4.15 Permeable ~~Bricks/Pavers~~Paver Systems

~~Limited Application~~
~~Structural Stormwater Control~~

Description: A pavement surface composed of structural units with void areas that are filled with pervious materials such as gravel, sand, or grass turf. ~~Porous~~Permeable ~~pavers~~paver systems are installed over a gravel base course that provides structural support as well as stores the stormwater runoff that ~~age as runoff~~ infiltrates through the ~~porous paver~~ system into underlying permeable soils.

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DESIGN CRITERIA

- Intended for low traffic areas, or for residential or overflow parking applications, not ideal for areas with a tree canopy
- ~~Based on 20 life span~~Will infiltrate water for 20 years, will provide structural support for 35 years
- Aesthetically pleasing
- Americans with Disabilities Act (ADA) compliant
- Should be a minimum of three feet above the natural water table
- Be a minimum of 15 feet away from buildings

ADVANTAGES/BENEFITS

- Surface flow reduction of peak flows, volume, and stormwater runoff
- High level of pollutant removal
- Attractive/aesthetic options
- Reusable product
- Longer life than traditional pavement
- Decreases impermeable area

DISADVANTAGES/LIMITATIONS

- High cost compared to conventional pavements
- Potential for high failure rate if not adequately maintained or used in unstabilized areas
- Geotechnical analysis of soils required
- Ineffective under tree canopy, due to clogging
- Requires specialized knowledge for proper installation

ROUTINE MAINTENANCE REQUIREMENTS

- High maintenance requirements
- Weed and remove grass out of bricks/blocks as necessary (unless concrete grid pavers are used)
- Sweep or vacuum the pavers as necessary

Pollutant Removal

- Total Suspended Solids – 80%
- Total Phosphorus – 50%
- Total Nitrogen – 50%
- Fecal Coliform – Not applicable
- Heavy Metals – 60%

STORMWATER MANAGEMENT SUITABILITY

- ☑ **Runoff Reduction**
- ☑ **Water Quality**
- ☺ **Channel Protection**
- ☺ **Overbank Flood Protection**
- ☺ **Extreme Flood Protection**

☺ in certain situations

IMPLEMENTATION CONSIDERATIONS

- L **Land Requirements**
- H **Capital Cost**
- H **Maintenance Burden**

Residential Subdivision Use: Yes

High Density/Ultra-Urban: Yes

Roadway Projects: Yes

Other Considerations: Overflow Parking, Driveways & related uses

~~**Pollutant Removal**~~

- ~~Total Suspended Solids – not applicable~~80%
- ~~Total Phosphorus – not applicable~~50%
- ~~Total Nitrogen – not applicable~~50%
- ~~Fecal Coliform – insufficient data~~Not applicable
- ~~Heavy Metals – 6~~90%

Runoff Reduction Credit

- 100% of the runoff reduction credit if an underdrain is not used
- 50% of the runoff reduction credit if an underdrain is used

4.15.1 General Description

Modular ~~porous~~permeable ~~pavers~~paver systems are structural units~~, such as concrete blocks, bricks, or reinforced plastic mats,~~ with regularly inter dispersed void areas used to create a load-bearing pavement surface. The void areas are filled with pervious materials (gravel) to create a system that allows for the infiltration of stormwater runoff. ~~Porous~~Permeable paver systems

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provide water quality benefits in addition to groundwater recharge and a reduction in stormwater volume. The use of ~~porous~~permeable paver systems results in a reduction of the effective impervious area on a site.

There are many different types of modular ~~porous~~permeable ~~pavers~~paver systems available from different manufacturers, including both pre-cast and mold in-place concrete blocks, concrete grids, interlocking bricks, and plastic mats with hollow rings or hexagonal cells (see Figure ~~3.3.8~~4.15-1).

Modular ~~porous~~permeable ~~pavers~~paver systems are typically placed on a gravel (stone aggregate) base course. Runoff infiltrates through the ~~porous~~permeable paver surface into the gravel base course, which acts as a storage reservoir as it exfiltrates to the underlying soil. The infiltration rate of the soils in the subgrade must be adequate to support drawdown of the entire runoff capture volume within ~~24 to~~ 48 to 72 hours. Special care must be taken during construction to avoid undue compaction of the underlying soils, which could affect the soils' infiltration capability.

Modular ~~porous~~permeable paver systems are typically used in low-traffic areas with low to no tree coverage such as the following types of applications:

- Parking pads in parking lots
- Overflow parking areas
- Residential driveways
- Residential street parking lanes
- Recreational trails
- Golf cart and pedestrian paths
- Emergency vehicle and fire access lanes

A major drawback is the cost and complexity of modular ~~porous~~permeable paver systems compared to conventional pavements. ~~Porous~~Permeable paver systems require a very high level of construction workmanship to ensure that they function as designed. In addition, there is the difficulty and cost of rehabilitating the surfaces should they become clogged. Therefore, consideration of ~~porous~~permeable paver systems should include the construction and maintenance requirements and costs.

4.15.2 Pollutant Removal Capabilities

As they provide for the infiltration of stormwater runoff, ~~porous~~permeable paver systems have a high removal of both soluble and particulate pollutants, where they become trapped, absorbed or broken down in the underlying soil layers. Due to the potential for clogging, ~~porous~~permeable paver surfaces should not be used for the removal of sediment or other coarse particulate pollutants.

For additional information and data on pollutant removal capabilities for bioretention areas, see the National Pollutant Removal Performance Database (~~2~~nd-3rd Edition) available at www.cwp.org and the National Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org.

4.15.3 Design Criteria and Specifications

- ~~Porous~~Permeable paver systems can be used where the underlying in-situ subsoils have an infiltration rate of at least 0.5 inches per hour. Therefore, ~~porous~~permeable paver systems are not suitable on sites with hydrologic group D or most group C soils, or soils with a high (>30%) clay content. During construction and preparation of the subgrade, special care must be taken to avoid compaction of the soils.

- ~~Porous~~Permeable paver systems should typically be used in applications where the pavement receives tributary runoff only from impervious areas. The ratio of the contributing impervious area to the ~~porous~~permeable paver surface area should be no greater than 3:1.

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- If runoff is coming from adjacent pervious areas, it is important that those areas be fully stabilized to reduce sediment loads and prevent clogging of the ~~porous~~permeable paver surface.

- It is recommended that the subsoil of the ~~porous~~permeable paver systems have a slope of 0% and the surface have a slope of 0.5% if possible.

- A minimum of 2 feet of clearance is required between the bottom of the gravel base course and underlying bedrock or the seasonally high groundwater table.

- ~~Porous~~Permeable paver systems should be sited at least 15 feet down gradient from buildings and
100 feet away from drinking water wells.

- An appropriate modular ~~porous~~permeable paver should be selected for the intended application. A minimum of 40% of the surface area should consist of open void space. If it is a load bearing surface, then the ~~pavers~~pavers should be able to support the maximum load.

- The ~~porous~~permeable paver infill is selected based upon the intended application and required infiltration rate. Masonry sand (such as ASTM C-33 concrete sand or GADOT Fine Aggregate Size No. 10) has a high infiltration rate (8 in/hr) and should be used in applications where no vegetation is desired. A sandy loam soil has a substantially lower infiltration rate (1 in/hr), but will provide for growth of a grass ground cover.

- A 1-inch top course (filter layer) of sand (ASTM C-33 concrete sand or GADOT Fine Aggregate Size No. 10) underlain by filter fabric is placed under the ~~porous~~permeable ~~pavers~~pavers ~~and~~ above the gravel base course.

- The gravel base course should be designed to store at a minimum the water quality volume (WQ_v). The stone aggregate used should be washed, bank-run gravel, 1.5 to 2.5 inches in diameter with a void space of about 40% (GADOT No.3 Stone). Aggregate contaminated with soil shall not be used. A porosity value (void space/total volume) of 0.32 should be used in calculations.

- The gravel base course must have a minimum depth of ~~9~~12 inches. The following equation can be used to determine if the depth of the storage layer (gravel base course) needs to be greater than the minimum depth:

$$RR_V = A * [(p1)(d1)]$$

Where:

~~d = Gravel Layer Depth (feet)~~
~~V = Water Quality Volume or Total Volume to be Infiltrated~~
~~A = Surface Area (square feet)~~
~~n = Porosity (use n value recommended by the gravel company)~~
RR_V - Runoff reduction volume (ft^3)
A - area of permeable ~~bricks/blocks~~paver system (ft^2)
p1 - porosity of base layer (% void)
d1 - depth of base layer (ft)
Note that this formula works for surfaces with a 0% slope.

- The surface of the subgrade should be lined with filter fabric or an 8-inch layer of sand (ASTM C-33 concrete sand or GADOT Fine Aggregate Size No. 10) and be completely flat to promote infiltration across the entire surface.

- ~~Porous~~Permeable paver system designs must use some method to convey larger storm event flows to the conveyance system. One option is to use storm drain inlets set slightly above the elevation of the pavement. This would allow for some ponding above the surface,

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but would accept bypass flows that are too large to be infiltrated by the ~~porous~~permeable paver system, or if the surface clogs.

- For the purpose of sizing downstream conveyance and structural control system, ~~porous~~permeable paver surface areas can be assumed to be 40~~35~~% impervious. In addition, credit can be taken for the runoff volume infiltrated from other impervious areas using the methodology in Section 3.1.

4.15.4 Design Procedures

Step 1: Determine the goals and primary function of the permeable ~~bricks/blocks~~paver system

Consider whether the permeable ~~bricks/blocks~~paver system are intended to:

- Meet a runoff reduction* target or water quality (treatment) target. ***Note that minimum infiltration rates of the surrounding native soils must be acceptable and suitable when used in runoff reduction applications.**
- Provide a possible solution to a drainage problem.

Check with local officials and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply. In addition, consider if the permeable ~~bricks/blocks~~ paver system have any special site-specific design conditions or criteria. List any restrictions or other requirements that may apply or affect the design.

The design of the permeable ~~bricks/blocks~~paver system should be centered on the restrictions/requirements, goals, targets, and primary function(s) of permeable ~~bricks/blocks~~paver system. By considering the primary function, as well as, topographic and soil conditions, the design elements of the permeable ~~bricks/blocks~~paver system can be determined (i.e. underdrain, inlet/outlet, overflow, etc.)

Step 2. Determine if the development site and conditions are appropriate for the use of a permeable ~~bricks/blocks~~paver system

Consider the application and site feasibility criteria in this chapter. In addition, determine if site conditions are suitable for permeable ~~bricks/blocks~~paver system. Create a rough layout of the permeable ~~bricks/blocks~~paver system dimensions taking into consideration existing trees, utility lines, and other obstructions.

Step 3. Calculate the Stormwater Runoff Reduction Target Volume

Calculate the Runoff Reduction Volume using the following formula:

$RR_V = (P)\ (R_V)\ (A) / 12$

Where:

RR_V = Runoff Reduction Target Volume (~~acre~~ feet^3)

P = Target runoff reduction rainfall (inches)

R_V = Volumetric runoff coefficient which can be found by:

$R_V = 0.05+0.009(I)$

Where:

I = new impervious area of the contributing drainage area (%)

A = Site area (~~acres~~feet^2)

12 = Unit conversion factor (in/ft)

The designed runoff reduction volume should meet or exceed the following equation:

$RR_V = A\ [(p1)(d1)]$

Where:

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RRV - Runoff reduction volume (ft^3)
A - area of permeable ~~bricks/blocks~~ paver system(ft^2)
p1 - porosity of base layer (% void)
d1 - depth of base layer (ft)
Note that this formula works for surfaces with a 0% slope.

Step 4. Outlet Design

Determine which type of outlet design will be used for the permeable ~~bricks/blocks~~paver system. There are two types of outlet design that are generally used if infiltration is not possible without additional assistance. They are an underdrain system and overflow system. The underdrain system should include a ~~seri~~series~~s~~ of perforated pipes that run longitudinal with the bricks/blocks to remove additional stormwater runoff that could not otherwise infiltrat~~ione~~ into the surrounding soil. An overflow system directs water that cannot be infiltrated into the subsoil and moves it to another location, for instance another BMP or storm sewer system.

Step 5. Erosion and Sediment Control/Base Protection

Determine the stormwater discharges to the construction site that could potentially erode and clog the system. Take the proper steps to stabilize the site and prevent erosion when construction begins.

Step 6. Select Permeable ~~Bricks/Blocks~~Paver System and finalize design

Select the ~~bricks/blocks~~paver system based on the specific site conditions. Finalize the design the of the practice. Make sure that the soil is stabilized by using filter fabric or other method as determined by the designer. ~~For articulated concrete blocks, ensure that an edge restraint is placed around the perimeter of the bricks/blocks. The choker course is placed between the bricks/blocks and it should be No.8 washed aggregate and is placed on the base layer.~~

4.15.45 Inspection and Maintenance Requirements

~~**Table 3.3.8-1 Typical Maintenance Activities for Modular Porous Paver Systems**~~**Permeable Bricks/Blocks**

~~Maintenance Activity~~	~~Schedule~~
• ~~Ensure that the porous paver surface is free of trash, debris, and sediment.~~ • ~~Check to make sure that the system dewaters between storms.~~ • ~~Keep weekds and grass out of the paved area (unless concrete grid pavers are being used)~~ • ~~Mow / trim adjacent vegetation and remove clippings from the area~~ • ~~Visually inspect the pavers after large storms to ensure the overflow drainage system is working~~ • ~~After cleaning, additional aggregate fill may need to be added and the pavers should be inspected for damage and repaired as needed~~	~~Monthly~~

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~~Table 3.3.8-1 Typical Maintenance Activities for Modular Porous Paver Systems~~Permeable ~~Bricks/Blocks~~

~~Maintenance Activity~~	~~Schedule~~
• ~~Ensure that contributing area and porous paver bricks/blocks surface are clear of debris.~~ • ~~Ensure that the contributing and adjacent area is stabilized and mowed, with clippings removed.~~	~~As needed, based on inspection~~
• ~~Vacuum sweep porous paver surface to keep free of sediment~~ • ~~Replace aggregate between pavers as necessary~~	~~2-5 times per year as needed for low traffic areas with little or no tree coverage; or 6-10 times per year as needed for high traffic areas with trees or other dust or grit sources~~
• ~~Sweep or vacuum the pavers with a street sweeper or street vacuum~~ • ~~If the pavers are installed in an area that is subject to higher than normal amounts of sediment (i.e. an area with large trucks traveling on it daily) it may need to be cleaned more often~~ • ~~Replace any joint material that may have eroded~~ • ~~Observe the system during a rain event~~ • ~~Areas should be routinely inspected for settling and loss of water flow through the system~~	~~Semi-annually in Spring and Fall~~
• ~~Organic deicers may be used to melt ice and snow~~ • ~~Snow plows may be used when necessary under the following conditions:~~ ~~-The edges of the plows are beveled~~ ~~-The blade of the snow plow is raised 1-2 inches~~ ~~-The snow plow is equipped with snow shoes which allow the blade to glide across uneven surfaces~~	~~As needed in winter~~
• ~~Inspect the surface for deterioration or spalling.~~	~~Annually~~
• ~~Totally rehabilitate the porous paver system, including the top and base course, as needed.~~	~~Upon failure~~

All best management practices require proper maintenance. Without proper maintenance, BMPs will not function as originally designed and may cease to function altogether. The design of all BMPs includes considerations for maintenance and maintenance access. For additional information on inspection and maintenance requirements, see Appendix XX.

~~4.15.5 Example Schematics~~

~~Figure 4.15-1 Examples of Modular Porous~~Permeable ~~Pavers~~Bricks/blocks

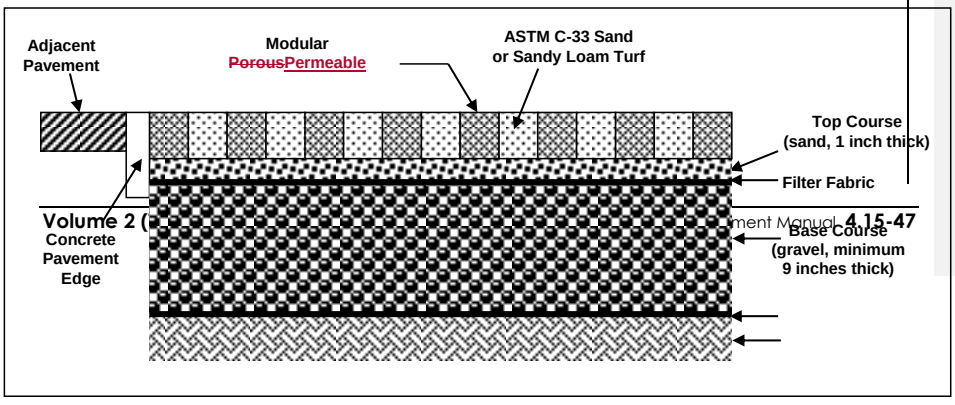

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Figure 4.15-2 Modular PorousPermeable Paver System Section

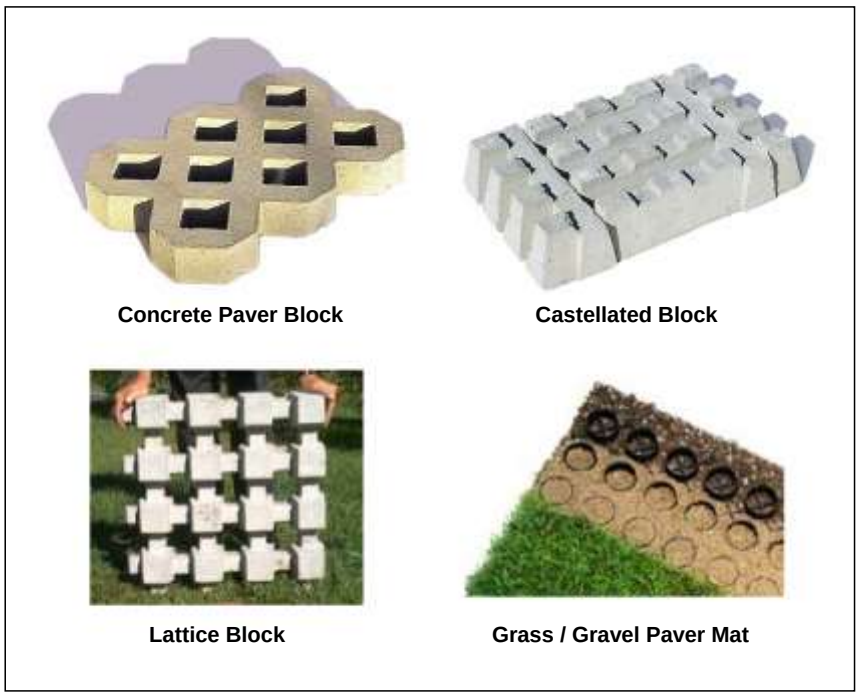

Figure 4.15-3 Typical Modular PorousPermeable Paver System Applications
(Source: UDFCD, 1999)

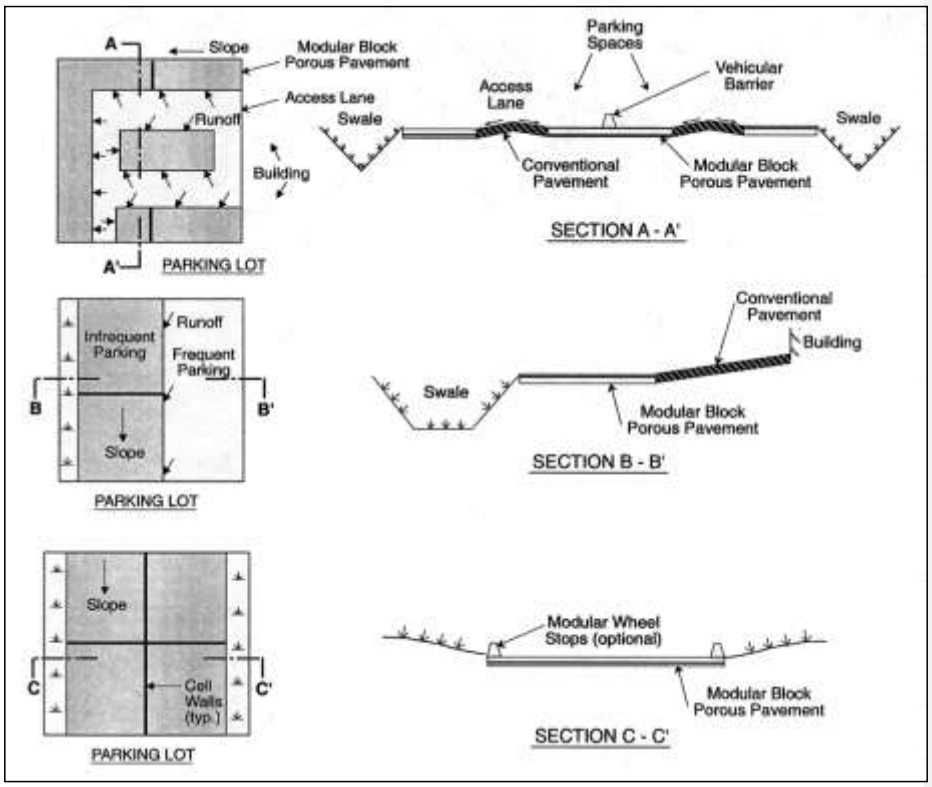
A
Slope
Modular Block
Porous Pavement
Access Lane
Runoff
Building
A'
PARKING LOT
Parking
Spaces
Vehicular
Barrier
Access
Lane
Swale
Swale
Conventional
Pavement
Modular Block
Porous Pavement
SECTION A - A'
Infrequent
Parking
Runoff
Frequent
Parking
B
B'
Slope
PARKING LOT
Conventional
Pavement
Building
Swale
Modular Block
Porous Pavement
SECTION B - B'
Slope
C
C'
Cell
Walls
(typ.)
PARKING LOT
Modular Wheel
Stops (optional)
Modular Block
Porous Pavement
SECTION C - C'

Figure 4.15-4 Examples of PorousPermeable Paver Surfaces
(Sources: Invisible Structures, Inc.; EP Henry Corp.)