ProFlow Permeable Paver™

Installation Manual

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Overview for permeable pavement

ProFlow Permeable Paver™: Permeable pavement can be an important tool for retention and detention of stormwater runoff. Permeable pavement may provide additional benefits, including reducing the need for de-icing chemicals, and providing a durable and aesthetically pleasing surface.

Permeable pavements allow stormwater runoff to filter through surface voids into an underlying stone reservoir where it is temporarily stored and/or infiltrated. Permeable pavements have been used for areas with light traffic at commercial and residential sites to replace traditionally impervious surfaces such as low-speed roads, parking lots, driveways, sidewalks, plazas, and patios.

While the designs vary, all permeable pavements have a similar structure, consisting of a surface pavement layer, an underlying stone aggregate reservoir layer, optional underdrains, and geotextile over uncompacted soil subgrade. From a hydrologic perspective, permeable pavement is typically designed to manage rainfall landing directly on the permeable pavement surface area. Permeable pavement surface areas may accept runoff contributed by adjacent impervious areas such as driving lanes or rooftops. Runoff from adjacent vegetated areas must be stabilized and not generating sediment as its transport accelerates permeable pavement surface clogging. Additionally, the capacity of the underlying reservoir layer limits the contributing area.

Schematic showing the process of infiltration into permeable pavement during and after a rain event. Note how infiltrating water includes precipitation falling directly on the pavement and runoff from the adjacent street directed onto the pavement. Caution should be used when runoff is diverted from impervious surfaces to permeable pavement.

Benefits and limitations

Benefits:

Permeable pavements allow conversion and/or design of typical impervious areas (i.e. parking lots) to pervious areas that infiltrate stormwater runoff. When compared to typical impervious areas, properly designed and maintained permeable pavements can reduce the runoff quantity, reduce total suspended solids (TSS) and total phosphorus (TP) loads into receiving water bodies, and reduce runoff temperatures. In addition, permeable pavements can reduce nitrogen, metals and process oils. Permeable pavements are well suited for high density urban areas with limited space for other BMPs such as ponds, swales or bioretention systems.

Limitations:

As with all BMP’s, permeable pavement has limitations that need to be considered before design and construction.

Pretreatment considerations

Pretreatment that removes sediment from runoff draining onto permeable pavement from impervious surfaces is desirable since sediment can clog permeable pavements. For that reason, pretreatment areas should emit practically no sediment onto the permeable pavement surface. Locating such areas next to impervious surfaces upslope from the permeable pavement may not be possible on some sites. Permeable pavement itself can be considered a pre-treatment device and included in a stormwater treatment train if underdrains are utilized within the storage reservoir. The underdrains will typically be routed to a bioretention area.

Permit applicability

Permeable pavements can be utilized to assist in meeting stormwater requirements for volume, total suspended solids, and total phosphorus. The section on credits provides guidance on the implementation of permeable pavements that may be utilized to meet various runoff volume and pollutant runoff reduction goals.

Retrofit suitability

In most cases, existing impervious surfaces can be replaced with permeable pavements to achieve improved runoff conditions. Retrofit requires the removal of the old pavement and subgrade and the installation of the underlying reservoir layer and the permeable pavement. For the greatest water quality credits, avoid compaction of subgrade soils. If this is not possible, compacted subgrade soils should be removed or loosened to achieve the maximum infiltration rate possible.

Cold climate suitability

Favorable permeable pavement performance has been documented in cold climates. Air in the aggregate base acts as an insulating layer and the higher latent heat associated with higher soil moisture delays the formation of a frost layer while maintaining permeability and this condition also reduces frost depths when frozen. Winter sanding should be avoided when possible and if used, removed by vacuuming the following spring. Permeable pavements require significantly less use of, or in some cases, no deicing chemicals and sand to maintain a safe walking or driving surface. Other climate considerations include high wind erosion (California 2003). Dramatic reductions in life span of the infiltration properties of the pavement may occur in these areas due to particulate clogging and this may require additional surface vacuum cleaning.

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Special receiving waters suitability

Many of the same design considerations and limitations apply to permeable pavement as to other infiltration practices.

- Infiltration of runoff from hotspots (e.g., gas stations, chemical storage areas, etc.) should be carefully considered and in many cases avoided.
- Special consideration also needs to be taken near wellhead areas and basement foundations.

- Some designs may require consideration of storms in excess of the infiltration capabilities of the pavement. For these situations the design should ensure the excess runoff does not negatively impact special surface waters (e.g.,trout streams) through the implementation of additional BMPs.

Water quality

In general, permeable pavement provides removal of TSS and other pollutants through processes similar to other filtration and infiltration BMPs. However, permeable pavements are not suggested for areas that may receive high loading rates of TSS due to their propensity for surface clogging. The expected annual volume and pollutant reductions for designs without an underdrain are a function of the underlying reservoir storage volume. The greater the storage volume, the greater the annual volume and pollutant reductions.

For designs with underdrains, reductions are typically lower depending on the drain outflow location that determines the volume of water removed by the underdrains before infiltration. Of the water intercepted and draining through the underdrain, 45 percent (with upper and lower 90 percent confidence bounds of 65 percent and 24 percent, respectively) of the total phosphorus and 74 percent (with upper and lower 90 percent confidence bounds of 93 percent and 33 percent, respectively) of total suspended solids removal can be expected.

Water quantity

The primary advantage of permeable pavements is providing volume reduction by reducing runoff from a site and/or providing attenuation from outflows. The volume of water that will be reduced during a given rainfall event will be equivalent to the volume available for storage below the pavement or underdrain (if an underdrain is present).

Summary of permit requirements for infiltration

The following are requirements of the Construction Stormwater General Permit.

Infiltration systems (including bioinfiltration)

- Permittees must design infiltration systems such that pre-existing hydrologic conditions of wetlands in the vicinity are not impacted (e.g., inundation or breaching a perched water table supporting a wetland).
- Permittees must not excavate infiltration systems to final grade, or within three (3) feet of final grade, until the contributing drainage area has been constructed and fully stabilized unless they provide rigorous erosion prevention and sediment controls (e.g., diversion berms) to keep sediment and runoff completely away from the infiltration area.
- When excavating an infiltration system to within three (3) feet of final grade, permittees must stake off and mark the area so heavy construction vehicles or equipment do not compact the soil in the infiltration area.
- Permittees must use a pretreatment device such as a vegetated filter strip, forebay, or water quality inlet (e.g., grit chamber) to remove solids, floating materials, and oil and grease from the runoff, to the maximum extent practicable, before the system routes stormwater to the infiltration system.

- Permittees must design infiltration systems to provide a water quality volume (calculated as an instantaneous volume) of one (1) inch of runoff, or one (1) inch minus the volume of stormwater treated by another system on the site, from the net increase of impervious surfaces created by the project.
- Permittees must design the infiltration system to discharge all stormwater (including stormwater in excess of the water quality volume) routed to the system through the uppermost soil surface or engineered media surface within 48 hours. Permittees must route additional flows that cannot infiltrate within 48 hours to bypass the system through a stabilized discharge point.
- Permittees must provide a means to visually verify the infiltration system is discharging through the soil surface or filter media surface within 48 hours or less.
- Permittees must provide at least one soil boring, test pit or infiltrometer test in the location of the infiltration practice for determining infiltration rates.
- For design purposes, permittees must divide field measured infiltration rates by 2 as a safety factor or permittees can use soil-boring results with the infiltration rate chart design infiltration rates. When soil borings indicate type A soils, permittees should perform field measurements to verify the rate is not above 8.3 inches per hour. This permit prohibits infiltration if the field measured infiltration rate is above 8.3 inches per hour.
- Permittees must employ appropriate on-site testing ensure a minimum of three (3) feet of separation from the seasonally saturated soils (or from bedrock) and the bottom of the proposed infiltration system.
- Permittees must design a maintenance access, typically eight (8) feet wide, for the infiltration system.
- This permit prohibits permittees from constructing infiltration systems that receive runoff from vehicle fueling and maintenance areas including construction of infiltration systems not required by this permit.
- This permit prohibits permittees from constructing infiltration systems where infiltrating stormwater may mobilize high levels of contaminants in soil or groundwater.
- The construction of infiltration systems in areas where soil infiltration rates (including amended soils) are field measured at more than 8.3 inches per hour unless they amend soils to slow the infiltration rate below 8.3 inches per hour.
- Prohibits constructing infiltration systems in areas that receive runoff from the following industrial facilities not authorized to infiltrate stormwater from industrial activities: automobile salvage yards; scrap recycling and waste recycling facilities; hazardous waste treatment, storage, or disposal facilities; or air transportation facilities that conduct deicing activities.

Additional considerations for permeable pavement

Permeable pavement can be an important tool for retention and detention of stormwater runoff. Permeable pavement may provide additional benefits, including reducing the need for de¬icing chemicals, and providing a durable and aesthetically pleasing surface.

Compliance with the Americans with Disabilities Act (ADA)

All permeable pavements are ADA compliant. PICP is compliant if designs are used with joints less than V inch wide.

Groundwater protection and underground injection control permits

The Safe Drinking Water Act regulates the infiltration of stormwater in certain situations pursuant to the Underground Injection Control (UIC) Program, which is administered either by the US EPA or a delegated state groundwater protection agency. The US EPA (USEPA 2008) determined that permeable pavement installations are not classified as Class V injection wells since they are always wider than they are deep. There may be an exception in karst terrain if the discharge from permeable pavement is directed to an improved sinkhole, although this would be uncommon.

Air and runoff temperature

Permeable pavement appears to have some value in reducing summer runoff temperatures which can be important in watersheds with sensitive cold-water fish populations (Hunt 2011). The temperature reduction effect is greatest when runoff is infiltrated into reservoir layer when underdrains are used. All permeable pavements exhibit cooler summer temperatures than their impervious counterparts.

Sustainable rating systems

All permeable pavements support sustainable rating systems such as LEED and others plus sustainable transportation rating systems such as those published by the Institute for Sustainable Infrastructure (Envision), Federal Highway Administration (INVEST), and the University of Washington (Greenroads).

Certification

Industry-trained and experienced supervisory personnel should be required on all jobsites and requirements written into project specifications. A specifications requirement can be contractor submittals demonstrating experience with previous projects.

For design professionals, industry and professional associations offer in-person and online continuing education programs on design, construction and maintenance of permeable pavements. Many of these programs are registered with continuing education programs offered for civil engineering professional development hours, the American Institute of Architects and the American Society of Landscape Architecture continuing education systems, and the Green Building Certificate Institute Credential Maintenance Program for LEED® accredited professionals. Designers are encouraged to participate in these programs.

Design criteria for permeable pavement

ProFlow Permeable Paver™ can be an important tool for retention and detention of stormwater runoff. Permeable pavement may provide additional benefits, including reducing the need for de-icing chemicals, and providing a durable and aesthetically pleasing surface.

This section provides information on design considerations, criteria and specifications for permeable pavement. Base/subbase thickness is determined for water storage using hydrologic sizing and/or dynamic modeling over time. Base/subbases thickness for supporting traffic is determined using structural design methods. The thicker of the two resulting designs is employed.

Design phase maintenance considerations

Implicit in the design guidance is the fact that many design elements of infiltration and filtration systems can minimize the maintenance burden and maintain pollutant removal efficiency. Key examples include:

- limiting drainage area;
- providing easy site access *(REQUIRED);* and
- providing pretreatment *(REQUIRED).*

Hydrologic design considerations

- Permeable pavement is subject to the following design considerations, including benefits and constraints.
- Available space - A significant advantage of permeable pavement is its ability to combine detention/ infiltration and pavement, thereby reducing or eliminating land required for detention facilities. This is especially important in urban areas with high land prices and highly developed sites with little or no space for stormwater detention.
- Soils - Soil conditions and infiltration rates determine the use of an underdrain. (NRCS Hydrologic Soil Group (HSG) C or D soils usually require an underdrain, whereas HSG A and B soils often do not.) Designers should evaluate existing soil properties during initial site layout with the goal of configuring permeable pavement that conserves and protects soils with the highest infiltration rates. In particular, areas of HSG A or B soils shown on soil surveys should be considered as primary locations for all types of infiltration practices.
- Soil surveys and HSG classifications provide a general estimate of the soil's infiltration rate. Soil infiltration rates can also be estimated from soil classifications per ASTM D2487. However, it is best to determine rates using on-site infiltration testing per ASTM D3385 Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer, D5093 Standard Test Method for Field Measurement of Infiltration Rate Using Double-Ring Infiltrometer with Sealed-Inner Ring or other available methods. The median rate determined from in-situ measurements should be reduced by a factor of 2.5 and this reduced value used in

design calculations. This reduction accounts for incidental compaction during construction and sedimentation of the subgrade over time.

Information: The safety factor of 2.5 is greater than a factor of 2 recommended in most guidance for permeable pavement. This manual utilizes recommended soil infiltration rates for hydrologic soil groups (see [6]). These are not as conservative as infiltration rates based on the Unified Soil Classification System, particularly for finer textured soils. We therefore recommended the more conservative value of 2.5

- In most cases, permeable pavement should not be situated above fill soils. Designs in compacted fill soils may require an impermeable liner and an underdrain. Permeable pavements should only be placed on fill soils when laboratory tests indicate the compacted fill will be stable when saturated and that slope stability of deep fills has been verified by a geotechnical engineer.
- Geotextiles - In the absence of full-depth concrete curbs or impermeable liners, geotextiles are recommended on the (vertical) sides of permeable pavements to separate the reservoir layers from the adjacent soil subgrade. Horizontally placed geotextiles between the aggregate base and soil subgrade are at the option of the designer. Geotextile use should be carefully evaluated and selection should be guided by AASHTO M-288 Geotextile for Highway Applications (AASHTO 2010). Specific selection guidance is provided under the Subsurface Drainage section. Class II geotextiles are generally used.
- Contributing drainage area - Permeable pavements sometimes capture runoff from adjacent areas, pavements, and roofs. Runoff from permeable areas is not recommended due to potential clogging of the permeable pavement. The at-grade contributing drainage area into permeable pavement should generally not exceed twice the surface area of the permeable pavement. This guideline helps reduce the rate of surface sedimentation. The 2:1 ratio can be increased to no greater than 5:1 if at least one of these conditions exists:
- Permeable pavement is receiving runoff from roofs as it tends to be very low in sediment; or
- runoff from adjacent impervious surfaces remains unburdened with sediment due to effective pre-treatment prior to entering the permeable pavement.

Caution: Permeable pavement and contributing impervious pavements are assumed to receive regular vacuuming to reduce and control sediment loads and surface clogging potential.

- Soil subgrade slope - The slope of the soil subgrade should be as flat as possible (i.e., less than 1 percent longitudinal slope) to enable even distribution and infiltration of stormwater. Lateral slopes should be less than 1 percent. Steep slopes can reduce the stormwater storage capacity of permeable pavement. Designers should consider using a terraced subgrade design for permeable pavement in sloped areas, especially when the subgrade slope exceeds 3 percent.
- Soil subgrade compaction - This should be avoided wherever possible to maximize infiltration. In some situations, compaction may be needed for supporting vehicular loads. In such cases, compaction density and subsequent soil infiltration should be assessed in a test pit(s) on the site to determine an acceptable soil density and its contribution to soil strength and infiltration. The measured infiltration rate for use in hydrologic calculations may be reduced by the designer to compensate for long-term sedimentation on the soil subgrade.

- Excavation methods - Excavation should be conducted in a manner that minimizes soil subgrade compaction. Tracked rather than wheeled equipment is recommended working from the sides of the excavation. For larger projects, excavation can create cells and berms where equipment removes soil from one area or cell while positioned on higher soil around each cell (see Construction specifications for permeable pavement). Other techniques include ripping or loosening soils compacted by construction equipment. This can be done with the teeth on excavation equipment buckets.
- Compaction of the aggregate base into these areas is especially important since scarified soil can settle and be reflected on the surface.
- Surface slope - Surface slopes for all permeable pavement types should be at least 1 percent to provide an alternate means for drainage should the surface become completely clogged due to lack of maintenance. Designs should provide an alternate means for stormwater to enter the aggregate reservoir if the pavement surface should ever become clogged, or for extreme storm events.
- Overflow structures - Permeable pavements are not designed to store and infiltrate all stormwater from all storms. Therefore, an outlet or outlets are required to prevent water from rising into and over the surface. One type of outlet control would be a catch basin with an internal weir and low-flow orifice. The catch basin can also handle runoff from the surface should it become clogged.
- Minimum depth to seasonal high water table - A high groundwater table may cause seepage into the bottom of permeable pavement and prevent complete drainage. Also, soil acts as a filter for pollutants between the bottom of the pavement base and the water table. Therefore, a minimum vertical separation of 3 feet is required between the bottom of the permeable pavement reservoir layer and the seasonal high groundwater table. For systems with impermeable liners, a minimum of one foot clearance is highly recommended between the liner and the seasonal high water table.
- Setbacks - To avoid harmful seepage, permeable pavement should not be hydraulically connected to building foundations unless an impermeable liner is placed against the foundation or basement wall. Even under these circumstances, great care should be taken to avoid creating a wet basement problem. If there is no liner, the permeable pavement base should be 10 feet or greater from structures (EPA recommends a minimum setback from building foundations of 10 feet down-gradient and 100 feet up-gradient. See EPA factsheet “Storm Water Technology Fact Sheet: Porous Pavement,” EPA 832-F-99-023). Again, it is the designer’s responsibility to avoid creating a wet basement problem. Likewise, permeable pavement bases should be hydraulically separated from adjacent road bases.
- Permeable pavements without underdrains infiltrate stormwater and should follow requirements for wellhead protection (EPA recommends a minimum setback of 100 feet from water supply wells). Underground utility lines are best located away from permeable pavement bases. However, if they need to penetrate the base, consideration should be given to waterproofing (depending on the utility) or possible encasement using low-strength flowable concrete fill. Setbacks can be reduced at the discretion of the local authority for designs that use underdrains and/or liners.
- Informed Owner - 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., vacuuming) to maintain the pavement’s hydrologic functions,

and avoid future practices (e.g., winter sanding, seal coating or repaving) that diminish or eliminate them. Maintenance agreements, covenants, maintenance easements or performance bonds are encouraged between the local authority and the property owner.

Green Infrastructure: Permeable pavement can be used at highly developed urban sites that have little or no space retention.

Caution: The required setback distance to a municipal water supply well is 50 feet, but it is recommended that permeable pavements be a minimum horizontal distance of 100 feet from any municipal water supply well

Warning: A minimum vertical separation of 3 feet is required between the bottom of the permeable pavement reservoir layer and the seasonal high groundwater table (saturated soil) or the top of bedrock (i.e. there must be a minimum of 3 feet of undisturbed soil beneath the infiltration practice and the seasonally high water table or top of bedrock).

- Limitations - There are several limitations for use of permeable pavement, as summarized below.
- Permeable pavements should not be used in high pollutant loading sites. High pollutant loading sites are those that receive constant sediment or trash and/or debris. Places where fuels and chemicals are stored or handled can be potential stormwater hotspots and permeable pavement should not be constructed in these places. Likewise, areas subject to wind borne dust and sediment should not use permeable pavement unless the pavement can be vacuumed regularly. The following limitations should be considered before utilizing permeable pavements in any design.
- Permeable pavement is suitable for pedestrian-only areas, low-volume roads, low speed areas, overflow parking areas, residential driveways, alleys, and parking stalls. These can be residential collector roads or other applications with similar traffic loads.
- Permeable pavement can be prone to clogging from sand and fine sediments that fill void spaces and the joints between pavers. As a result, it should be used carefully where frequent winter sanding is necessary because the sand may clog the surface of the material. Periodic maintenance is critical, and surfaces should be cleaned with a vacuum sweeper at least two times a year.
- Fuel may leak from vehicles and toxic chemicals may leach from asphalt and/or binder surface. Porous pavement systems are not designed to treat these pollutants.

Design criteria

Base/subbase thickness is determined for support traffic using structural design methods and for water storage using hydrologic sizing and/or dynamic modeling over time. The thicker of the two resulting designs is used.

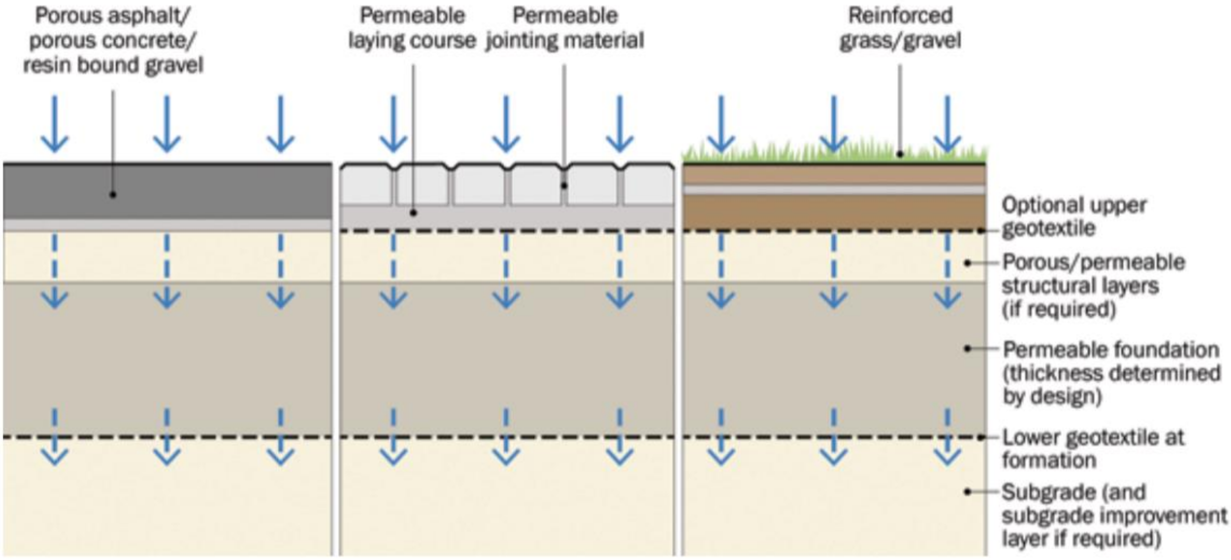

Figure 20.12 Pervious pavement system types: Type A – total infiltration

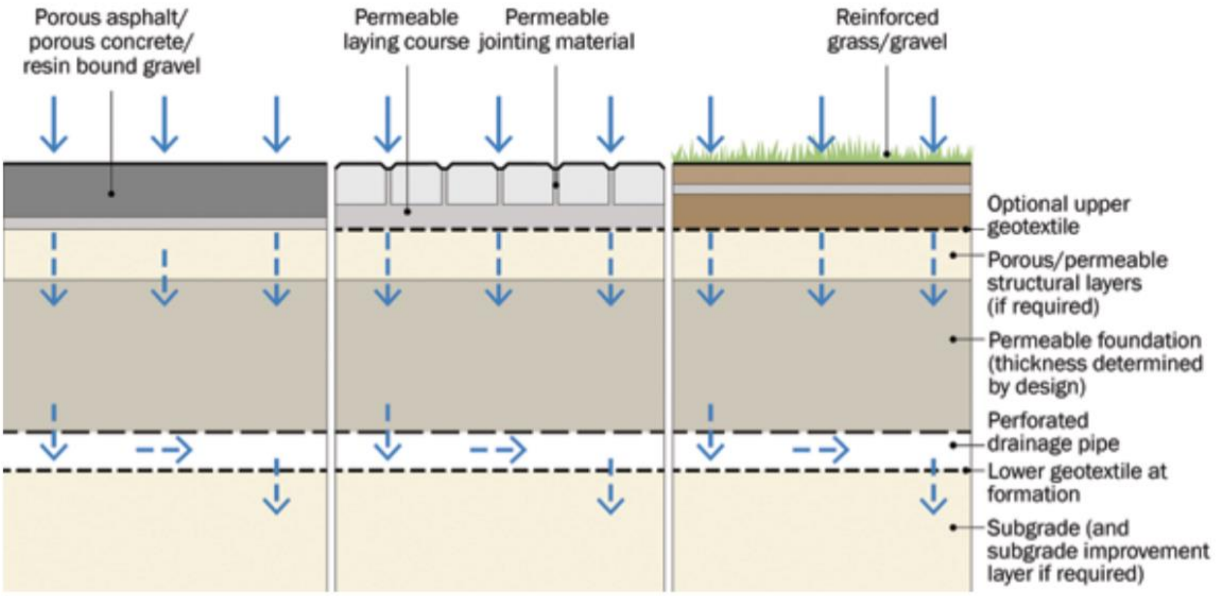

Figure 20.13 Pervious pavement system types: Type B – partial infiltration

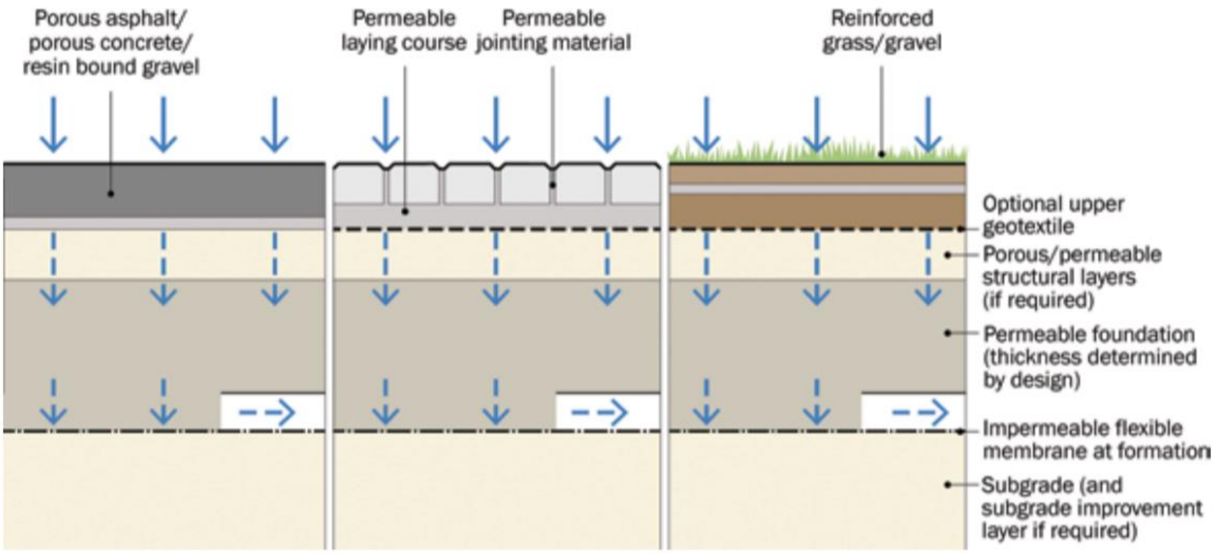

Figure 20.14 Pervious pavement system types: Type C – no infiltration

Structural design

ProFlow Permeable Paver™ has done limited research on full-scale testing of the structural behavior of open-graded bases used under permeable pavements to better characterizing relationships between loads and deformation. Therefore, conservative values (i.e., AASHTO layer coefficients) should be assumed for open-graded base and subbase aggregates in permeable pavement design.

Regardless of type of permeable pavement, structural design methods consider the following in determining surface and base thicknesses to support vehicular traffic:

- pavement life and total anticipated traffic loads expressed as 18,000 pounds equivalent single axle loads or ESALs (This method of assessing loads accounts for the additional pavement wear caused by trucks.);
- soil strength expressed as the soaked California Bearing Ratio (CBR), R-value or resilient modulus (Mr);
- strength of the surfacing, base and subbase materials; and
- environmental factors including freezing climates and extended saturation of the soil subgrade.

Soil stability under traffic should be carefully reviewed for each application by a qualified geotechnical or civil engineer and lowest anticipated soil strength or stiffness values under saturated conditions used for design. Structural design for vehicular applications should generally be on soil subgrades with a CBR (96-hour soaked per ASTM D 1883 or AASHTO T 193) of 4 percent, or a minimum R-value = 9 per ASTM D 2844 or AASHTO T-190, or a minimum Mr of 6,500 pounds per square inch (45 Mega Pascals) per AASHTO T-307.

Soil compaction required to achieve these soil strengths will reduce the infiltration rate of the soil. Therefore, the permeability or infiltration rate of soil should be assessed at the density required to achieve one of these values. If soils under vehicular traffic have lower strengths than those noted above, or are expansive when wet, there are several options, including

- underdrains;
- thickened base/subbase layer(s);
- cement or asphalt stabilized base layers; and

- lime or cement stabilized (with design consideration given to practically no infiltration in such cases).

These options are typically used in combination. Pedestrian applications can be placed on lower strength soils than those noted.

Pedestrian applications can be placed on lower strength soils than those noted.

Outflow rate and volume through underdrains

If the depth of the base/subbase for the full infiltration system is excessive, because, as an example, the design subgrade soil infiltration rate is not adequate to remove the water from the design storm within the designated period of time, then the design should include underdrains. The following procedure is for sizing the base/subbase for partial infiltration designs (i.e. contains underdrains).

The outflow rate from underdrain(s) can be approximated by

$q_u = km$ qu=km where

q_u = outflow through underdrain, feet/hour

k = Coefficient of permeability for each 6 inch diameter underdrain, feet/hour m = underdrain pipe slope, feet/feet

This equation is based on Darcy's Law, which summarizes several properties that groundwater exhibits while flowing in aquifers. Although the hydraulic conductivity (measure of the ease with which water can move through pore spaces of a material) of the aggregate subbase is very high (approximately 17,000 feet per day or 8,500 inches per hour), the discharge rate through underdrains is limited by the cross sectional area of the pipe. As the storage volume above/around the underdrain(s) decreases (i.e., the hydraulic head or water pressure decreases), the base/subbase and in turn the underdrain(s) will drain increasingly slower. To account for this change in flow conditions within the subbase and underdrain(s) over time, a very conservative coefficient of permeability (k) of 100 feet per day per pipe can be used to approximate the average underdrain outflow rate.

Once the outflow rate through each underdrain has been approximated, the depth of the base/subbase needed to store the design storm can be determined by

$d_p = ((0.95 * RP)-(i/2)t_f))/n$ dp=((0.95*RP)-(i/2)tf))/n

where

0.95 is the runoff coefficient for impermeable surfaces; dp = the depth of the reservoir layer (feet);

$R = A_c/Ap$ The ratio of the contributing drainage area (A_c, including the permeable paving surface), to the permeable pavement surface area (Ap);

tf = the time to fill the reservoir layer (day) - typically 2 hours or 0.083 day;

P = the rainfall depth for the design storm (feet); i = field-verified infiltration rate (ft/day); and n = porosity (cubic feet/cubic feet)

To estimate the number of underdrain pipes (N), take the dimension of the parking lot in the direction the pipes are to be placed and divide by the desired spacing between pipes - round down to the nearest whole number.

With full infiltration systems, the maximum allowable drain time (tj) needs to be calculated to make sure the stored water within the base/subbase does not take too long to infiltrate into the soil subgrade.

$t_d = (d_p n)/(0.5i)$ td=(dpn)/(0.5i)

The total storage in the permeable pavement system, V_s, is given by

$V_s = A_p(d_p n + 0.5it_f)$ Vs=Ap(dpn+0.5itf)

where

Ap is the surface area of the permeable pavement (ft).

When calculating the storage volume for compliance with the Construction Stormwater Permit, only the instantaneous storage volume is considered

$V_s = A_p(d_p n)$ Vs=Ap(dpn)

Permeable pavement can also be designed to augment detention storage needed for channel protection and/or flood control. The designer can model various approaches by factoring in storage within the base/subbase, expected infiltration and any outlet structures used as part of the design.

Once runoff passes through the surface of the permeable pavement system, designers should calculate outflow pathways to handle subsurface flows. Subsurface flows can be regulated using underdrains, the volume of storage in the reservoir layer, the bed slope of the reservoir layer, and/or a control structure at the outlet.

Design for nutrient and TSS reductions

Permeable pavements can be designed to reduce nutrient loadings to the ground or surface waters. The design needs to be specifically designed to capture phosphorus. The permeable pavement system can also be designed to capture nitrogen, although it is important to note that nitrogen and phosphorus each require specific designs to facilitate their removal from stormwater. The following paragraphs describe the design characteristics necessary for the removal of phosphorus and nitrogen.

A study by (Bean, 2007a) showed higher nitrate concentrations in the exfiltrate compared to the infiltrate. Nitrogen reduction capabilities of permeable pavement can be enhanced in partial infiltration designs that detain water in the base/subbase for over 24 hours. This time is required to ensure complete de-nitrification occurs.

PICP can use specially coated aggregates in the joints and bedding and all systems can use them in the base to reduce phosphorous. Coated aggregates (sometimes called “engineered aggregates”) have an effective life of seven to ten years and target the removal of dissolved phosphorous, according to manufacturer’s literature.

A filter layer made of sand or fine aggregate placed under or sandwiched within permeable pavement bases are occasionally used as a means to reduce nutrients. This layer can be enhanced with iron filings for phosphorous reduction (Erickson 2010). Their effectiveness, initial cost, reduction in flow rates, and maintenance costs should be weighed against other design options for nutrient reductions. Sand filters will incur additional construction expense and this can be reduced by placing sand filters under the subbase at the down slope end of a permeable pavement. The disadvantage of sand filters is that they will eventually require removal and restoration if continued phosphorus reduction credit is desired. Concentrating their location in the down slope areas of the site can help reduce future maintenance costs and site disruptions.

A second approach useful for nutrient and TSS reduction can occur on sloping sites by creating intermittent berms in the soil subgrade. These enable settlement of suspended solids and encourage de-nitrification if appropriately designed. A third alternative is using a "treatment train" approach where a permeable pavement initially filters runoff and the remaining water outflows to bioswales or rain gardens adjacent to the pavement for additional processing and nutrient reduction. There may be additional BMPs used to remove nutrients as the water moves through the watershed.

Soil infiltration rate testing

Prior to infiltration testing, soil borings should be taken with an auger to assess the consistency of the soil type and horizons. Guidance for conducting infiltration tests and for determining the number of borings can be found here.

Conveyance and overflow

Permeable pavement designs should include methods to convey larger storms (e.g., 2-year, 10-year) to the drain system. The following is a list of methods that 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). Pipe placement should be away from wheel loads to prevent damage.
- Increase the thickness of the top of the reservoir layer.
- 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.
- Route excess flows to another detention or conveyance system that is designed for management of extreme event flows.
- Set the storm drain inlets level with the elevation of the permeable pavement surface to effectively convey excess stormwater runoff past the system. The design should also make allowances for relief of unacceptable ponding depths during larger rainfall events.

Reservoir layer

The reservoir below the permeable pavement surface should be composed of clean, washed crushed stone aggregate and thickness sized for both the storm event to be stored and the structural requirements of the expected traffic loading. The recommended minimum void ratio should be 40 percent per ASTM C29. Reservoir base layers for pervious concrete are typically washed AASHTO No. 57 stone and those for porous asphalt are AASHTO No. 2, 3, or 5. PICP uses AASHTO No. 2, 3, or 4 stone.

If exposed to vehicular loads, all crushed stone should be Class A or B coarse aggregate, minimum 80 percent crushed, typically granite, basalt, gneiss, trap rock, diabase, gabbro, or similar material. The maximum Los Angeles Rattler

Loss should be 35 percent per AASHTO T-96 and no greater loss than 10 percent per AASHTO T-104 Magnesium Sulfate Soundness Test on the non-igneous portions and as modified by the MnDOT Laboratory Manual (MNDOT 2005). Limestone aggregates not meeting these requirements are not recommended in vehicular applications. Class C and D aggregates may be used in areas subject only to pedestrian traffic.

Underdrains

Underdrains install quickly when placed on or in the soil subgrade, surrounded by stone base materials. The outflow portion at the end is not perforated and is raised to a designed height that allows for some water detention prior to outflow. Placement at this elevation also protects the pipe with aggregate during base compaction. For permeable pavement bases/subbases using 2 or 3 inch maximum size aggregates, underdrain pipes with them should be surrounded with at least 4 inches of ASTM No. 57 (maximum 1 inch size aggregate) to protect the pipes during compaction. 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.

Maintenance

Proper maintenance of permeable pavement is crucial for ensuring its longevity and functionality. Some portions of the maintenance plan require planning during the design stages. These items are noted below.

- Observation Well - Typically this consists of a well-anchored, six-inch diameter perforated PVC pipe that extends vertically to the bottom of the reservoir layer. This is installed at the down slope end of the permeable pavement. The observation well should be fitted with a lockable cap installed flush with the ground surface (or under the pavers) to facilitate periodic inspection and maintenance. The observation well enables visual monitoring of drawdown within the reservoir layer after a storm.
- Overhead Landscaping - Some communities require a certain percentage of parking lots to be landscaped. Large-scale permeable pavement should be carefully planned to integrate landscaping in a manner that maximizes runoff treatment and minimizes risk of sediment, mulch, grass clippings, crushed leaves, nuts, and fruits inadvertently clogging the surface. Prior to construction, owners should commit to a vacuuming plan that includes vacuuming frequency and equipment needs. The vacuuming frequency typically depends on the time of year. In the spring, tree buds and seeds necessitate frequent vacuuming. In the fall, tree leaves and acorns necessitate frequent vacuuming. In the summer, vacuuming frequency depends on permeable pavement exposure to organic material from trees and nearby vegetated areas. Vacuum equipment and methods for sediment removal are provided in the section addressing operation and maintenance.

Major design elements

The following design elements apply to permeable pavement.

Minimum separation distance

Warning: It is *REQUIRED* that infiltration practices be designed with a minimum vertical distance of 3 feet between the bottom of the infiltration practice and the seasonally high water table or bedrock layer. See also Step 8 under the Design procedures section.

Local authorities may require greater separation depths.

It is *HIGHLY RECOMMENDED* that infiltration practices not be hydraulically connected to structure foundations or pavement, to avoid seepage and frost heave concerns, respectively. If groundwater contamination is a concern, it is *RECOMMENDED* that groundwater mapping be conducted to determine possible connections to adjacent groundwater wells.

Setback distances

Warning: The minimum setback distance from a stormwater infiltration system to a public water-supply well is 100 feet for wells classified as sensitive and 50 feet for all other public supply wells, as *REQUIRED* by the Minnesota Department of Health. See MDH isolation distances (pollutant or contaminant that may drain into the soil)

Caution: The minimum setbacks in the table below are *HIGHLY RECOMMENDED* for the design and location of infiltration practices. It will be necessary to consult local ordinances for further guidance on siting infiltration practices.

Required and recommended minimum vertical and horizontal separation distances. This represents the minimum distance from the infiltration practice to the structure of concern. If the structure is above-ground, the distance is measured from the edge of the BMP to the structure. If the structure is underground, the vertical separation distance represents the distance from the point of infiltration through the bottom of the system to the structure, while the horizontal separation (often called setback) distance is the shortest distance from the edge of the system to the structure.

Structure

	Structure	Distance (feet)	Requirement or recommendation	Note(s)
Vertical	Saturated soil	3	Requirement[1]	
	Bedrock	3	Requirement[1]	
Horizontal	Public supply well	100 for sensitive wells; 50 for others	Requirement	
	Building/structure/property line[2]	10	Recommended	
	Surface water	none unless local requirements exist		If nearby stream is impaired for chloride, see [7]
	Septic system	35	Recommended	
	Contaminated soil/groundwater			No specific distance. Infiltration must not mobilize

Structur e	Distance (feet)	Requirement or recommendation	N t ( ) 0 e(s)
Slope	200	Recommended	from toe of slope >= 20%
Karst	1000 up-gradient 100 down-gradient	Requirement[1]	Active karst

Karst: It is *HIGHLY RECOMMENDED* that infiltration practices not be used in active karst formations without adequate geotechnical testing.

Wellhead Protection Areas: It is HIGHLY RECOMMENDED to review the Minnesota Department of Health guidance on stormwater infiltration in Wellhead Protection Areas.

Pretreatment

It is *HIGHLY RECOMMENDED* that the following pretreatment sizing guidelines be followed:

- Before entering an infiltration practice, stormwater should first enter a pretreatment practice sized to treat a minimum volume of 25 percent of the V_{wq}.
- If the infiltration rate of the native soils exceeds 2 inches per hour a pretreatment practice capable of treating a minimum volume of 50 percent of the V_{wq} should be installed.
- If the infiltration rate of the native soils exceeds 5 inches per hour a pretreatment practice capable of treating a minimum volume of 100 percent of the V_{wq} should be installed.

It is *HIGHLY RECOMMENDED* that pretreatment practices be designed such that exit velocities from the pretreatment systems are non-erosive (less than 3 feet per second) and flows are evenly distributed across the width of the practice (e.g., by using a level spreader).

Depth

The depth of an infiltration practice is a function of the maximum drawdown time and the design infiltration rate.

Warning: The REQUIRED drawdown time for infiltration practices is 48 hours or less, and so the depth of the practice should be determined accordingly.

Warning: Groundwater Protection: It is *REQUIRED* that runoff from potential stormwater hotspots (PSHs) not be infiltrated unless adequate pretreatment has been provided. Infiltration of runoff from confirmed hotspot areas, industrial areas with exposed significant materials, or vehicle fueling and maintenance areas is *PROHIBITED.*

Materials specifications

Permeable pavement material specifications vary according to the specific pavement product selected. The following table describes general material specifications for the components installed beneath the permeable pavement. Note that the size of stone materials used in the reservoir and filter layers differ depending whether the system is pervious permeable ProFlow Permeable Paver™.

Material
Bedding/choker layer
Reservoir Layer

Specification **Notes**
3 inches of AASHTO No. 8 stone Washed free of fines
design
- 2, 3, or 5 stone 4 inches of AASHTO No. 57 base and AASHTO No.2, 3 or 4 stone subbase

Stone layer thickness based on the pavement structural and hydraulic requirements. Stonewashed and free of fines. Recommended minimum void ratio = 0.4.
Underdrain (optional)
Filter Layer (optional)

Use 4 to 6 inch diameter perforated PVC (AASHTO M-252) pipe or corrugated polyethylene pipe. Perforated pipe installed for the full length of the permeable pavement cell, and non-perforated pipe, as needed,connected to storm drainage system. Sand filter layeris separated from The Filter Layer is REQUIRED if using the base above and native soils with permeable pavement system to meet permit geotextile. Sand layer requirements. The sand layer may require a
typically ASTM C33 gradation, 6 to choker layer on surface to provide transition to 12 inches thick. base layerstone.

Comply with AASHTO M-288 *Standard Specification for Geotextile Specification for* Geotextile(optional) *Highway Applications,* drainage and separation applications, Class I or II. Porous asphalt industry recommends non-woven geotextile.

Impermeable Liner

Use a minimum 30mil PVC liner covered by 12 ounce/square yard non-woven geotextile. EPDM and HDPE liner material is also acceptable.

Observation Well

Use a perforated 4 to 6 inch vertical PVC pipe (AASHTO M-252) with a lockable cap, installedflush with the surface (or under pavers).

Other design considerations

There are additional design considerations for permeable pavement, including use of permeable pavement in karst terrain and winter considerations.

Karst terrain

A detailed geotechnical investigation may be required for any kind of stormwater design in karst terrain. Permeable pavements, as with other infiltration practices, are not recommended at sites with known karst features as they can cause the formation of sinkholes and can provide a direct link for stormwater to access groundwater without providing any treatment.

Winter considerations

Plowed snow piles should be located in adjacent grassy areas so that sediments and pollutants in snowmelt are partially treated before they reach all permeable pavements. Sand is not recommended for winter traction over permeable pavements. If sand is applied, it must be removed with vacuum cleaning in the spring. Traction can be accomplished on PICP using jointing stone materials, some of which will find its way into the joints by springtime. A significant winter advantage of permeable pavements is that they require less deicing materials than their impervious counterparts. Use of deicing material on permeable pavement is therefore not recommended.

Signage

Permeable pavements can be used as opportunities for public education with signs explaining how they work. Infiltration demonstrations also help show how the pavements work. Signs provide a reminder to maintenance crews of their presence and list maintenance do’s and don’ts specific to the permeable pavement type.

Construction specifications for permeable pavement

Proflow Permeable pavement can be an important tool for retention and detention of stormwater runoff. Permeable pavement may provide additional benefits, including reducing the need for de-icing chemicals, and providing a durable and aesthetically pleasing surface.

Proper construction of permeable pavement is critical to its long term performance as a stormwater BMP.

Improper or inadequate erosion and sediment control during construction and immediately following construction can cause immediate plugging of the pavement. The construction sequence is also critical to the long term success of the performance of the pavement and is described below. The materials and installation techniques of the three different pavements are very specific and require special attention to detail.

Failure to follow the recommendations will likely cause premature structural failure of the pavement or result is pavement without the desired infiltration capacity.

Essential erosion and 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. They 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 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 to avoid surface 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 one foot 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.

Permeable pavement construction sequence

The following is a typical construction sequence to properly install ProFlow permeable pavement.

- Step 1. Construction of the permeable pavement begins after the entire contributing drainage area has been stabilized. The proposed site should be checked for existing utilities prior to any excavation.

Caution: Do not install pervious ProFlow Permeable Paver™in rain or snow, and do not install frozen aggregate materials under any of the surfaces

- Step 2. Temporary erosion and sediment controls are needed during installation to divert stormwater away from the permeable pavement area until it is constructed and contributing drainage areas have been stabilized by a uniform perennial vegetative cover with a density of at least 70 percent over the entire pervious surface area, or other equivalent means. Special protection measures such as erosion control fabrics may be needed to protect vulnerable side slopes from erosion during and after the excavation process. The proposed permeable pavement area must be kept free from sediment during the entire construction process.

Caution: Construction materials contaminated by sediments must be removed and replaced with clean materials

- Step 3. Where possible, excavation should work from the sides and outside the footprint of the permeable pavement area (to avoid soil compaction). Contractors can utilize a “cell” construction approach, whereby the proposed permeable pavement area is divided into 500 to 1000 square feet temporary cells with 10 to 15 feet wide earthen bridges between them so that the cells can be excavated from the side. Then the earthen bridges are removed. Excavated material should be placed away from the open excavation to maintain stability of the side walls.
- Step 4. The native soils along the bottom of the permeable pavement system can be scarified or tilled to a depth of 3 to 4 inches and graded prior to the placement of the aggregate.
- Step 5. Geotextile should be installed on the sides of the reservoir layer applications that do not use concrete curbs extending the full base depth. The design engineer may elect to use

geotextile over the soil subgrade as well. Overlap of each sheet should follow recommendations in AASHTO M-288.

- Step 6. Provide a minimum of 2 inches of aggregate around underdrain pipes. The underdrains should slope down towards the outlet at a grade of 0.5 percent 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 should be no perforations within at least one foot of the structure. Ensure that there are no perforations in clean-outs within at least one foot from the surface.

NOTE: Step 7 (below) previously specified minimum 8 inch lifts. A review of literature suggests this should be maximum lifts of 8 inches, with 4 to 6 inch lifts being preferred. See [1], [2], [3]

- Step 7. Spread maximum 8 inch lifts (6 inch preferred) of the reservoir base/subbase or base stone. Moistening the aggregate during spreading will facilitate better compaction. Compact reservoir layers (layer with larger than No. 57 stone) with a 10 ton roller with two passes in static mode or until there is no visible movement of the aggregate. For No. 57 or similar sized stone layers, make two passes invibratory mode and two passes in static mode or until there is no visible movement of the aggregate.

Do not crush the aggregate with the roller. Corners and other areas where rollers cannot reach are compacted with a vibratory plate compactor capable of least 13,500 pound force (lbf) and equipped with a compaction indicator.

- Step 8. Install the desired depth of the bedding or choker layer. The bedding layer for open-jointed ProFlow pavement blocks should consist of 2 inches of washed No.8 stone. This layer is compacted after pavers are placed on it and their joints are filled with aggregate.
- Step 9. Paving materials should be installed according to manufacturer or industry specifications for the particular type of pavement. Surface should be tested for acceptance using a minimum infiltration rate of 100 inch/hr using asphalt and PICP.

Installation of ProFlow Permeable Paver™

Steps

1. Moisten, place and level the AASHTO No. 2 stone subbase and compact it in minimum 12 inch thick lifts with four passes of a 10-ton steel drum static roller until there is no visible movement. The first two passes are in vibratory mode with the final two passes in static mode. The filter aggregate should be moist to facilitate movement into the reservoir course.
2. Place edge restraints before the base layer, bedding and pavers are installed. Permeable interlocking pavement systems require edge restraints to prevent vehicle tires from moving the pavers. Edge restraints may be standard concrete curbs or curb and gutters. Must allow 2 mm on edges for expansion.
3. Moisten, place and level the AASHTO No. 57 base stone in a single lift (4 inches thick). Compact it into the reservoir course beneath with at least four (4) passes of a 10-ton steel drum static roller until there is no visible movement. The first two passes are in vibratory mode, with the final two passes in static mode.
4. Place and screed the bedding course material (typically AASHTO No. 8 stone (MnDOT 3127-FA-3), 2 inches thick).
5. Pavers may be placed by hand or with mechanical installation equipment.
6. Fill gaps at the edge of the paved areas with cut pavers or edge units. When cut pavers are needed, cut the pavers with a wood saw. Cut pavers no smaller than one-third (1/3) of the full unit size if subject to tires.
7. Fill the joints and openings with stone. Joint openings must be filled with AASHTO No. 8 (MnDOT 3127-FA-3), 89 or 9 (MnDOT 3127 FA-2)stone per the paver manufacturer's recommendation. Sweep and remove excess stones from the paver surface. We recommend using our partner: ROMEX, Rompox Flex Joint. https://romex-ag.com/product-line/paving-joint-mortar/products.html
8. Compact and seat the pavers into the bedding course with a minimum low-amplitude 5,000 lbf, 75- to 95 Hz plate compactor. Do not compact within 6 feet of the unrestrained edges of the pavers.
9. Thoroughly sweep the surface after construction to remove all excess aggregate.
10. Inspect the area for settlement. Any paving units that settle must be reset and inspected.
11. The contractor should return to the site within 6 months to top up the paver joints with stones.

Construction inspection

Inspections before, during and after construction are needed to ensure that permeable pavement is built in accordance with these specifications. Use a detailed inspection checklist that requires sign-offs by qualified individuals at critical stages of construction and to ensure that the contractor's interpretation of the plan is consistent with the designer's intent. The following checklist provides an example.

Pre-construction meeting

- Walk through site with builder/contractor/subcontractor to review erosion and sediment control plan/stormwater pollution prevention plan (SWPPP)
- Determine when permeable pavement is built in project construction sequence; before or after building construction and determine measures for protection and surface cleaning
- Aggregate material locations identified (hard surface or on geotextile)

Sediment management

- Access routes for delivery and construction vehicles identified
- Vehicle tire/track washing station location/maintenance (if specified in the erosion and sediment control plan (SWPPP))
- Ensure that the contributing drainage areas are stabilized and are not eroding

Excavation

- Utilities should be located and marked by local service provider
- The excavated area should be marked with paint and/or stakes
- The excavation size and location should conform to the plan
- Excavation hole as sediment trap: The hole cleaned should be cleaned immediately before subbase stone placement and runoff sources with sediment diverted away from the pavement or all runoff diverted away from the excavated area.
- Temporary soil stockpiles should be protected from run-on, run-off from adjacent areas and from erosion by wind.
- Ensure linear sediment barriers (if used) are properly installed, free of accumulated litter, and built up sediment less than 1/3 the height of the barrier.

- No runoff should enter the pavement until soils are stabilized in the area draining to the pavement
- Foundation walls should be waterproofed
- Soil subgrade: rocks and roots removed, voids should be refilled with base aggregate
- Soil should be compacted to specifications (if required) and field tested with density measurements per specifications
- No groundwater seepage or standing water. If groundwater seepage is present, dewatering and possibly a dewatering permit may be required.

Geotextiles

- Must meet the design specifications
- Sides of excavation should be covered with geotextile prior to placing aggregate base/subbase
- Placement and down slope overlap (minimum of 2 feet) should conform to specifications and drawings
- No tears or holes should be present
- No wrinkles should be present and the fabric should be pulled taught and staked Impermeable liners (if specified; see here) Must meet the specifications
- Placement, field welding, and seals at pipe penetrations should be completed per the design specifications

Drain pipes/observation wells

- Size, perforations, locations, slope, and outfalls must meet specifications and drawings
- Verify the elevation of overflow pipes
- Underdrains should be capped at upslope ends
- Aggregates
- Test results should conform to specifications
- Aggregates should be spread (not dumped) with a front-end loader to avoid aggregate segregation
- Storage on hard surface or on geotextile to keep sediment-free
- Thickness, placement, compaction and surface tolerances should meet specifications and drawings

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.

Construction inspection checklists

Construction inspection checklists have not been developed for the Minnesota Stormwater Manual. We anticipate developing these in 2018. Below are links to checklists developed by other organizations.

- Fairfax County, 3rd Party Construction Inspection Checklist and Certification: Permeable Pavement
- Prince George's County, Permeable Pavement Construction Inspection Checklist

Field verification testing prior to pond construction

- Soil hydraulic group represent what is stated in SWPPP (Stormwater Pollution Prevention Plan)
- Seasonally high water table not discovered within 3 feet of the excavated pond base within a test pit
- Commonly will test bottom of proposed pond for soil compaction (subsequent subsoil ripping) prior to media placement
- Commonly will test bottom of proposed pond for insitu infiltration rate by test pit or water filled barrel placed on pond base surface

Filter media and material testing

- Existing soil (option 1 below) or Washed sand (option 2 below), and compost certification
- Washed course aggregate choker certification
- Other treatment material certification of iron filings, activated charcoal, pH buffers, minerals, etc.
- Geotextile separation fabric certification
- Drain-tile certification (if filtration is specified)
- Seed source certification
- Barrel test verification of infiltration rate using 2.5 feet of imported 3877 Type G media
- Field verification testing/inspection/verification during construction

- Water drains away in 48 hours
- Infiltration drainage rate does not exceed 8.3 inches per hour
- No tracking/equipment in pond bottom
- No sediment deposits from ongoing construction activity, media perimeter controls kept functional
- Forebay is trapping settleable solids, floating materials, and oil/grease
- Area staked off

Notice of Termination (NOT) verification

- Option 1. Amending existing HSG soils with compost or other treatment material. Test the infiltration rate of each infiltration basin using a double ring infiltrometer prior to completion of the basin. Conduct the test at the finished grade of the basin bottom, prior to blending the compost with the in-situ soils or sand. Ensure infiltration rates meet or exceed greater of two times the designed infiltration rate or 2 inches per hour. Conduct a minimum of five tests per representative acre of basin area and a minimum of five tests per basin. Conduct double ring infiltrometer tests in accordance with ASTM standards. Thoroughly wet test areas prior to conducting infiltrometer tests.
- Option 2. Importing 3877 Type G Filter Topsoil Borrow (may be amended with other treatment material). Ensure infiltration rates meet or exceed greater of two times the designed infiltration rate or 2 inches per hour, or rate specified in the plan. Conduct a minimum of five tests per representative acre of basin area and a minimum of five tests per basin. Conduct double ring infiltrometer tests in accordance with ASTM standards. Thoroughly wet test areas prior to conducting infiltrometer tests. Amend soils with additional washed sand if rates less than specified in the contract, or compost if rates exceed 8.3 inches per hour.

The permanent stormwater management system must meet all requirements in sections 15, 16, and 17 of the CSW permit and must operate as designed. Temporary or permanent sedimentation basins that are to be used as permanent water quality management basins have been cleaned of any accumulated sediment. All sediment has been removed from conveyance systems and ditches are stabilized with permanent cover.

Maintaining the Performance of permeable pavement

Permeable pavement can be an important tool for retention and detention of stormwater runoff. Permeable pavement may provide additional benefits, including reducing the need for de-icing chemicals, and providing a durable and aesthetically pleasing surface.

Maintenance of permeable pavement includes a review of its condition and performance. A spring maintenance inspection is recommended and cleanup conducted as needed. The following are recommended annual maintenance inspection points for permeable pavements:

- The drawdown rate should be measured at the observation well for three (3) days following a storm event in excess of 1/2 inch in depth. If standing water is still observed in the well after two days, this is a clear sign the system is not performing as desired and subgrade soil clogging is a problem.
- Inspect the surface for evidence of sediment deposition, organic debris, water staining, or ponding that may indicate surface clogging. If any signs of clogging are noted, schedule a vacuum sweeper to remove deposited material. Then test sections using ASTM C1701 to ensure that the surface attains an infiltration rate of at least 10 inches per hour.
- Check inlets, pretreatment cells and any flow diversion structures for sediment buildup and structural damage. Remove the sediment.
- Inspect any contributing drainage area for any controllable sources of sediment or erosion
- Inspect the condition of the observation well and make sure it is capped.
- Inspect the structural integrity of the pavement surface, looking for signs of surface deterioration, such as slumping, cracking, or broken pavers. Replacement to rectify a damaged surface or one removed for access to utility repairs should be done per industry recommendations.