UNI-GROUP U.S.A.

Permeable UNI® Paver Installation

Overview – UNI® Permeable Paver Design and General Construction Guidelines

UNI-GROUP U.S.A. offers design professionals a variety of tools for designing the Eco-Stone® family of permeable pavements. We offer design manuals, case studies, and Lockpave® Pro structural interlocking pavement design software, featuring PC-SWMM PP™ for the hydraulic design of Eco-Stone® permeable pavements.

As members of the Interlocking Concrete Pavement Institute, our manufacturers can offer additional design and reference information, such as ICPI's *Permeable Interlocking Concrete Pavements* manual, which offers detailed design specification guidance, Tech Specs™ and CAD digital files.

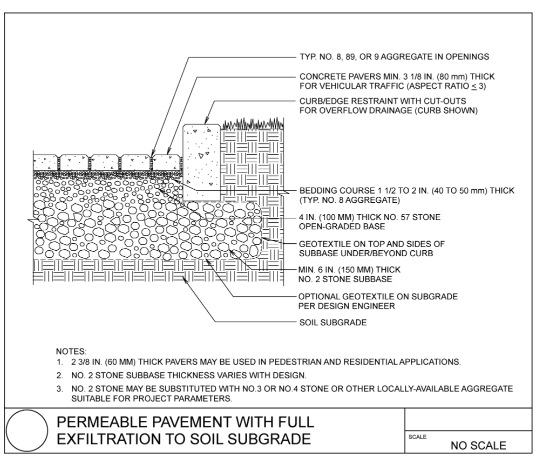
It is recommended that a qualified civil engineer with knowledge in hydrology and hydraulics be consulted for applications using permeable interlocking concrete pavement to ensure desired results. Information provided in this guide is intended for use by professional designers and is not a substitute for engineering skill or judgment. It provides an overview of construction guidelines and research to date and is not meant to replace the services of experienced, professional engineers

Permeable interlocking concrete pavements require greater initial site evaluation and design effort compared to traditional concrete paver installations. They require a greater level of construction skill, inspection during construction and after installation, and attention to detail. In addition, maintenance is an important design aspect to help ensure long-term pavement performance. Because permeable pavements are designed and constructed differently from traditional paver installations, we've included some basic design guidance here as well.

Design Options - Full, Partial and No Infiltration

Eco-Stone® pavements can be designed with full, partial, or no infiltration into the soil subgrade. Optimal installation is infiltration through the base aggregate, with complete infiltration into a permeable subgrade. This allows for not only runoff and pollutant reduction, but also groundwater recharge. For full infiltration under vehicular loads, the minimum soil infiltration rate is typically 0.52 in./hr (3.7 x 10-6 m/sec). For maximum infiltration, subgrade soils should have less than 5% passing the No. 200 (0.075mm) sieve, though up to 25% passing may be adequate for drainage depending on site conditions and other characteristics. It is possible that site soils with a permeability of less than the 0.52 in./hr rate will infiltrate water, however the soils must be stable while saturated, especially under vehicular loading. Pedestrian pavements that will not receive vehicular loading can be constructed over soils with lower permeability rates.

Where soil conditions limit the amount of infiltration and only partial infiltration can be achieved, some of the water may need to be drained by perforated pipe. Where soils have extremely low or no permeability or there is a high water table, poor soil strength, or in areas over aquifers where there isn't sufficient depth of the soil to filter pollutants, no exfiltration should occur. In these cases, the EPA recommends using an impermeable liner and perforated pipe to drain all stored water to an outfall pipe. This design still allows for infiltration of stormwater and some filtering of pollutants and slows peak rates and volumes, so it still can be beneficial for managing stormwater. It may also be possible to collect this water for further treatment. In some cases, there may be a more permeable soil layer below a low or non-permeable layer, where it may be cost effective to drain the water with a French drain or pipes through this layer into the soil with greater permeability. For extreme rainfall events, if any overflows occurs, it can be controlled via perimeter drainage to bio-retention areas, grassed swales, or storm sewer inlets.



PERMEABLE PAVEMENT WITH FULL EXFILTRATION TO SOIL SUBGRADE

The cross-section shown above depicts a full infiltration design. Other cross-sections and a permeable paver specification are shown on our web site – www.uni-groupusa.org. Download or request our Eco-Stone® Design Guide and Research Summary for more information.

Site Selection Guidelines

Eco-Stone® permeable interlocking concrete pavers can be used for a wide variety of residential, commercial, municipal and industrial (Ecoloc® and Eco-Optiloc®) applications. They can be used for parking lots, driveways, overflow parking, emergency lanes, boat ramps, walk-ways, low-speed roadways, and storage facilities. Permeable or porous pavements should not exceed 5% slope for maximum infiltration.

In addition to some of the guidelines previously described, permeable pavements should typically be sited at least 100 ft (30m) from water supply wells, streams, and wetlands, though local jurisdictional regulations may supercede these guidelines. The minimum estimated depth from the bottom of the pavement base to the high level of the water table should be greater than 2 ft (0.6m) to allow for filtration of pollutants through the soils.

There are however, certain circumstances when permeable pavements should not be used. Any site classified as a stormwater hotspot (anywhere there is risk that stormwater could infiltrate and contaminate groundwater) is not a candidate for permeable pavements. This might include salvage and recycling yards; fueling, maintenance, and cleaning stations; industrial facilities that store or generate hazardous materials; storage areas with contents that could damage groundwater and soil; and land uses that drain pesticides and/or fertilizers into permeable pavements. In addition, permeable pavements may not be feasible when the land surrounding and draining into the pavement exceeds a 20% slope, or the pavement is downslope from buildings where the foundations have piped drainage at the footers.

Infiltration Rate Design

Permeable interlocking concrete pavements are typically designed to infiltrate frequent, short duration storms, which make up 75-85% of rainstorms in North America. However, it also may be possible to manage runoff volumes from larger storms, including 100-year storms, through engineering design and the use of complementary best management practices, such as bio-retention areas and vegetated swales.

One of the most common misconceptions when designing or approving permeable interlocking concrete pavement is the assumption that the amount or percentage of open surface area of the pavement is equal to the percentage of perviousness. For example, a designer or municipal agency might incorrectly assume that a 15% open area is only 15% pervious. Actually, the permeability and amount of infiltration are dependent on the infiltration rates of the aggregates used for the joint and drainage openings, the bedding, base, and subbase, and ultimately, the subgrade.

Compared to soils, the materials used in Eco-Stone® permeable pavement systems have very high infiltration rates – from 500 in./hr (12 cm/hr) to over 2000 in./hr (5080 cm/hr). This is far more pervious than any existing site soils. Though initial infiltration rates are very high, it is important to consider lifetime design infiltration of the entire pavement cross-section, including the soil subgrade when designing PICPs. Based on research to date, a conservative design rate of 10 in./hr (25 cm/hr) can be used as the basis for the design surface infiltration rate over a 20-year pavement life. As lifetime design infiltration rates may be difficult to predict, designers may want to use a conservative approach when calculating the design infiltration rate. Limited research has shown that permeability decreases with the age of the pavement, rainfall intensities, and the conditions under which it is used and maintained.

Infiltration tests conducted by Dr. Soenke Borgwardt in 2006 demonstrated that newly installed pavements, with an approximate 12% open surface area and a 2-5mm drainage void fill aggregate, infiltrated approximately 62 in./hr (1300 l/s ha). After 10 years, the infiltration rate was approximately 16 in./hr (1300 l/s ha). His data showed that even with minimal maintenance, the pavements were capable of infiltrating virtually any design storm. Engineers should account for these factors when designing infiltration rates for permeable interlocking concrete pavements and should encourage the establishment of a maintenance program to ensure optimal long-term performance.

A number of design methods may be used for sizing of the open-graded base. The ICPI Permeable Interlocking Concrete Pavement manual uses a design method adapted from the state of Maryland's Standard Specifications for Infiltration Practices and Maryland Stormwater Manual. You may obtain a copy of ICPI's manual from your local UNI® manufacturer. The method assumes familiarity with NRCS TR 55 method for calculating stormwater runoff.

For designers who use Natural Resources Conservation Service (NRCS) curve numbers in determining runoff calculations, the curve number for PICP can be estimated at 45-80, assuming a life-time design infiltration rate of 10 in./hr (25 cm/hr) with an initial abstraction of 0.2 (applies to NRCS group A soils). Other design professionals may use coefficient of runoff for calculating peak runoff discharges. For peak runoff calculations, the coefficient of runoff, C for the design life of permeable interlocking concrete pavements can be estimated with the following formula:

$$C = \frac{I - \text{Design infiltration rate, in./hr}}{I}$$

where I = design rainfall intensity in inches per hour. The formula should not be used in water quality calculations however, as it does not account for volume.

Other quantitative models such as HEC-1 and EPA SWMM may be modified to include permeable interlocking pavements. The

PC-SWMM PP™ software program included with our LOCKPAVE PRO® structural design software is based on the EPA's model and also may be used for calculations.

Construction Materials and General Installation Guidelines

It is preferable and highly recommended that site subgrade soils not be compacted if structural strength is suitable, as compaction reduces infiltration rates. Design procedure typically assumes a soil CBR (minimum 96-hour soaked per ASTM D 1883 or AASHTO T 193) strength of at least 5% or an R-value of 24 to support vehicular traffic. Low CBR soils (<5%) may require compaction and/or stabilization for vehicular traffic applications. Perforated pipe also would typically be required to drain excess water in the base in applications over low CBR soils. Applications subject to strictly pedestrian traffic should not require compaction of the subgrade. If soils must be compacted, the reduced infiltration rates must be factored into the design. Care should be taken during excavation and tracked vehicles should be used to minimize inadvertent compaction.

A civil or geotechnical engineer experienced in local site conditions and stormwater management should be consulted to ensure all project parameters and objectives are met and to determine the suitability of the site for permeable pavement installation. It is highly recommended that the designing engineer inspect the site during the construction of permeable pavements (as is the case with infiltration trenches). This will help ensure the specified materials and design parameters selected by the engineer are followed. It is of utmost importance to prevent sediment from entering the base and pavement surface during construction of permeable interlocking concrete pavements. Use of construction controls such as silt fences and drainage swales is encouraged and care should be taken to stabilize the surrounding areas that will drain on to the pavement prior to the pavers receiving runoff.

Subbase, Base, Bedding and Joint/Void Fill

Permeable interlocking concrete pavements are typically built over open-graded aggregate bases consisting of washed, hard, crushed stone, though a variety of aggregate materials, including dense-graded, may be used depending on project parameters. Generally, stone materials used for PICP bases should have less than 1% fines passing the No. 200 sieve. Geotextiles may be used in some PICPs, but are optional when using a No. 2 aggregate subbase as described below. If filter criteria between the layers of the pavement (subgrade, base, and bedding) cannot be maintained with the aggregate materials selected for the project, or if traffic loads or soils require additional structural support, geotextiles may be used. Consult AASHTO for information on geotextile filter criteria. Curb cut-outs and/or catch basins are typically incorporated into permeable pavement designs to handle emergency overflow of stormwater under extreme storm conditions. As noted earlier, perforated drainage pipe is usually included in designs with partial or no exfiltration into the subgrade. Perforated drainage pipes can provide drainage in heavy, overflow conditions or provide secondary drainage if the base loses some of its capacity over time.

Current industry recommendations call for a subbase of open-graded aggregate (typically ASTM No. 2 or equivalent) at a minimum thickness of 6 in. (150mm) for pedestrian applications and 8 in. (200mm) for vehicular applications. (Other aggregate materials may be suitable depending on project parameters and locally available materials.) This makes it easier for contractors to construct the base and adds structural stability. A base layer of open-graded aggregate (typically ASTM No. 57 or equivalent) is then installed over the subbase. This helps meet filter criteria between the layers. The recommended thickness for this layer is 4 in. (100mm). It may be possible, however, to use a single material for the base and subbase depending on project design parameters and contractor experience. The thickness of the base/subbase depends on the amount of water storage required, the permeability and strength of the soil subgrade, and susceptibility to frost, as well as anticipated traffic loads. The water infiltration capacity of the base will vary with its depth and the percentage of void spaces in it (void space of a certain material can be supplied by the quarry or determined by testing). The open-graded materials described here typically have an in-situ porosity of at least 0.32 for void space for water storage. This translates to a water storage capacity in the void spaces between the aggregates of 20-40%. A 40% void space means that the volume of the base will need to be 2.5 times the volume of water that will be stored.

The No. 2 subbase aggregate should be spread in 4 to 6 in. (100-150mm) lifts and compacted with a static roller. The No. 57 base layer can be spread and compacted in a single 4 in. (100mm) lift. Aggregate materials should be moist when compacting. Initial passes of the roller can be with vibration to consolidate the stone, however, final passes should be without vibration. When all lifts are installed and compacted, the bedding layer can be installed. Material equivalent to ASTM No. 8 stone is recommended for the bedding layer, which is screeded and leveled to a thickness of 1 1/2-2 in. (25-50mm) to provide a setting bed for the pavers. The No. 8 material should be moist to facilitate choking into the No. 57 base material. The Eco-Stone® pavers are then installed on this bedding layer. The same No. 8 aggregate can be used to fill the drainage openings and joints. If desired, material equivalent to No. 9, 10 or 89 stone also may be used to fill the smaller joints between the pavers. Bedding and jointing sand used in the construction of traditional interlocking concrete pavements should not be used for PICP. Once the drainage openings and joints are filled, the surface is swept and then compacted with a plate compactor. After the initial compaction, refill the joints and openings, sweep clean and compact again. Repeat if necessary to completely fill the joints and openings. For vehicular pavements, proof-rolling may be considered with at least 2 passes of a 10T rubber-tired roller. UNI Eco-Stone® can be manually or mechanically installed and trafficked immediately after final compaction, unlike other types of porous and pervious pavements.

In cases where it may be necessary to increase the structural capacity of the pavement either due to existing site soil strength or traffic loads, bases may be stabilized with asphalt or cement prior to installation. Just enough asphalt or cement to coat the aggregate is required, though care must be taken during construction not to fill the void spaces with asphalt or excess paste, as this may reduce storage capacity of the base. The Asphalt Institute and Portland Cement Association provide guidelines on constructing these types of bases.

Like traditional interlocking concrete pavements, PICP uses edge restraints to secure the edges of the pavement. Cast-in-place and precast concrete curbs are recommended for PICP. Permeable interlocking concrete pavement conforms to current ADA requirements that surfaces be firm, stable, and slip resistant. If the openings in the surface are not desirable, solid pavers can be installed in areas used by disabled persons. If ADA design requirements change in the future, UNI® permeable interlocking paver designs can be adapted to meet new guidelines.

This information is intended as an overview. Please see our UNI® Permeable Paver specification for detailed guidance on installation.

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