6.8 Permeable Pavement BMPs

Figure 6-15: Permeable Pavers

Applications

- Parking Lots & Driveways
- Low traffic roads
- Boat ramps
- Golf cart paths

Advantages

- Allows runoff to infiltrate into subsoil; groundwater recharge
- Easily integrated into existing infrastructure

Limitations

- Not ideal for high traffic areas
- Not suitable for stormwater hotspot sites
- Requires extensive maintenance

6.8.1 Description

Permeable pavements are alternatives to conventional impervious asphalts and concretes. However, permeable pavements allow water to pass through them into a subsurface gravel layer that doubles as a storage/infiltration area and a structural base layer. Where site conditions allow, the subsurface gravel layer (open-graded base/sub-base) is configured to allow water to infiltrate into the surrounding subsoil. If site conditions do not allow for infiltration, the water is detained in the gravel storage layer and then routed to a storm water conveyance system. In either case, the initial infiltration through the surface layers increases the time of concentration, T_c, provides some filtering of pollutants, and decreases the peak flows. Only when the water is allowed to infiltrate does it significantly decrease the runoff volume. Depending on the infiltration rate measured during the Soil Assessment (see Chapter 3) and the type of land use (i.e., hotspot areas), it may be necessary to install an impermeable liner around the base layer as well as an underdrain system. There are several styles of permeable pavement available, including those that are poured in place (i.e., porous concrete and porous asphalt), and modular paving systems (i.e., interlocking concrete, grass and gravel pavers).

Pour in place permeable pavements

Pour in place permeable pavements are poured where they will ultimately be used and allowed to setup (cure) in place. Typically, the pore spaces in the pavement make up about 10% of the total surface area. Porous asphalt and porous concrete are similar to each other in that the porosity is created by removing the small aggregate or fine particles from the conventional recipe, which leaves stable air pockets (gaps through the material) for water to drain through into the subsurface. Porous concrete is rougher than its conventional counterpart, and unlike oil-based asphalt will not release harmful chemicals into the environment. These types of permeable pavements shall only be used in areas of slow and low traffic (e.g., parking lots, low traffic streets, pedestrian areas, etc.).

Modular paving systems

There are several varieties of pavers that allow for infiltration, including (but not limited to) interlocking concrete pavers, grass pavers, and gravel pavers. Typically, the pore spaces in the pavement make up about 10% of the total surface area. Interlocking concrete pavers are not porous themselves, rather the mechanism that allows them to interlock creates voids and gaps between the pavers that are filled with a pervious material and can withstand heavy loads. Grass and gravel pavers are nearly identical to each other in structure (rigid grid of concrete or durable plastic) but differ in their load bearing support capacities. The grids are embedded in the soil to support the loads that are applied, thereby preventing compaction, reducing rutting and erosion. Grass pavers are generally filled with a mix of sand, gravel, and soil to support vegetation growth (e.g., grass, low-growing groundcovers, etc.), which provides habitat, pollutant removal, and reduces storm water runoff volumes and rates. Grass pavers are good for low-traffic areas, while gravel pavers are good for high-frequency, low speed traffic areas. Gravel pavers differ from grass pavers in that they are filled with gravel (often underlain with a geotextile fabric to prevent the migration of the gravel into the subbase) which support greater loads and higher traffic volumes.

6.8.2 Performance, Applicability, and Limitations

Table 6-38 provides a summary of BMP performance, applicability, and limitations for permeable pavement areas. *It is important to note that information in these tables shall be used to provide general guidance for permeable pavement areas and shall not replace the evaluation performed by a water quality professional.*

Applicability and Performance

Table 6-38 and associated guidance provide general volume reduction capabilities and treatment effectiveness rankings for permeable pavement areas. Refer to Section 6.4 for the process that shall be used for selecting BMPs based on pollutants of concern. Refer to Table 6-1 to determine the ranking of permeable pavement BMPs for removal of pollutants of concern as compared with other storm water runoff BMPs provided in Chapter 6. Refer to Table 6-2 to assess the applicability of permeable pavement BMPs for your site based on site suitability considerations as compared with other storm water runoff BMPs provided in Chapter 6. Permeable pavement areas are volume-based BMPs intended, primarily, for water quality treatment and, depending on site slope and soil conditions, can provide high volume reduction (see Table 6-38). Where site conditions allow for infiltration (i.e., omitting underdrain), the volume reduction capability of permeable pavement areas can be used to meet the volume reduction requirement, $V_{reduction}$. In addition, for permeable pavement areas where underdrains are used with an impermeable liner, additional depth may be added to the subsurface gravel layer (open-graded base/sub-base) to provide additional storage and detention capacity. Permeable pavement areas can also be used to help meet the peak runoff discharge requirement. See Section 6.2 for specific storm water runoff requirements for Tier 3 projects.

Table 6-38: Volume Reduction & Treatment Effectiveness for Permeable Pavement

Storm Water Runoff BMP	Volume Mitigation (% of inflow)	Treatment Effectiveness for Pollutants of Concern[1]					
		Trash	Nutrients	Bacteria	Metals (particulate and dissolved fractions)	Sediment	Organics (hydro-carbons, oil, and grease)
Permeable Pavement	◓	○	◉	◓	◓	●	◓
Volume/Treatment Effectiveness: ● = Very High, ◓ = High, ◉ = Moderate, ◒ = Low, ○ = Very Low							

[1] Effectiveness may change based on design variations; standard BMP designs have been assumed.

Permeable pavement areas remove pollutants through physical, chemical, and biological mechanisms. Specifically, they use infiltration, absorption, microbial activity, plant uptake, sedimentation, and filtration. The subsurface gravel layer and subsoil beneath the facility (if designed for infiltration) adsorb pollutants to the aggregate and soil particles. In addition, biological degradation and chemical precipitation also lower pollutant concentrations. As the water filters through the permeable pavement layer, the subsurface gravel layer, and the subsoil, particulates and suspended solids are physically removed through filtration. The degree of infiltration, filtration, and adsorption in the subsoil is dictated by the soil type (i.e., clayey soils will adsorb and filter more pollutants than sandy soils, while sandy soils will infiltrate the water more quickly). The removal of nitrogen depends on the degree of infiltration into the subsoil where microbial activity can convert nitrogen. Vegetation that is present in grass pavers increases the amount of biological treatment by providing treatment within the structure itself. Other permeable pavement surfaces can also provide biological treatment within the structure itself and to different degrees depending on the level of pollutants in the source water and the permeable pavement type. Microbial bacteria will begin forming over time within the pavement pore spaces providing treatment as the water flows through.

Site Suitability Recommendations and Limitations

Table 6-39 and associated guidance provide general considerations for assessing a site's suitability for permeable pavement.

Table 6-39: Site Suitability Considerations for Permeable Pavement

BMP	Tributary (Site) Area (Acres)[1]	Site Slope (%)	Depth to Seasonally High Groundwater Table (ft)	Hydrologic Soil Group	Horizontal Setback from Drinking Water Wells (ft)
Permeable Pavement	< 5 [2]	< 5 [3,4]	> 2 with underdrains; > 5 without underdrains	Underdrains shall be provided for "C" and "D" soils	100 [5]

[1] Tributary area is the area of the site draining to the BMP. Tributary areas provided here shall be used as a general guideline only. Tributary areas can be larger or smaller in some instances.

[2] Impervious surfaces draining to the BMP are limited to surfaces immediately adjacent to the permeable pavement, rooftop runoff, or other surfaces that do not contain significant sediment loads.

[3] If slope exceeds given limit or is within 200 feet from the top of a hazardous slope or landslide area, a geotechnical investigation is required.

[4] If a gravel base is used for storage of runoff: (1) slopes shall be restricted to 0.5% (steeper grades reduce storage capacity) and (2) underdrains shall be used if within 50 feet of a sensitive steep slope.

[5] Setbacks apply to systems without underdrains or systems underlain by "A" or B" hydrologic soil groups.

Table 6-40 provides additional site applicability considerations for special design districts within the City including coastal bluff areas and hillside design districts.

Table 6-40: Applicability of Permeable Pavement for Special Design Districts

Coastal Bluff Area	Hillside Design District
Acceptable if: (1) the facility is fully contained with an impermeable liner, underdrain system, and overflow to a storm water conveyance system, and (2) the site slope meets the criteria provided in Table 6-39.	Acceptable if: (1) a geotechnical investigation proves that the facility does not compromise the stability of the site slope or surrounding slopes, or (2) the facility is fully contained with an impermeable liner, underdrain system, and overflow to a storm water conveyance system.

The following describes additional site suitability recommendations and limitations for permeable pavement.

- The tributary area (area draining to the permeable pavement) shall be less than 5 acre
- If located on a site with a slope greater than 2%, the permeable pavement area shall be terraced to prevent lateral flow through the subsurface
- If located in an area with soil infiltration rates less than 0.05 in/hr or greater than 2.4 in/hr, an underdrain shall be provided.

- Seasonal high groundwater table shall be at least 2 ft lower than the bottom of the permeable pavement system if underdrains area provided and 5 ft lower than the bottom of the permeable pavement system if underdrains are not provided.
- If no underdrains and no impermeable membrane, permeable pavement areas shall not be placed within 100 feet of a drinking water well or a structural foundation (upgradient), or within 10 feet of a structural foundation (downgradient).
- If underdrains are provided, site must have adequate relief between land surface and the storm water conveyance system to permit vertical percolation through the gravel drainage layer (open-graded base/sub-base) and underdrain to the storm water conveyance system.
- Shall not be located in hotspot areas where environmental releases may occur (e.g., commercial sites, gas stations).
- Permeable pavement located within 50 feet of a sensitive steep slope shall incorporate an underdrain. A geotechnical investigation and report must be provided to address the potential effects of infiltration on steep slopes if the permeable pavement area promotes infiltration (i.e., does not have underdrains) and is within 200 feet of the slope or mapped landslide area.
- Porous concrete and porous asphalt shall not be located in areas where sand tends to accumulate. Sand will clog the surface.
- Gravel-pave must be at least 200 feet from the street for driveways and parking areas preventing gravel from being displaced from vehicle tires onto streets. If the driveway or parking area is to be used for fire access, approval must be provided from the City fire department. Gravel-pave shall not be placed on walkways that are required to be handicap accessible.
- The type of pedestrian traffic shall be considered when determining which type of permeable pavement to use in a particular locations (e.g., pavers may not be a good option for locations where people will be walking wearing high heels)

Multi-Use and Treatment Train Opportunities

Permeable pavement areas can be applied in various settings, including:

- Individual lot driveways, walkways
- Parking lots, overflow parking lots
- Low-traffic roads
- High-traffic (with low speeds) roads/lots
- Golf cart paths
- Within right-of-ways along roads
- In parks and along open space edges

In addition, permeable pavement areas can be combined with other basic and storm water runoff BMPs to form a “treatment train” that can provide enhanced water quality treatment and reductions in runoff volume and rate. For example, overflow from permeable pavement can be directed to a vegetated swale or a bioretention area for further treatment, volume reduction, and, flow control. Both facilities can be reduced in size based upon demonstrated performance for meeting the storm water runoff requirements as outlined in Section 6.2 and addressing targeted pollutants of concern.

6.8.3 Design Criteria and Procedure

The main challenge associated with permeable pavement is sediment removal, which is critical to performance of this BMP. A schematic illustrating permeable pavement is provided in Figure 6-16.

Principal design criteria for permeable pavement are listed in Table 6-41.

Table 6-41: Permeable Pavement Design Criteria

Design Parameter	Unit	Design Criteria
Water quality design volume, V_{wq}	ft^3	See Section 6.2 and Appendix C for calculating V_{wq}.
Volume reduction requirement, $V_{reduction}$	ft^3	Only applicable for configurations that do not use underdrains. See Section 6.2 and Appendix C for calculating $V_{reduction}$.
Pretreatment	-	Runoff from pervious areas shall be minimized but, if provided, a vegetated swale or filter strip shall be provided for all runoff from off-site sources that are not directly adjacent to the permeable pavement.
Drawdown time of gravel drainage layer	hrs	72 (maximum)
Minimum depth to bedrock	ft	3
Minimum depth to seasonal high water table	ft	2 (with underdrains); 5 (without underdrains)
Maximum site slope	%	5
Infiltration rate of subsoil	in/hr	0.05 (minimum); 2.4 (maximum)
Underdrain	-	6 inch minimum diameter; 0.5% minimum slope
Overflow device	-	Required

Pretreatment

1. Depending on how and where permeable pavement will be used, pretreatment of the runoff entering the pavement may be necessary. This is particularly important when the pavement will be accepting run-on from pervious areas or areas that are not completely stabilized. If this is the case, then the run-on shall be treated prior to contacting the permeable pavement. Without adequate pretreatment, the life of the permeable pavement may be significantly decreased.

2. If sheet flow is conveyed to the treatment area over stabilized grassed areas, the site must be graded in such a way that minimizes erosive conditions.

Geometry and Size

1. Permeable pavement shall be sized to capture and treat the water quality design volume, V_{wq}. Where site conditions allow for infiltration, the permeable pavement may also be sized to infiltrate the volume reduction requirement, $V_{reduction}$. For permeable pavement designs that allow for partial infiltration (i.e., there is a permeable membrane between the gravel layer and subsoil), then 20% of the design detention volume, $V_{detention}$, of the subsurface gravel layer (open-graded base/sub-base) can be assumed to infiltrate allowing partial infiltration permeable pavement facilities to gain credit towards meeting the volume reduction requirement. See Section 6.2 and Appendix C for further detail.

2. Depth of each layer shall be determined by a licensed civil engineer based on analyses of not only the hydrology and hydraulics, but also the structural requirements of the site.

3. Permeable pavement (including the base layers) shall be designed to drain in less than 72 hours. Intent: Soils must be *allowed to dry out periodically in order to restore hydraulic capacity to receive flows from subsequent storms, maintain infiltration rates, maintain adequate sub soil oxygen levels for healthy soil biota, and to provide proper soil conditions for biodegradation and retention of pollutants.*

Sizing Methodology

Permeable pavement shall be sized to capture and treat the water quality design volume, V_{wq}, and where site conditions allow, shall also be sized to infiltrate the volume reduction requirement, $V_{reduction}$. See Section 6.2 and Appendix C for specific sizing requirements and calculation methodologies. Procedures for sizing permeable pavement are summarized below. A permeable pavement sizing example is provided in Appendix D.

Step 1: Calculate the volume required for sizing

The volume required for sizing the subsurface gravel layer (open-graded base/sub-base) depends on whether the system will be designed for no infiltration, partial infiltration, or full infiltration:

1. **No infiltration -** if underdrains are required and no infiltration is acceptable into the subsoil (i.e., an impermeable membrane must be used), the volume of the gravel drainage layer shall be sized to accommodate the water quality design volume, V_{wq}.

2. **Partial infiltration** - If underdrains are required but partial infiltration is acceptable (i.e., a permeable membrane may be used and the soil type is of type B or C), the gravel drainage layer can be sized to accommodate the water quality design volume, V_{wq}, plus an additional 20% of V_{wq}. This would be advantageous if the volume reduction requirement, $V_{reduction}$, is greater than V_{wq} since it provides an additional credit towards meeting the volume reduction requirement. In this situation, it is assumed that 20% of the volume in the drainage layer will infiltrate into the subsoil rather than enter the underdrain and; therefore, a credit is given of $0.2*V_{wq}$ towards meeting the volume reduction requirement.

3. **Full infiltration** - If underdrains are not provided and infiltration is allowed, the design volume, V_{design}, is the larger of the water quality design volume, V_{wq}, and the volume reduction requirement, $V_{reduction}$.

Step 2: If underdrains are incorporated, determine the required depth of the gravel drainage layer (open-graded base/sub-base). If underdrains will not be incorporated, skip to Step 3.

If underdrains are incorporated, the gravel drainage layer may be designed depending on whether there is no infiltration or partial infiltration. If there is no infiltration, $V_{design} = V_{wq}$. If there is partial infiltration, $V_{design} = V_{wq} + 0.2*V_{wq}$.

$$d_{min} = \frac{V_{design}}{A * n} \quad \text{(Equation 6-28)}$$

Where:

d_{min} = minimum depth of gravel drainage layer (feet)

V_{design} = design volume of runoff to be treated/infiltrated (ft^3)

n = gravel drainage layer porosity (unitless)

A = surface area of gravel drainage layer (ft^2)

Step 3: If underdrains will not be incorporated, calculate the design infiltration rate, k_{design}, of the native subsoil

See the Bioretention Area Section 6.6.1 for the method used to determine the design infiltration rate of the native subsoil.

Step 4: Sizing calculations for permeable pavement if no underdrains are incorporated.

As with infiltration BMPs, permeable pavement can be sized using one of two methods: a simple sizing method or a routing modeling method. With either method, the runoff entering the facility must be completely infiltrated within 72 hours. Permeable pavement provides all of its storage in the voids of the gravel drainage layer (open-graded base/sub-base). The simple sizing procedure is described below. For the routing modeling method, refer to the Bioretention Area Section 6.6.1.

Simple Method. Determine the size of the required infiltrating surface by assuming the design runoff volume (i.e., all or part of the water quality design volume, V_{wq}, or the volume reduction requirement, $V_{reduction}$, whichever is larger) will fill the available void spaces based on the computed porosity of the gravel drainage layer media (normally about 32% for gravel).

Determine the maximum depth of runoff that can be infiltrated within the required drain time (72 hr) as follows:

$$d_{max} = \frac{k_{design}}{12} \times t \qquad \text{(Equation 6-29)}$$

Where:

t	=	required drain time (hrs) [Use 72 hours]
k_{design}	=	infiltration rate of native subsoil soils (in/hr)
d_{max}	=	the maximum depth of water that can be infiltrated within the required drain time (ft)

Choose the gravel drainage layer depth (l) such that:

$$d_{max} \geq n \times l \qquad \text{(Equation 6-30)}$$

Where:

n	=	gravel drainage layer porosity (unitless)
l	=	depth of gravel drainage layer (ft)
d_{max}	=	the maximum depth of water that can be infiltrated within the required drain time (ft)

Calculate the infiltrating surface area (filter bottom area) required:

$$A = \frac{V_{design}}{\frac{Tk_{design}}{12} + nl} \qquad \text{(Equation 6-31)}$$

(Adapted from Georgia Stormwater Manual: http://www.georgiastormwater.com/vol2/3-2-5.pdf)

Where:

V_{design}	=	design volume of runoff to be infiltrated (ft^3)
n	=	gravel drainage layer porosity (unitless)
k_{design}	=	design infiltration rate (in/hr)
l	=	depth of gravel drainage layer (ft)
T	=	fill time (time to fill infiltration BMP with water) (hrs) [use 2 hours for most designs]
A	=	surface area of gravel drainage layer (ft^2)

Permeable Pavement Material Layer

This is the top layer and consists of either poured in place materials (i.e., porous concrete and porous asphalt), or modular paving materials (i.e., interlocking concrete, grass and gravel pavers). The thicknesses of these layers vary depending on design. Concrete pavers shall have a minimum thickness of 3 1/8”.

Bedding Course Layer

1. A layer of smaller sized aggregate (e.g., No. 8) just under the permeable pavement provides a level surface for installing the permeable pavement and also acts as a filter to trap particles and help prevent the reservoir layer from clogging.

2. Bedding course layer is typically about 1.5" to 3" inches deep and may be underlain by a geotextile fabric or choking stone to prevent the smaller sized aggregate from migrating into the larger aggregate base layer.

Geotextile Layer

If a geotextile fabric is used, it must meet the minimum materials requirements shown in the table below.

Geotextile Property	Value	Test Method
Trapezoidal Tear (lbs)	40 (min)	ASTM D4533
Permeability (cm/sec)	0.2 (min)	ASTM D4491
AOS (sieve size)	#60 - #70 (min)	ASTM D4751
Ultraviolet resistance	70% or greater	ASTM D4355

Liner Layer

Geomembrane liners shall have a minimum thickness of 30 mils.

Subsurface Gravel Layer

1. Must be designed to function as a support layer as well as a reservoir layer
   a. Consideration must be given to the soil conditions as well as the expected loads
2. This layer may be divided into two layers, a filter layer that underlies the choking layer and a reservoir layer (typically washed, open-graded No. 57 aggregate without any fine sands)

3. If infiltration or partial infiltration is allowed, a geotextile fabric, choking stone, or both shall be placed on top of the subsurface gravel layer. If no infiltration is allowed, an impermeable liner shall surround the subsurface gravel layer. See above for typical specifications for each.

4. The subsurface gravel layer shall have zero slope (i.e., level).

5. The drawdown time for the subsurface gravel layer shall not exceed 72 hours.

Underdrains

If site conditions allow (i.e., soil infiltration rate and site slope are adequate), the volume reduction capability of permeable pavement areas can be enhanced by omitting the underdrain.

If underdrains are required, then they must meet the following criteria:

1. 6-inch minimum diameter.

2. Underdrains must be made of slotted, polyvinyl chloride (PVC) pipe conforming to ASTM D 3034 or equivalent or corrugated high density polyethylene (HDPE) pipe conforming to AASHTO 252M or equivalent. *Intent: As compared to round-hole perforated pipe, slotted underdrains provide greater intake capacity, clog resistant drainage, and reduced entrance velocity into the pipe, thereby reducing the chances of solids migration.*

3. Slotted pipe shall have 2 to 4 rows of slots cut perpendicular to the axis of the pipe or at right angles to the pitch of corrugations. Slots shall be 0.04 to 0.1-inch and shall have a length of 1-inch to 1.25-inch. Slots shall be longitudinally spaced such that the pipe has a minimum of one square inch per lineal foot.

4. Underdrains shall be sloped at a minimum of 0.5%.

5. Rigid non-perforated observation pipes with a diameter equal to the underdrain diameter shall be connected to the underdrain every 250 to 300 feet to provide a clean-out port as well as an observation well to monitor dewatering rates. The wells/cleanouts shall be connected to the perforated underdrain with the appropriate manufactured connections. The wells/cleanouts shall be placed flush with the pavement surface and shall be capped with a lockable screw cap. The ends of underdrain pipes not terminating in an observation well/cleanout shall also be capped.

6. The following aggregate gradation (i.e., drain rock) shall be used to provide a gravel blanket and bedding for the underdrain pipe. Place the underdrain on a 3-foot wide bed of the drain rock at a minimum thickness of 6 inches and cover with the same aggregate to provide a 1-foot minimum depth around the top and sides of the slotted pipe.

Sieve size	Percent Passing
¾ inch	100
¼ inch	30-60
US No. 8	20-50
US No. 50	3-12
US No. 200	0-1

7. At the option of the designer, a geotextile fabric may be placed between the subsurface gravel layer and the drain rock although it is preferable to place the geotextile fabric between the permeable pavement material and the subsurface gravel layer for easier maintenance if the geotextile becomes clogged. If a geotextile fabric is used it must meet the minimum materials requirements as discussed above. Another option is to place a thin, 2- to 4-inch layer of pure sand and a thin layer (nominally two inches) of choking stone (such as #8) between the subsurface gravel layer and the drain rock.

8. The underdrain must drain freely to an acceptable discharge point. The underdrain can be connected to a downstream open conveyance (vegetated swale), to another bioretention cell as part of a connected treatment system, daylight to a vegetated dispersion area using an effective flow dispersion device, stored for reuse, or to a storm water conveyance system.

Overflow

An overflow mechanism is required. Two options are provided:

<u>Option 1: Perimeter control</u>

1. Flows in excess of the design capacity of the permeable pavement system will require an overflow system connected to a downstream conveyance or other storm water runoff BMP. In addition, if the pavement becomes clogged and infiltration decreases to the point that there is ponding, the runoff will migrate off of the pavement via overland flow instead of infiltrating into the subsurface gravel layer. There are several options for handling overflow using perimeter controls such as:
    a. Perimeter vegetated swale
    b. Perimeter bioretention
    c. Storm drain inlets
    d. Rock filled trench that funnels flow around pavement and into the subsurface gravel layer

<u>Option 2: Overflow pipe(s)</u>

1. A vertical pipe shall be connected to the underdrain.
2. The diameter, location, and quantity vary with design and shall be determined by a licensed civil engineer
3. Shall be located away from vehicular traffic.
4. May incorporate an observational and/or cleanout well.
5. Top of overflow pipe shall be covered with a screen fastened over the overflow inlet.

6.8.4 Construction Considerations

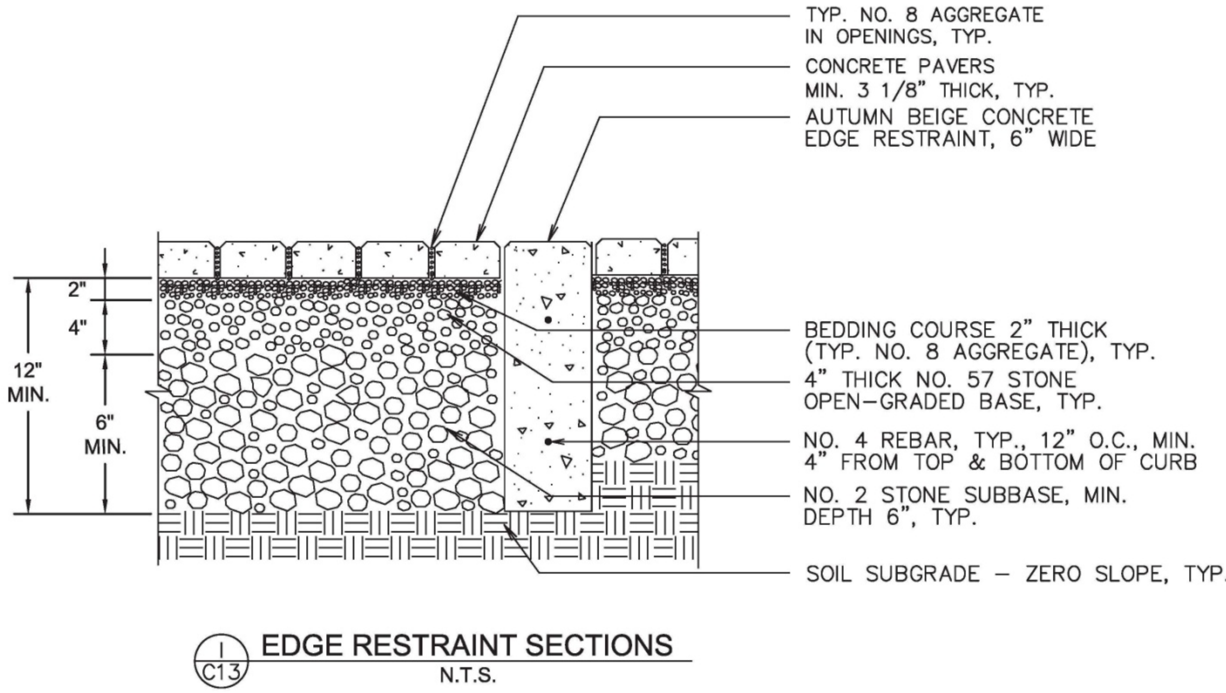
1. Permeable pavement shall be laid close to level, the bottom of the base layers must be level to ensure uniform infiltration.
2. Permeable pavement surfaces shall not be used to store site materials, unless the surface is well protected from accidental spillage or other contamination.
3. To prevent/minimize soil compaction in the area of the permeable pavement installation, use light equipment with tracks or oversized tires.

4. Divert storm water from the area as needed (before and during installation)

5. The pavement shall be the last installation done at a development site. Landscaping shall be completed and adjacent areas stabilized before pavement installation to minimize risk of clogging.

6. Vehicular traffic shall be prohibited for at least 2 days after installation.

Figure 6-16: Permeable Pavement Schematic



All gravel base below the pavers is open graded, crushed aggregate. This means the gravel is not mixed with sand so there are open spaces between the rocks for water storage, and it is angular so the gravel pieces lock together once compacted. This design example uses a minimum 6" layer of No. 2 (2"-4") gravel sits on top of a level soil subgrade. On top of that is a 4" thick layer of No. 57 (1/4"-1") gravel. On top of that is a 2" layer of No. 8 aggregate (1/8"-1/2") which serves as a bedding layer for the permeable pavers. This No. 8 aggregate is also placed between the pavers.

6.8.5 Operations and Maintenance

General Requirements

Permeable pavement mainly requires vacuuming and management of adjacent areas to limit sediment contamination and prevent clogging by fine sediment particles; therefore, little special training is needed for maintenance crews. The following maintenance concerns and maintenance activities shall be considered and provided:

1. Trash tends to accumulate in paved areas, particularly in parking lots and along roadways. The need for litter removal shall be determined through periodic inspection.

2. Regularly (e.g., monthly for a few months after initial installation, then quarterly) inspect pavement for pools of standing water after rain events, this could indicate surface clogging.

3. Actively (3-4 times per year, or more frequently depending on site conditions) vacuum sweep the pavement to reduce the risk of clogging by frequently removing fine sediments before they can clog the pavement and subsurface layers; also, to help prolong the functional period of the pavement.

4. Inspect for vegetation growth on pavement and remove when present.

5. Inspect for missing sand/gravel in spaces between pavers and replace as needed.

6. Activities that lead to ruts or depressions on the surface shall be prevented or the integrity of the pavement shall be restored by patching or repaving. Examples are vehicle tracks and utility maintenance.

7. Spot clogging of porous concrete may be remedied by drilling 0.5" holes every few feet in the concrete.

8. Interlocking pavers that are damaged shall be replaced.

9. Maintain landscaped areas; reseed bare areas.

Maintenance Standards

A summary of the routine and major maintenance activities recommended for permeable pavement is shown in Table 6-42. Detailed routine and major maintenance standards are listed in Table 6-43 and Table 6-44.

Table 6-42: Permeable Pavement Maintenance Quick Guide

Inspection and Maintenance Activities Summary	
Routine Maintenance	• Clean area of trash and debris accumulations • Prevent the washing of soil onto the pavement • Clean area of sediments; vacuum sweep frequently (3-4 times/year) • Check that paving is draining properly • Maintain landscaped areas o Seed bare areas • Inspect outlets
Major Maintenance	• Restore infiltration rates caused by clogging • Repair any signs of deterioration, roughening, ruts or depressions • Sub-surface layers may require cleaning and/or replacing

Table 6-43: Routine Maintenance – Permeable Pavement

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
Sediment Accumulation	Sediment is visible	Sediment deposits removed	Semi-annually, prior to wet season and after the wet season After major storm events (>0.75 in/24 hrs) if spot checks indicate widespread damage/ maintenance needs
Missing gravel/sand fill	There are noticeable gaps in between pavers	There are not gaps in between pavers	
Weeds/mosses filling voids	Vegetation is growing in/on permeable pavement	No vegetation growth	

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
Trash and Debris Accumulation	Trash and debris accumulated on the permeable pavement.	Trash and debris removed from permeable pavement.	Monthly or quarterly (or as dictated by agreement between City and landscape contractor) Litter removal frequency is dependent on site conditions and desired aesthetics and shall be done at a frequency to meet those objectives
Dead or dying vegetation in adjacent landscaping	Vegetation is dead or dying leaving bare soil prone to erosion	Vegetation is managed and soil is stabilized	
Surface clog	Clogging is evidenced by ponding on the surface	Well draining surface	Ongoing
Overflow clog	• Excessive build up of water accompanied by observation of low flow in observation well (connected to underdrain system) • If a surface overflow system is used, observation of an obvious clog	Well draining system with adequate flow out	
Visual contaminants and pollution	Any visual evidence of oil, gasoline, contaminants or other pollutants.	No visual contaminants or pollutants present.	
Erosion	Tributary area • Exhibits signs of erosion • Noticeably not completely stabilized	Tributary area completely stabilized	

Table 6-44: Major Maintenance – Permeable Pavement

Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed	Frequency
Deterioration/ Roughening	Integrity of pavement is compromised (i.e., cracks, depressions, crumbling, etc.)	Smooth and even surface	As needed
Subsurface Clog	Clogging is evidenced by ponding on the surface and is not remedied by addressing surface clogging.	Well draining system; excavation of pavement and gravel drainage layer is required.	