Permeable Pavement


Source: UConn NEMO Program

Stormwater BMP Type	
Pretreatment BMP	□
Infiltration BMP	■
Filtering BMP	□
Stormwater Pond BMP	□
Stormwater Wetland BMP	□
Water Quality Conveyance BMP	□
Stormwater Reuse BMP	□
Proprietary BMP	□
Other BMPs and Accessories	□

Stormwater Management Suitability	
Retention*	■
Treatment	■
Pretreatment	□
Peak Runoff Attenuation	■

*Exfiltration systems only

Pollutant Removal	
Sediment*	**High**
Phosphorus	**Moderate**
Nitrogen	**Moderate**
Bacteria	**High**

*Includes sediment-bound pollutants

Implementation	
Capital Cost	**High**
Maintenance Burden	**High**
Land Requirement	**Low**

Description

Permeable pavement is an alternative paved surface and stormwater management facility designed to capture stormwater runoff and snowmelt and allow it to move through void spaces in the surface course or through the joints in paver units. The captured stormwater is filtered as it moves vertically through the surface course, a transition and filter course, and a storage bed of open-graded aggregate where it is temporarily stored. The stormwater is discharged from the system through infiltration into the underlying soil or using an optional underdrain. Permeable pavement can be used to manage stormwater that falls on the pavement surface, but it may also accept some runoff from adjacent impervious areas.

When design for infiltration, permeable pavement can provide retention of stormwater, reducing runoff volumes and recharging groundwater. Filtration of stormwater is the primary pollutant removal mechanism in permeable pavement systems, although hydrocarbons and other pollutants can biodegrade in the system. Permeable pavement can be designed to store larger volumes of water and provide peak runoff attenuation for larger storms. Similar to other Infiltration BMPs, permeable pavement systems should be lined for certain applications.

There are many types of permeable pavement systems, but the most common are porous asphalt, pervious concrete, and permeable interlocking concrete pavers (PICP). The following photographs show common types of permeable pavement installations in Connecticut.

Porous Asphalt (Storrs Hall, UConn, Storrs, CT)

Grass and Grid Pavers (Hole in the Wall Parking Lot, East Lyme, CT)

Pervious Concrete (Residential Subdivision, East Haddam, CT)

Concrete Pavers (residential driveway, Middletown, CT)

Photos Source: UConn NEMO Program

Advantages

- Well-suited to locations where space for other stormwater BMPs is limited.
- Provide dual functions, and therefore co-benefits including retention (volume reduction), groundwater recharge, treatment, and some stormwater quantity control.

- Other benefits include improved traction while wet, reduced surface ponding, reduced freeze-thaw, and reduced need for de-icing due to well drained base.

Limitations

- Susceptible to clogging by sediment.
- Not recommended in areas with high traffic volumes. Should only be used in low speed and low traffic areas or outside main travel lanes.
- Avoid areas of excessive sediment loading.
- Do not apply sand in winter months, as sand increases need for vacuum sweeping.
- Some permeable pavement surfaces (i.e., pavers) may be damaged by snow removal without modified equipment such as special plow blades.
- Quality control for material production and installation are essential for success.
- Accidental seal-coating or similar surface treatment will result in failure of porous asphalt installations.
- Successful long-term functioning of permeable pavement systems is highly dependent on regular and appropriate maintenance (routine vacuum sweeping).
- Higher material cost than conventional pavement (although ay be offset by reduced stormwater infrastructure costs).

Siting Considerations

- **Potential Locations:** Low traffic areas such as within the roadway outside of the travel way (roadside rights-of-way and emergency access lanes), parking stalls and other low traffic areas of parking lots, driveways for residential and light commercial use, walkways, plazas, bike paths, and patios, where sanding will not occur within the contributing drainage area. Useful in stormwater retrofit applications where space is limited and where additional runoff control is required.
- **Drainage Area:** Contributing drainage area to the permeable pavement should not exceed three times the surface area of the permeable pavement. Runoff from upgradient permeable surfaces should be minimal. Porous asphalt installations of 0.5 acre or less are generally not cost effective.
- **Slopes:** Locate where pavement slopes do not exceed 5%.
- **General:** Meet the soils, water table, bedrock, and horizontal setback requirements specified in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems (General Design Guidance for Stormwater Infiltration Systems).

Soil Evaluation

- Conduct an evaluation of the soil characteristics and subsurface conditions at the location of the proposed system including soil type, depth to the seasonal high groundwater table, depth to bedrock, and soil infiltration rate. Refer to Chapter 10 - General Design Guidance for Stormwater Infiltration Systems for soil evaluation guidance.

Design Recommendations

General Considerations

This section addresses design considerations for the most common types of permeable pavement systems.

- **Porous Asphalt:** Porous asphalt consists of a contiguous permeable asphalt surface course installed over a filter course and a base course that serves as a storage reservoir. Stormwater runoff moves vertically through the interconnected void spaces (10-25%) of the surface course and the filter course and temporarily accumulates in the underlying storage reservoir until it is discharged from the system or infiltrated into the underlying soil. The high infiltration rate through the surface course is achieved by eliminating the finer aggregates that are typically used in conventional asphalt. The remaining aggregates are bound together with an asphalt or Portland cement binder.

- **Pervious Concrete:** Like porous asphalt, pervious concrete consists of a contiguous permeable concrete surface course installed over a filter course and a base course that serves as a storage reservoir. Pervious concrete is like conventional concrete except the fine particles are absent from the mix, creating the interconnected void space and high infiltration capacity.

- **Permeable Interlocking Concrete Pavers (PICP):** This system uses concrete pavers that come in a variety of shapes, sizes, and many possible interlocking arrangements. Stormwater infiltrates vertically through the permeable joints between the paver units, or through voids in the permeable concrete units (similar to pervious concrete), then through the bedding layer, choker course, and an underlying storage reservoir.

Figure 13-15. is a typical section of porous asphalt and pervious concrete, and a typical section of permeable interlocking concrete pavers designed for vehicle and non-vehicle loads. Other open course paver systems are available that can be filled with pea gravel or topsoil and seeded with grass, ranging from plastic turf reinforcing grids to concrete grid pavers.

All types of permeable pavement systems can be used with an impermeable liner and underdrain. A liner and underdrain system are required for use with Land Uses with Higher Potential Pollutant Loads (LUHPPLs) (see Chapter 10 - General Design Guidance for Stormwater Infiltration Systems), in locations where contaminated soils exist, where the required vertical separation to SHGT cannot be met, or in locations with unacceptable horizontal setbacks for infiltration. Such systems are suitable for providing treatment and peak runoff attenuation but do not provide retention credit.

Pretreatment

- Pretreatment is not required for permeable pavement but may be appropriate if system receives stormwater runoff from pervious surfaces.

Inlet

- An inlet structure is not required if porous pavement receives evenly distributed sheet flow. Provide a level spreader or other feature to convert concentrated flow to sheet flow in accordance with the Inlet and Outlet Controls section of this Manual.

- Conveyance to porous pavement is typically overland and must be sheet flow; avoid concentrating flows due to features such as raised islands. Porous pavement receiving concentrated flow is more likely to clog and require additional maintenance.

Sizing and Dimensions

Surface Area and Volume

- Permeable pavement should be designed by either the Static or Dynamic Methods as described in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems.

- Size the filter and reservoir course to retain the Required Retention Volume (100% or 50% of the Water Quality Volume or WQV) and fully drain within 48 hours after the end of the design storm as described in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems.

- Assume a porosity of 40% when computing the amount of available storage within the aggregate courses.

- Size the permeable pavement surface area such that the contributing drainage area to the permeable pavement does not exceed three times the surface area of the permeable pavement.

Porous Asphalt and Pervious Concrete

- Surface Course
    - Porous Asphalt:
        - Thickness: 4 to 6 inches
    - Pervious Concrete
        - Thickness: 4 inches (minimum)
    - Design the surface course to support anticipated traffic and other design loads, including additional stresses that may be anticipated at the edges of the installation.

- Choker Course
  - Thickness: 4 to 8 inches

- Filter Course
  - Thickness: 8 to 12 inches; increase to 18 inches if an underdrain is used or there is inadequate separation from SHGT/bedrock.

- Filter Blanket
  - Thickness: 3 inches

- Reservoir Course
  - Thickness (without underdrain): 4 inches minimum
  - Thickness (with underdrain system): 8 inches minimum
  - Thicker reservoir course may be needed to retain the Required Retention Volume (100% or 50% of the WQV) or larger storms for stormwater quantity control
  - Ensure the reservoir course depth is sufficient to prevent winter freeze-thaw and heaving.
    - Combined pavement system and subbase thickness should exceed 0.65 times the design frost depth for the area.

Permeable Interlocking Concrete Pavers

- Surface Course
  - Pavers
    - Thickness: Per manufacturer
    - Gap Width: Per manufacturer
  - Design the surface course to support anticipated traffic and other design loads, including additional stresses that may be anticipated at the edges of the installation.

- Bedding Course
  - Thickness: 2 inches

- Base Reservoir Course
  - Thickness: 6 inches

- Subbase Reservoir Course
  - Thickness (without underdrain): 6 inches (non-vehicle loads), 8 inches (vehicle loads)
  - Thickness (with underdrain system): 8 inches minimum

Underdrain System

- Install an underdrain system when a proposed permeable pavement installation meets one or more of the following conditions:

- Is in native soil that has an infiltration rate less than 0.3 inch per hour (HSG C and D soils)
- Does not meet vertical separation distance to SHGT or bedrock (Chapter 10 - General Design Guidance for Stormwater Infiltration Systems) and should be lined
- Does not meet minimum horizontal setback distances (Chapter 10 - General Design Guidance for Stormwater Infiltration Systems) and should be lined
- Is within a Land Use with Higher Potential Pollutant Loads (LUHPPL) (Chapter 10 - General Design Guidance for Stormwater Infiltration Systems) or area of contaminated soils and should be lined.

- Minimum underdrain pipe diameter: 4 inches

- Minimum underdrain pipe slope: 0.5%

- Install perforated underdrains within a minimum 8-inch-thick reservoir course with a minimum of 2 inches of crushed stone above and below the underdrain.

- For unlined systems, install the perforated underdrain pipe 2 inches below the top of the reservoir course to promote infiltration. For systems that are lined with an impermeable liner to prevent infiltration, install the underdrain pipe 2 inches above the bottom of the reservoir course so the system can drain between storm events.

- Lay underdrain such that perforations are on the bottom of the pipe.

- Use solid (non-perforated) pipe sections and watertight joints wherever the underdrain system passes below berms, extends down steep slopes, connects to a drainage structure, and/or daylights.

- Other considerations when designing/installing underdrains:
  - Provide a marking stake and an animal guard for underdrains that daylight at grade.
  - If designed with laterals, space collection laterals every 25 feet or less.

- Include a minimum of two observation wells/cleanouts for each underdrain, one at the upstream end and one at the downstream end.
  - Cleanouts should be at least 4 inches in diameter, be nonperforated, and extend to the surface (flush with the surface). Cap cleanouts with a watertight removable cap. The cleanout should be highly visible.
  - Provide one cleanout for every 1,000 square feet of surface area (at a minimum) or for every 250 linear feet of total pipe length in larger systems.

Materials

Porous Asphalt and Pervious Concrete

- Porous Asphalt
  - Should conform to the latest version of the University of New Hampshire Stormwater Center Design Specifications for Porous Asphalt Pavement and Infiltration Beds.

- Pervious Concrete
  - Should conform to the latest version of the American Concrete Institute Specification for Pervious Concrete Pavement (ACI SPEC-522.1-13).

- Choker Course
  - Should consist of AASHTO No. 57 clean, washed stone.

- Filter Course
  - Should consist of washed concrete sand (ASTM C33 or AASHTO M-6) or coarse washed sand with a hydraulic conductivity of 10 to 60 feet per day at 95% Standard Proctor.

- Filter Blanket
  - Should consist of 3/8" AASHTO No. 8 stone. Pea gravel should be clean (washed and free from dirt and debris) and rounded in shape.

- Reservoir Course
  - Should consist of 3/4" AASHTO No. 5 stone. Gravel should be clean (washed and free from dirt and debris), crushed, and angular.

Permeable Interlocking Concrete Pavers

- Pavers
  - PCIP: Concrete pavers should conform to ASTM C936 and have a minimum thickness of 3.125 inches when subject to vehicular traffic.
  - Other open course paver systems should conform to manufacturer guidelines.

- Bedding Course
  - Non-vehicle Loads: washed concrete sand (ASTM C33 or AASHTO M-6)
  - Vehicle Loads: pea gravel, 3/8" AASHTO No. 8 washed crushed stone

- Base Reservoir Course
  - Non-vehicle Loads: pea gravel, 3/8" AASHTO No. 8 washed crushed stone
  - Vehicle Loads: AASHTO No. 57 washed crushed stone

- Subbase Reservoir Course
  - Non-vehicle Loads: 3/4" AASHTO No. 5 washed crushed stone

- Vehicle Loads: 1.5" AASHTO No. 4 washed crushed stone

General

- Filter Fabric
  - Use along sides of excavation; filter fabrics should not be used between aggregate courses or beneath the bottom course.
  - Where reservoir courses extend beneath conventional pavement, use filter fabric at the top of the reservoir course.
  - Use non-woven filter fabric that complies with State of Connecticut Department of Transportation Standard Specifications, Section M.08.01.19 (Drainage – Geotextiles).

- Underdrain (perforated and non-perforated pipe sections)
  - Polyethylene or polyvinyl pipe.

- Liner
  - If used, should consist of a 30 mil (minimum) HDPE or PVC liner, or one of the alternative liner systems described in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems with the approval of the review authority.

Stormwater Quantity Control Design – Adjusted Runoff Curve Number

- Permeable pavement systems reduce the volume of runoff from the paved surface and therefore result in a reduced NRCS Runoff Curve Number (CN), which should be used for stormwater hydrologic and hydraulic routing calculations that are required for stormwater quantity control design.

- Determine adjusted CN values for the permeable pavement surface by the following method:

  1. Calculate the volume of stormwater retained by the permeable pavement system as described above.
  2. Calculate the stormwater runoff volume for the water quality storm and the 2-, 10-, and 100-year, 24-hour storms as described in Chapter 4 - Stormwater Management Standards and Performance Criteria of this Manual.
  3. Subtract the volume of stormwater retained by the permeable pavement system from the stormwater runoff volume for the various storm events. The result is the runoff volume that will be discharged from the permeable pavement during each storm event.
  4. Convert the volume of stormwater discharged from the permeable pavement system to an equivalent discharge depth (in inches) by dividing the volume discharged by the area of the permeable pavement surface.
  5. Using the calculated discharge depth described above and the precipitation for each design storm event, calculate the adjusted CN values using the equation or graphical

solution (Figure 2-1 from TR-55) presented in Appendix D of this Manual (i.e., Graphical Peak Discharge Method).

- Once the adjusted CN values are determined, also calculate the time of concentration and either follow the remaining steps in the Graphical Peak Discharge Method in Appendix D or use a stormwater hydrologic/hydraulic routing model based on the NRCS Curve Number method (e.g., Hydro CAD or similar software) to calculate peak discharge rates for each design storm event.

Outlet & Overflow

- Permeable pavement should be graded to convey runoff to a properly designed conveyance system for storms greater than the design storm event.

- In addition to underdrains, common overflow outlets include curb cuts, catch basins, or a perimeter stone trench.

- Design the outlet in accordance with the Inlet and Outlet Controls section of this Manual.

Other Considerations

- The existing native subgrade material under permeable pavement should not be compacted or subject to excessive construction equipment traffic.

- The entire contributing drainage area should be completely stabilized prior to directing any flow to permeable pavement.
    - Adequate vegetative cover should be established over any pervious area adjacent or contributing to the installation before runoff can be accepted.

- Provide terraces and impermeable baffles or graded impermeable berms to maximize storage and prevent lateral reservoir course flow when subgrade slope exceeds 2%.

- In systems where pervious pavement is installed adjacent to conventional pavement, a full-depth barrier (impermeable liner) should be used between the two types of pavements to ensure that structural integrity is maintained and to prevent inadvertent saturation of the adjacent impervious pavement surface course.

Construction Recommendations

- The designing qualified professional should develop a detailed, site-specific construction sequence.

- The designing qualified professional r should inspect the installation during the following stages of construction, at a minimum:
    - After excavation of the system and scarification of bottom and sidewalls of excavation
    - After placement of each gravel layer and drainpipes (if any)

   - After installation of bypass, outlet/overflow, and inlet controls
   - Before and during placement of the pavement material (porous asphalt, pervious concrete, or pavers)
   - After pavement and pavers have been installed

- The designing qualified professional should provide an as-built plan of the completed permeable pavement system along with a certification that the system was designed in accordance with the guidance contained in this Manual and other local or state requirements and that the system was installed in accordance with the approved plans.

- Materials testing requirements per the applicable specifications for each type of permeable pavement system.

- The entire contributing drainage area should be completely stabilized prior to directing any flow to the system. Adequate vegetative cover must be established over any pervious area adjacent or contributing to the system before runoff can be accepted.

- Erosion and sediment controls should be in place during construction in accordance with the Connecticut Guidelines for Soil Erosion and Sediment Control and the Soil Erosion and Sediment Control (SESC) Plan developed for the project.

- During clearing and grading of the site, measures should be taken to avoid soil compaction at the location of the proposed permeable pavement system.

- The system should be fenced off during the construction period to prevent disturbance of the soils.

- The system should be excavated to the dimensions, side slopes, and elevations shown on the plans. The method of excavation should avoid compaction of the bottom of the system. A hydraulic excavator or backhoe loader, operating outside the limits of the system, should be used to excavate the system. Excavation equipment should not be allowed within the limits of the system.

- The various gravel layers should be placed in the excavation by a hydraulic excavator or backhoe loader located outside the limits of the system and compacted.

- The pavement material should be placed in accordance with the applicable installation requirements, as specified below:

- **Porous Asphalt:** The latest version of the University of New Hampshire Stormwater Center Design Specifications for Porous Asphalt Pavement and Infiltration Beds.[85]

- **Pervious Concrete:** The latest version of the American Concrete Institute Specification for Pervious Concrete Pavement (ACI SPEC-522.1-13)

- **Permeable Interlocking Concrete Pavers:** Manufacturer guidelines.

- For open course paver systems with vegetation, install grass according to the manufacturer's guidelines and in accordance with these general recommendations:
  - At least 1/8" to 1/4" of the paver must remain above the soil to bear the traffic load.
  - Sod or seeding method may be used.
  - If sod is used, the depth of backfill required will depend on the depth of the sod. Sod is laid over the pavers, watered thoroughly, and then compressed into the cells of the pavers.
  - If grass is planted from seed, the appropriate soil should be placed in the cells, tamped into the cells, and then watered thoroughly so that the appropriate amount of paver is exposed. The soil is then ready for planting with a durable grass seed.
  - Traffic should be excluded from the area for at least a month to allow for establishment of grass.

Maintenance Needs

- Permeable pavement systems should be designed with easy access to all components of the system for maintenance purposes. Refer to Chapter 7 - Overview of Structural Stormwater Best Management Practices for general design considerations to reduce and facilitate system maintenance.

- Detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance should be identified on the plans and in the Stormwater Management Plan.

- Maintenance must be performed by properly trained personnel trained in the use of the special equipment necessary in accordance with industry or manufacturer's requirements such as vacuum sweeping, specialized snow plowing accessories, etc.

- Maintenance should be detailed in a legally binding maintenance agreement.

85 https://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/pubs_specs_info/unhsc_pa_spec_10_09.pdf

- Maintenance activities such as sediment removal, mowing, and repairs should be performed with rakes and light-weight equipment rather than heavy construction equipment to avoid compaction of the bioretention soil media and underlying soils. Heavy equipment may be used for sediment removal and other maintenance activities if the equipment is positioned outside the limits of the bioretention system. Heavy construction equipment should not be allowed within the limits of the bioretention system for maintenance purposes.

Recommended Maintenance Activities

- Inspect surface course after major storms (1 inch or more of precipitation) in the first year following construction.
- Inspect surface course annually.
- Refer to Appendix B for maintenance inspection checklists, including items to focus on during the inspections.
- Vacuum sweep and air blow (using a leaf blower or equipment recommended by the manufacturer) the permeable pavement surface quarterly.
- Regularly remove tracked mud or sediment and leaves. Power washing can be effective for cleaning clogged areas.
- Do not apply sand during winter operations.
- Minimize use of deicing chemicals. Only use as necessary based on site-specific drainage and icing conditions.
- Do not use deicing chemicals on pervious concrete less than one year old. Never use deicers containing magnesium chloride, calcium magnesium acetate or potassium acetate on pervious concrete.
    - Use caution when removing snow from the surface course. Some permeable paving surface courses such as pavers may be damaged by snowplows or loader buckets not equipped with a rubber blade guard to avoid catching on the paver units.
    - Under no circumstances may any sealants or coatings be applied to permeable paving systems, except for those approved by the manufacturer to improve surface course resistance to deicing chemicals or refresh traffic striping.
    - Take corrective action if the system fails to drain the design storm volume within 48 hours after the end of a storm.

Figure 13-15.. Permeable Pavement – Typical Sections