- Owners should be judicious when using chloride products for deicing over all permeable pavements designed for infiltration, since the salts will most assuredly be transmitted into the groundwater. Salt can be applied but environmentally sensitive deicers are recommended. Permeable Pavement applications will generally require less salt application than traditional pavements.

Maintenance agreements must be executed between the owner and the local authority. The agreements will specify the property owner’s primary maintenance responsibilities and authorize local agency staff to access the property for inspection or corrective action in the event that proper maintenance is not preformed.

All permeable pavement areas must be covered by a drainage easement to allow inspection and maintenance by local authority staff. When Permeable Pavements are installed on private residential lots, homeowners will need to (1) be educated about their routine maintenance needs, (2) understand the long-term maintenance plan, and (3) be subject to a maintenance agreement as described above.

It is highly recommended that a spring maintenance inspection and cleanup be conducted at each Permeable Pavement site, particularly at large-scale applications. Example maintenance inspection checklists for permeable pavements can be found in Appendix F.
# REFERENCES


