Improving Storm Water Management

Situation / Impervious surfaces' negative effects / Challenges for city officials

Sustainable development is meeting the needs of the present without compromising the ability of future generations to meet their own needs. (Our common future, 1987, World Commission on Environment and Development. Oxford, UK. Oxford University Press).

As the need for sustainable development increases, city officials are faced with the challenge of rehabilitating municipal infrastructures to ensure a better use of nature's resources and minimize the impact of human activity on our environment, while still promoting the development of North America's urban landscapes.

Previous urban sprawl over the continent as happened with little regards for the environment, nor towards the potential further development of growing cities. The proliferation of impervious surfaces over the land and the conveyance of rain water via urban infrastructure have had grave consequences over the natural hydrological cycle.

A study by the US EPA (*Urbanization and Streams: Studies of Hydrologic Impacts)* shows that increased imperviousness leads to:

?? increased flow volumes, peaks and peak durations
?? increased stream temperature
?? changes in sediment loading
?? reduction of infiltration to aquifers
?? entrainment of pollutants to receiving waters

The rising impermeability of surfaces has limited the recharging of soil water reserves, thus drying out the soils from which plant roots draw their nutrients. Dry soils also become more prone to erosion.

Unable to leech down through the surface, rain water gathers sediments and ground pollutants as they dramatically increase surface runoffs through urban infrastructure, flowing down to receiving waters.

This has affected humans at the expense of the environment around which we live, as well as economically, raising costs of development and maintenance of infrastructures.

Economics

Citizens the world over are now more than ever aware of the financial costs of poor environmental planning. The increasing presence of impervious surfaces proves very costly, as government authorities must spend more to build larger sewer infrastructures to carry increasing flows.

Land developers are also losing money. Wishing to connect the sewers of new developments to existing pipes already functioning at capacity, retention ponds must be built on land, which would otherwise be sold to residential owners.

The combination of increased flow rates and drying of the soil has dramatically amplified erosion of streams and embankments of receiving water bodies. And while very onerous engineered methods are implanted to counter erosion, the true cost of soil deterioration is still unknown.

Poor water quality is also proving very costly. Polluted waters reaching main water bodies degrade the natural habitat, adversely affecting industries such as tourism and fisheries. The decontamination of overflows is also very expensive as the activities at sewer treatment plants augment.

Realizing the impact of today's actions on the world of tomorrow, elected officials, municipal engineers, architects and urban planners are now more than ever concentrating their efforts on finding solutions that are economically and environmentally viable for the next generations.

Best Management Practices

To improve sustainable development, U.S. federal law now requires, through the National Pollution Discharge Elimination System (NPDES), that states control non-point source water pollution. Best Management Practices are techniques identified by state authorities to achieve this goal. Regional laws include limitations on the percentage of impervious surface over a total development, restrictions on outflow volume and velocity to the existing infrastructures, outflow contaminant concentrations, and others.

Adopting a BMP is not only encouraged through legislation, but provides promoters, authorities and residents with a great tool to enhance their comfort while ensuring great medium and long term return on investment.

Objectives

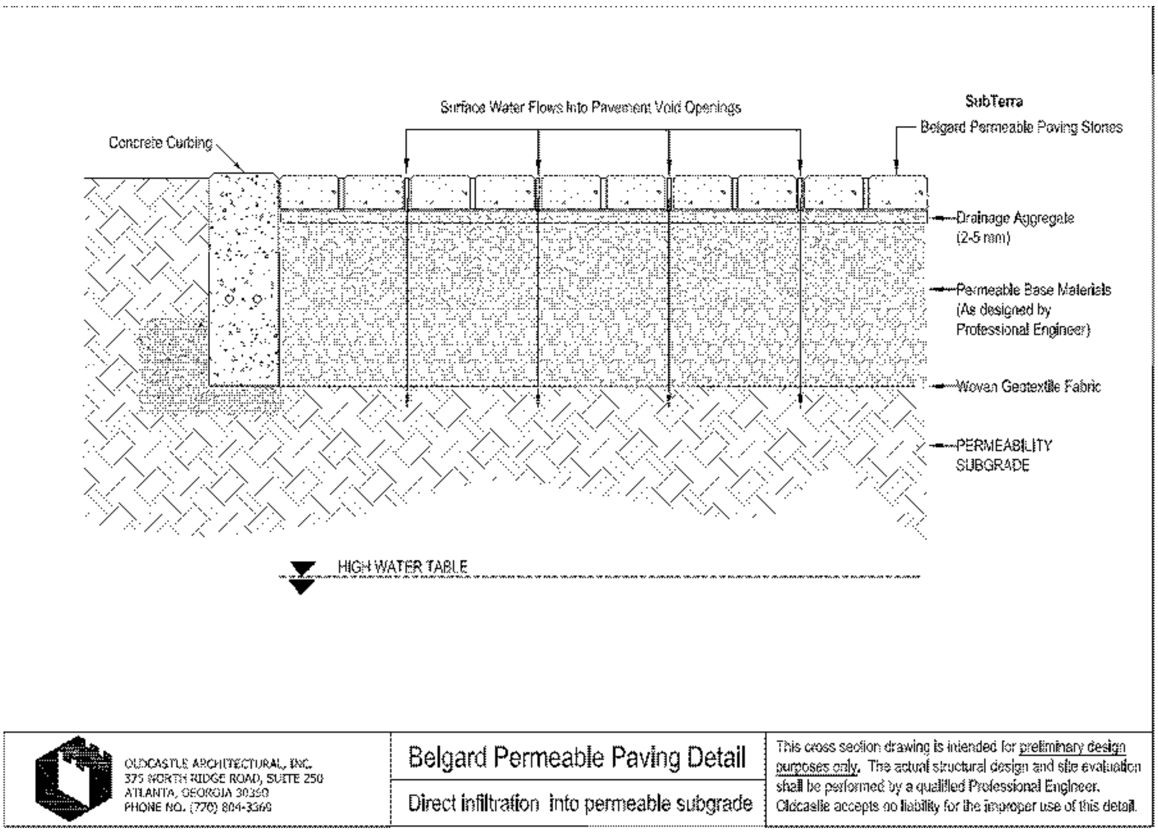
When choosing a BMP, administrators should consider a wide range of factors. The right solution will answer the immediate environmental needs, through a long life-cycle, at a reasonable price. The right solution must also answer the most issues, as the owner wishes to limit the variety of techniques implemented.

Permeable Pavement

Permeable pavements are one of the most popular and appreciated BMPs. They answer both qualitative and quantitative needs for precipitation water flows. As water rains on the pavement, it seeps through to the ground, reducing surface flows, often even eliminating the need for sewers and manholes.

The key to understanding permeable pavements is to perceive the pavement and the base aggregates as a system, instead of separate products. As water rains down on the pavement, it begins its journey by seeping through the pavement, and then through the base aggregates, which naturally filter the pollutants. As it travels down, the water is stored in the base, until it reaches the natural underlying soils and recharges the ground aquifers. Thus, permeable pavement serves as an underground storage basin that filters the water while allowing pedestrian and vehicular traffic on the surface.

Depending on site conditions and owner preferences, permeable pavement can be designed to obtain full, partial or zero exfiltration (figures 1 a,b,c). Full exfiltration is the most often desired and used application, which sees all the rain water stored in the base leeching down to the underlying subgrade. When natural soils are not permeable enough, or storms too heavy, perforated pipes are added to alleviate the excess water. Thirdly, an impermeable geo-membrane can be installed above the natural soils to prevent exfiltration of contaminated flows when the pavement is installed in industrial sites.



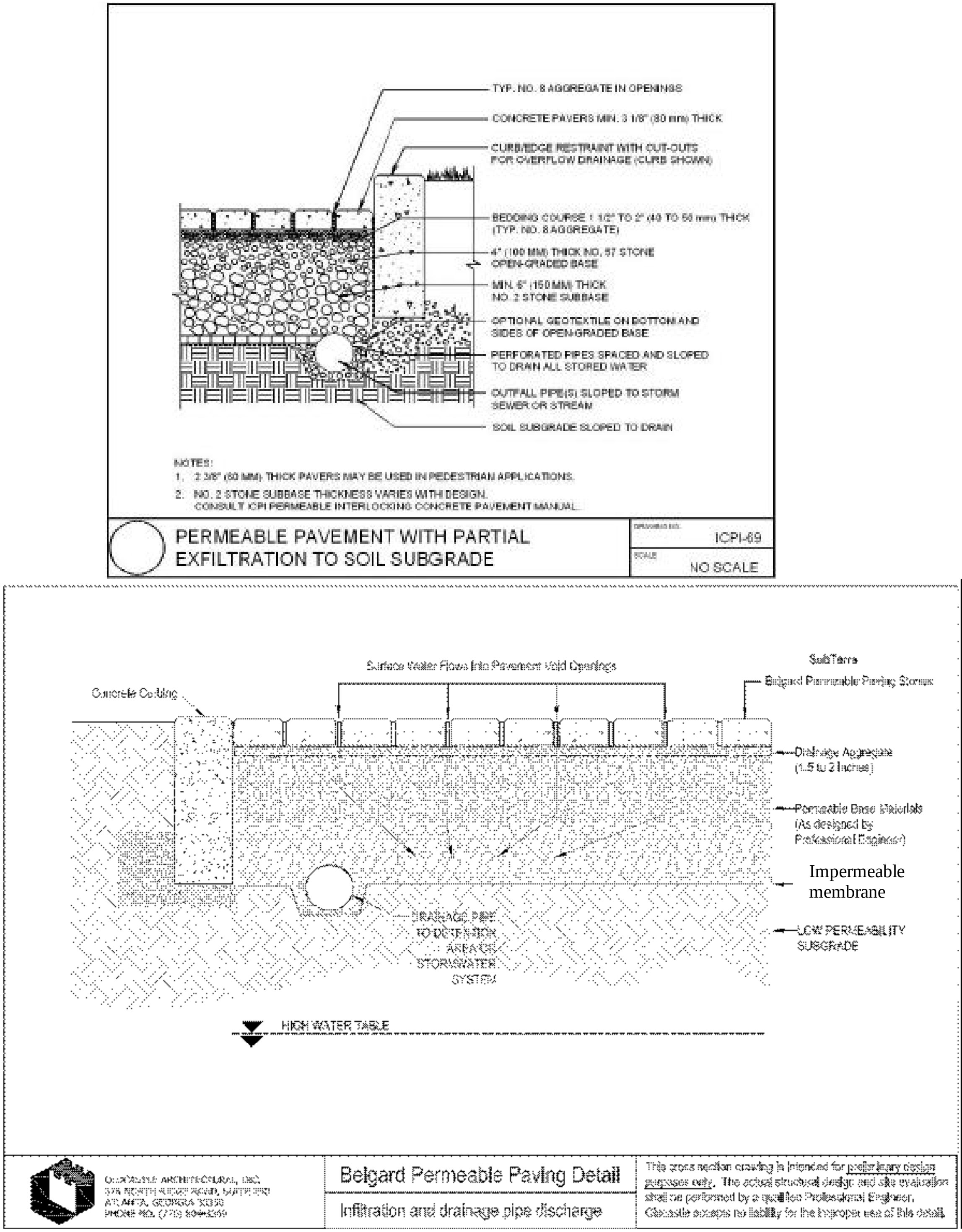


Figure 1 a) Full exfiltration to subgrade (Oldcastle, 2008). b) Partial exfiltration to subgrade (ICPI, 2006). c) No exfiltration to subgrade (Oldcastle, 2008)

Choosing permeable pavement technology, the designer or owner will benefit from (ICPI, 2006):

- ?? Conservation of space on the site and reduction of impervious cover
- ?? Reduction of runoff
  - o Reduced peak discharge and stress on sewers
  - o Reduction of downstream erosion
- ?? Improved water quality
- ?? Reduction of water temperature
- ?? Increased recharge of groundwater
  - o Promote tree survival by providing air and water to the roots
- ?? Reduction of total development costs
  - o Reduction of infrastructure construction
  - o Decrease in retention basins and other unsellable land
- ?? Reduces risks of accidents/injuries
  - o Eliminates puddling and flooding on parking lots
  - o Faster snow melt drainage
- ?? Contributes to urban heat island reduction
- ?? Eligible for LEED® credits

LEED® Credits

As detailed on ICPI's Tech Spec 16, more than 13 LEED points can be obtained, directly or indirectly, through the use of permeable pavements.

The most obvious credits attainable through the use of permeable pavements are Sustainable Sites 6.1 and Sustainable Sites 6.2, covering imperviousness and pollutant filtration respectively.

Also, through the right choice of permeable pavements, points can be attributed for reduction of heat island effect, reused or recycled materials, regional materials, pavement lifecycle, water efficiency and utility durability plans.

Permeability and Beyond

Though the main use of permeable pavements is reduction of storm water flows, it can sure be the main entryway for other technologies, mainly water harvesting. While the infiltrated water isn't quite potable for consumption, it can be stored for a wide array of uses, ranging from

- ?? landscape irrigation
- ?? root system maintenance
- ?? building graywater applications (flushes, and such)

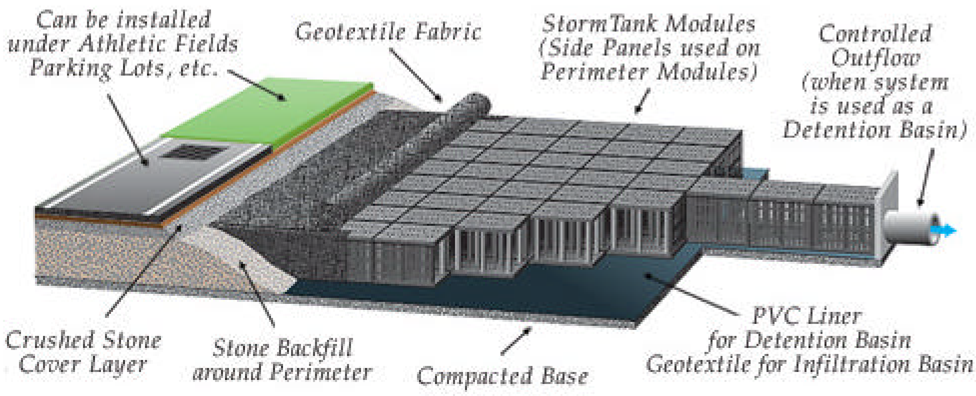


Figure 1

Permeable Interlocking Concrete Pavement

To answer the growing needs of the emerging permeable pavement market, manufacturers have brought forth products that can be separated in two major categories:

- ?? interlocking units that let the water seep through **pervious** material filling the joints and openings
- ?? **porous** material that lets the water seep through itself

Permeable interlocking concrete pavements, PICP, consist of separate paver units, laid down on a surface in a particular pattern, separated by narrow joints and shaped holes, both filled with pervious aggregates. Porous material, whether it is asphalt or concrete, presents a sponge-like matrix. Water flows through the PICP's aggregate-filled joints, or directly through the porous material.

While both have their merits, interlocking units are often preferred for their:

- ?? better aesthetics (wide range of shapes, colors, textures)
- ?? ease of replacement, rehabilitation
- ?? ease of maintenance

Holes and cavity are rampant all over the face of porous concrete or asphalt, strongly limiting the textures that can be applied to the visible surface. However, PICP unit pavers can be textured the same way regular pavers are, giving the pavement any look the designer desires.

Also, when the pavement undergoes damage, PICP is easier to repair as the separate units can easily be lifted off and replaced. Meanwhile, asphalt and poured concrete, require that the pavement be sawed and that excavators be used to lift the material. Not to worry, the pavers are vandalism proof as special clamps are required to remove the pavers from the pavement.

Finally, porous concrete's matrix like structure makes it difficult to vacuum sediments clogged inside the pores. The maintenance of PICP consists simply of vacuuming the superficial layer of aggregates and replenishing the joints. The vacuumed aggregates can then be cleaned and reused; some vacuum equipment can be controlled to remove sediment particles while minimizing removal of the aggregate.

Design

A proper permeable pavement will be designed according to regional factors and environment. While general guidelines are provided, a local engineer should always confirm the design to suit the client's needs.

Based on site specific geological surveys, local hydrological collected data and predictions, as well as the owner's design purposes, the engineer will prepare and approve plans that are best suited for the particular project. Figure 3 presents the general variables that must be accounted for through the design of the permeable interlocking concrete pavement system.

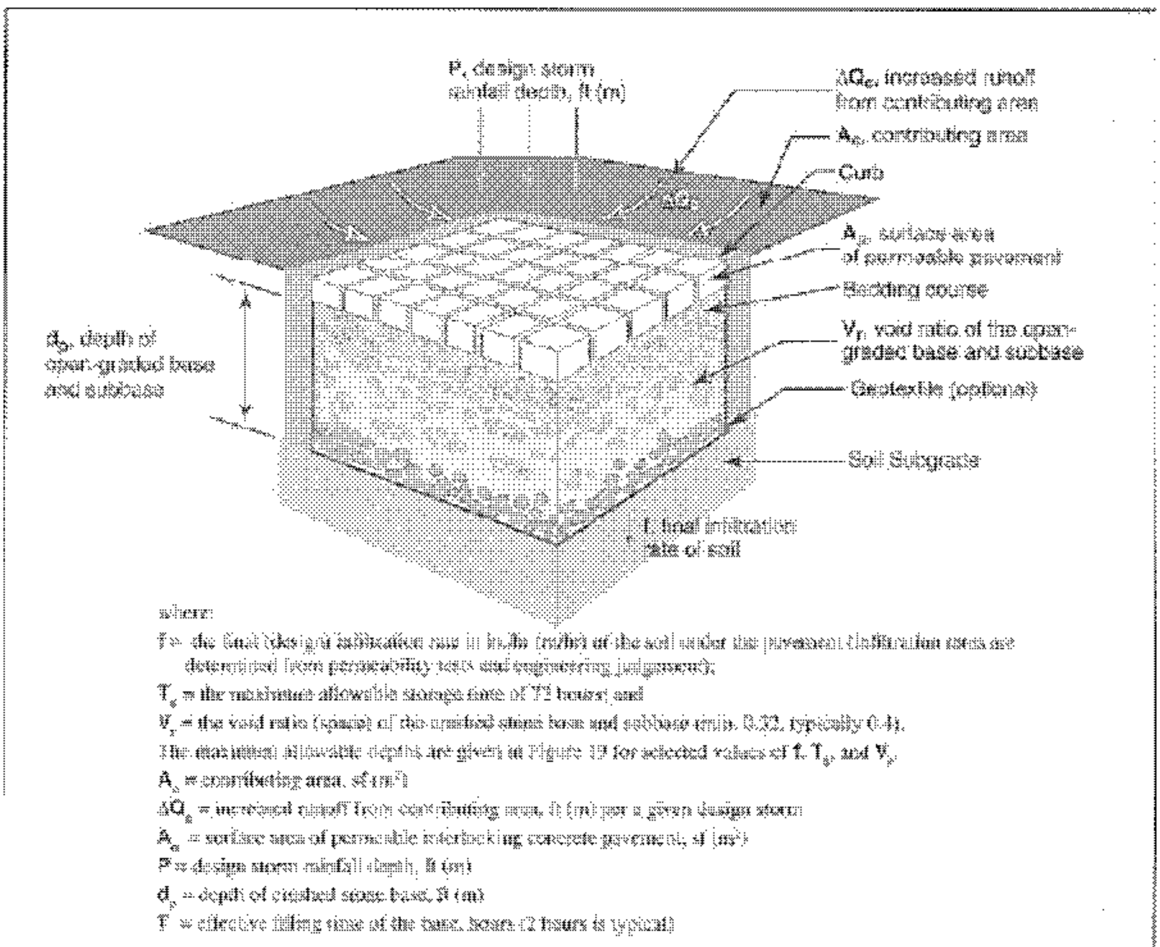


Figure 3 Figure is property of ICPI. May be used with permission only.

Sustainable urban development requires that the infrastructure be designed for a longer life-cycle. The life expectancy of a PICP system depends on the proper maintenance of the pavement. As time goes by, sediments from all sources will deposit over the draining aggregates, clogging the pores and reducing the system's efficiency. To preserve the optimal drainage qualities of the pavement, the owner should implement a maintenance program, vacuuming debris once or twice a year.

Studies performed by the Interlocking Concrete Pavement Institute have shown that a non-maintained system's permeability could decrease by 90% of its original design value (figure 4). While continued maintenance of the system would prevent such dramatic reduction in the infiltration rate, the designing engineer should prepare for the worst case scenario. To avoid system failure, it is recommended that the engineer design the pavement to still function after an 80 to 90% decrease in permeability.

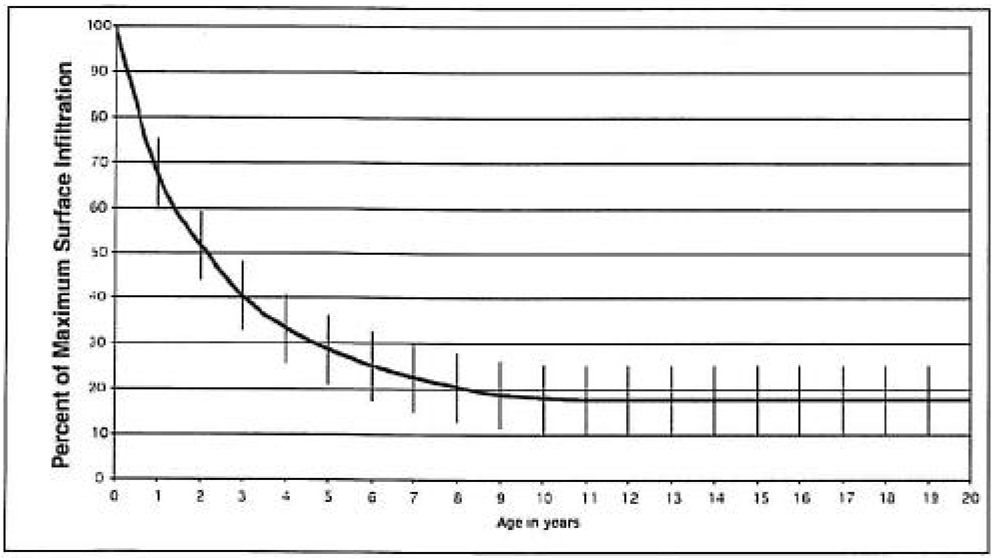


Figure 4 Overall trend of infiltration performance (Borgwardt, 2006) To be used with permission only.

Installation

The most common cause of failure in permeable pavements is faulty installation. It is crucial for the best functioning of the pavement that care be taken during installation to avoid fine particle contamination of the open-graded aggregate base. To maximize system efficiency and customer satisfaction, the Interlocking Concrete Pavement Institute offers PICP training as part of its Level II Paver Contractor Certification. It is recommended that clients seek out accredited professionals. Pavement installation guidelines are attached in Annex 1.

Subterra Permeable Pavement

Definition

The Subterra is the industry's best looking permeable paver, combining Oldcastle's renowned textures and colors with all the technical characteristics necessary to ensure an efficient environmentally-friendly pervious surface. Subterra was created to answer the sustainable development needs of eco-aware residential owners/promoters and municipalities eager to bestow a premier look to their pedestrian and low-traffic areas.

Shape

Subterra® consists of twelve (12) different stones. While each stone has a constant rectangular shape, easing installation, false joints run along the stone's surface, giving it a unique randomly set, modular look of natural cobble stone, which is easily enhanced through three possible laying patterns.

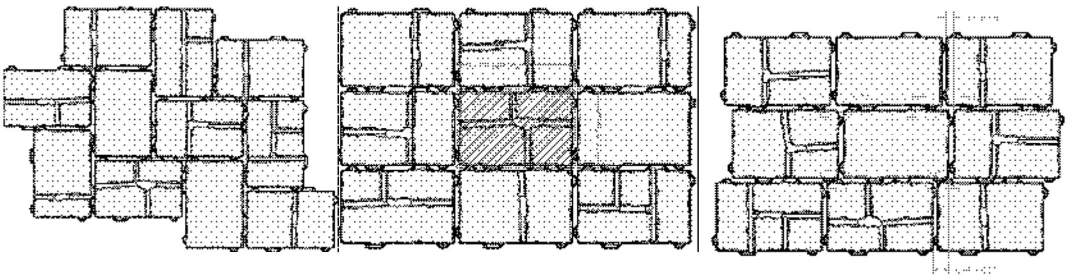


Figure 5 Herringbone, stacked and offset laying patterns

Subterra's patented hole at the cross-section of the false joints in the middle of the paver also increases the open-ratio without comprising the aesthetics of the landscaped area.

Texture

Beyond shape, Subterra also seduces homeowners with its bush-hammered texture, bringing Subterra a full generation ahead of the other permeable pavers on the market. Up to six different natural looking face textures are available.

Technical data

Permeability

Like most natural processes the environmental efficiency of a PICP system marvels by its simplicity. The permeability is determined by the amount of water that infiltrates through the surface in a given period of time, also referred to as the flow rate. Mathematically, it is the speed at which water travels through the pervious media, multiplied by the area of the surface, which is filled by the aggregates.

The speed at which water travels through the aggregate is a characteristic property of the aggregate itself. The more pores between the aggregates, the faster the water travels. The quality of the aggregate is therefore determined, in part, by the gradation of the sieved material, which must contain the least proportion of fines as possible (see installation guideline).

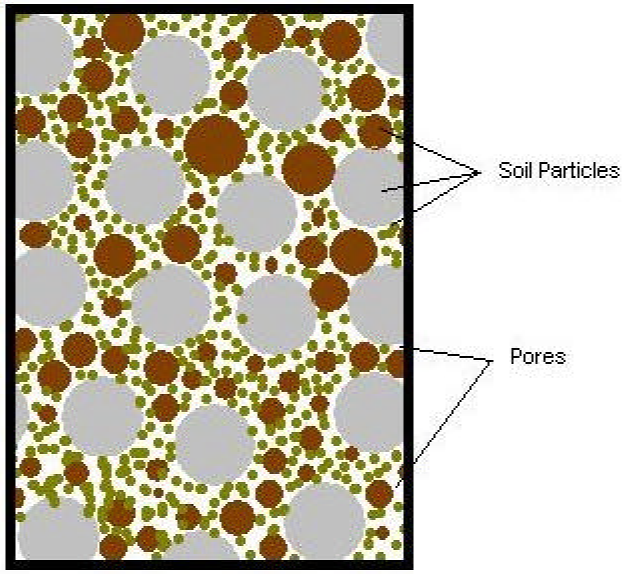


Figure 6

Of course, any paver can be installed with wide joints. Combining elegance with functionality, Subterra as been designed so as to optimize the joint widths without sacrificing the hardscaped architecture. The combination of joint and hole open-space on a Subterra pavement averages a 6.8% opening ratio.

To determine the amount of water percolating through the surface, the hydraulic conductivity is thus, multiplied by the area of the opening.

A recurrent error in the design of permeable pavements is the use of a brand new system's infiltration rate as a basis for design. American and German experience recommend that a conservative design rate of 10% of the initial rate be used to take into account clogging over a 20 year period (Interpave, www.paving.org.uk). To help engineers plan storm water structures, an independent firm has tested a brand new Subterra stone's infiltration, which has then been reduced for a conservative estimate of 90% clogging.

Freeze and Thaw

In colder climates, pavements are often in poor condition as the expanded ice melts and surfaces crumble. Fortunately, the pores between the open-graded aggregates are enough as to allow the typical 10% expansion of frozen water, thus safeguarding the permeable pavement from the heaving motion. The reduction in potholes provides more secure surfaces for the public and cheaper maintenance for the owner.

Dimensions

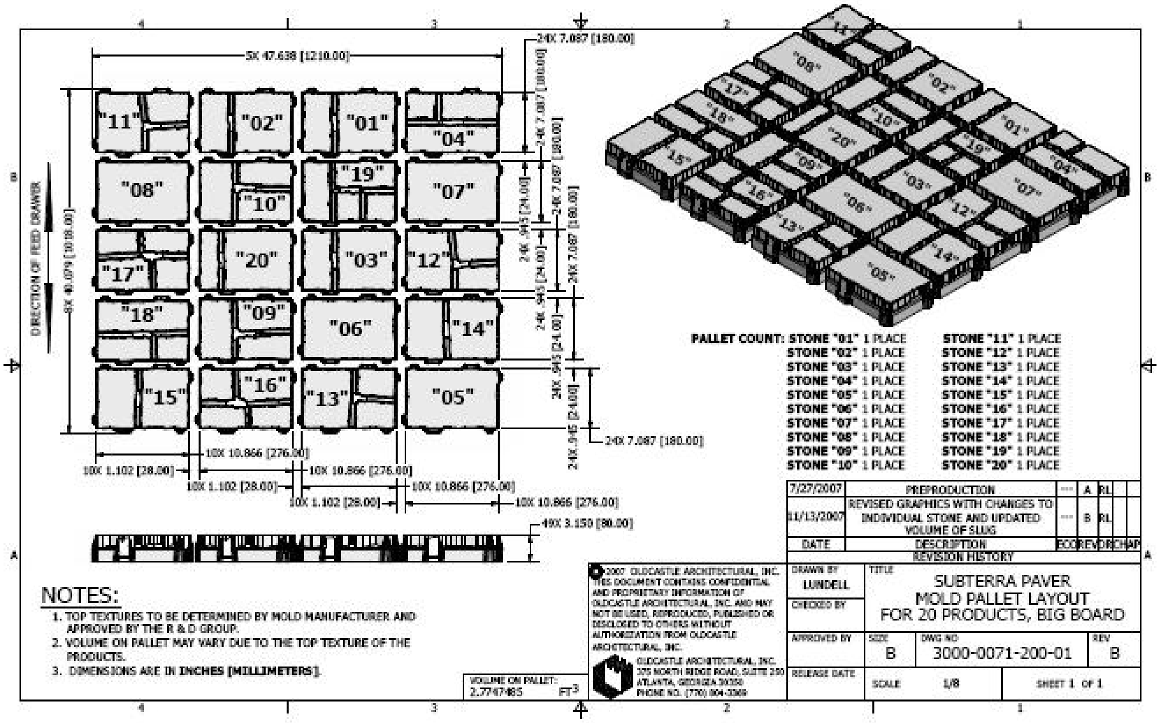


Figure 7 **Subterra Board Layout**

A board layout of Subterra stone comes with twenty stones, each unique in its combination of textures and false joints, guaranteeing a truly random cobble stone look. Though the finished appearance seems to gather pieces of different size, every stone is actually rectangular in shape (80 mm high X 276 mm long X 180 mm wide), thus easing installation.

ADA Compliancy

The American Disabilities Act requires that safe and easy to travel paths be available to guarantee access for people with reduced mobility. It is required that a surface be stable, slip-free, and that difference in elevations and joint spacing do not surpass a quarter and half of an inch, respectively. Mindful of the safety and comfort of all users, Subterra stone textures and spacers (11 mm) have been designed to respect these criteria.

Case Study

Since its inception on the market, brand new Subterra stones have been highlighted throughout the country, notably on the HGTV specialty show, Inside Out. As seen on figure 2, the result is a classic look, sure to harmonize with most residential and neighborhood architectures.

Figure 8 **Subterra, installed on HGTV show Inside Out**

ANNEX 1
DETAILED PAVEMENT INSTALLATION GUIDELINES

SECTION 32 14 13.19
PERMEABLE INTERLOCKING CONCRETE PAVEMENT

Note: This guide specification for Canadian applications describes construction of permeable interlocking concrete pavers on a permeable, open-graded crushed stone bedding layer (typically No. 8 stone). This layer is placed over an open-graded base (typically No. 57 stone) and sub-base (typically No. 2 stone). The pavers and bedding layer are placed over an open-graded crushed stone base with exfiltration to the soil subgrade. In low infiltration soils or installations with impermeable liners, some or all drainage is directed to an outlet via perforated drain pipes in the subbase. While this guide specification does not cover excavation, liners and drain pipes, notes are provided on these aspects.

The text must be edited to suit specific project requirements. It should be reviewed by a qualified civil or geotechnical engineer, or landscape architect familiar with the site conditions. Edit this specification term as necessary to identify the design professional in the General Conditions of the Contract.

PART 1 GENERAL

1.01 SUMMARY
A. Section Includes

1. Permeable interlocking concrete pavers.
2. Crushed stone bedding material.
3. Open-graded subbase aggregate.
4. Open-graded base aggregate.
5. Bedding and joint/opening filler materials.
6. Edge restraints.
7. [Geotextiles].

B. Related Sections
1. Section [________]: Curbs.
2. Section [________]: [Stabilized] aggregate base.
3. Section [________]: [PVC] Drainage pipes
4. Section [________]: Impermeable liner.
5. Section [________]: Edge restraints.
6. Section [________]: Drainage pipes and appurtenances.
7. Section [________]: Earthworks/excavation/soil compaction.

1.02 REFERENCES

A. American Society for Testing and Materials (ASTM)
1. C 67, Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units.
2. C 131, Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.
3. C 136, Method for Sieve Analysis for Fine and Coarse Aggregate.
4. C 140, Test Methods for Sampling and Testing Brick and Structural Clay Tile, Section 8 – Freezing and Thawing.
5. D 448, Standard Classification for Sizes of Aggregate for Road and Bridge Construction.
6. C 979, Specification for Pigments for Integrally Colored Concrete.
7. D 698, Test Methods for Moisture Density Relations of Soil and Soil Aggregate Mixtures Using a 5.5-lb (2.49 kg) Rammer and 12 in. (305 mm) drop.
8. D 1557, Test Methods for Moisture Density Relations of Soil and Soil Aggregate Mixtures Using a 10-lb (4.54 kg) Rammer and 18 in. (457 mm) drop.
9. D 1883, Test Method for California Bearing Ratio of Laboratory-Compacted Soils.
10. D 4254, Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density.

B. Canadian Standards Association (CSA)
1. A231.2 Precast Concrete Pavers

C. Interlocking Concrete Pavement Institute (ICPI)
1. Permeable Interlocking Concrete Pavement manual.

1.03 SUBMITTALS

A. In accordance with Conditions of the Contract and Division 1 Submittal Procedures Section.
B. Manufacturer’s drawing and details: Indicate perimeter conditions, junction with other materials, expansion and control joints, paver [layout,] [patterns,] [color arrangement,] installation [and setting] details. Indicate layout, pattern, and relationship of paving joints to fixtures and project formed details.
C. Minimum 2 kg samples of subbase, base and bedding aggregate materials.
D. Sieve analysis of aggregates for subbase, base and bedding materials per ASTM C 136.
E. Soils report indicating density test reports, classification, and infiltration rate measured on-site under compacted conditions, and suitability for the intended project.
F. Erosion and sediment control plan.
G. [Stormwater management (quality and quantity) calculations.]
H. Permeable concrete pavers:

1. Manufacturer’s product catalog sheets with specifications.
2. [Four] representative full-size samples of each paver type, thickness, color, and finish. Submit samples indicating the range of color expected in the finished installation.
3. Accepted samples become the standard of acceptance for the work of this Section.
4. Laboratory test reports certifying compliance of the concrete pavers with ASTM C 936.
5. Manufacturer’s material safety data sheets for the safe handling of the specified materials and products.
6. Manufacturer’s written quality control procedures including representative samples of production record keeping that ensure conformance of paving products to the project specifications.

H. Paver Installation Subcontractor:
1. A copy of Subcontractor’s current certificate from the Interlocking Concrete Pavement Institute Concrete Paver Installer Certification program.
2. Job references from projects of a similar size and complexity. Provide Owner/Client/General Contractor names, postal address, phone, fax, and email address.
3. Written Method Statement and Quality Control Plan that describes material staging and flow, paving direction and installation procedures, including representative reporting forms that ensure conformance to the project specifications.

1.04 QUALITY ASSURANCE

A. Paver Installation Subcontractor Qualifications:
1. Utilize an installer having successfully completed concrete paver installation similar in design, material and extent indicated on this project.
2. Utilize an installer holding a current certificate from the Interlocking Concrete Pavement Institute Concrete Paver Installer Certification program.

B. Regulatory Requirements and Approvals: [Specify applicable licensing, bonding or other requirements of regulatory agencies.].

C. Review the manufacturers’ quality control plan, paver installation subcontractor’s Method Statement and Quality Control Plan with pre-construction meeting of representatives from the manufacturer, paver installation subcontractor, general contractor, engineer and/or owner’s representative.

C. Mock-Ups:
1. Install a 3 x 3 m paver area.
2. Use this area to determine surcharge of the bedding layer, joint sizes, lines, laying pattern(s), color(s) and texture of the job.
3. This area will be used as the standard by which the work will be judged.
4. Subject to acceptance by owner, mock-up may be retained as part of finished work.
5. If mock-up is not retained, remove and properly dispose of mock-up.

1.05 DELIVERY, STORAGE, AND HANDLING

A. General: Comply with Division 1 Product Requirement Section.

B. Comply with manufacturer’s ordering instructions and lead-time requirements to avoid construction delays.

C. Delivery: Deliver materials in manufacturer’s original, unopened, undamaged container packaging with identification tags intact on each paver bundle.
1. Coordinate delivery and paving schedule to minimize interference with normal use of buildings adjacent to paving.
2. Deliver concrete pavers to the site in steel banded, plastic banded, or plastic wrapped cubes capable of transfer by forklift or clamp lift.
3. Unload pavers at job site in such a manner that no damage occurs to the

product or existing construction

D Storage and Protection: Store materials in protected area such that they are kept free from mud, dirt, and other foreign materials.

1.06 ENVIRONMENTAL REQUIREMENTS

A. Do not install in rain or snow.
B. Do not install frozen bedding materials.

1.07 MAINTENANCE

A. Extra materials: Provide [Specify area] [Specify percentage] additional material for use by owner for maintenance and repair.
B. Pavers shall be from the same production run as installed materials.

PART 2 PRODUCTS

Note: Some projects may include permeable and solid interlocking concrete pavements. Specify each product as required.

A. Manufacturer: Permacon
   1. Contact: [Specify ICPI member manufacturer contact information.].
B. Permeable Interlocking Concrete Paver Units:
   1. Paver Type: [Specify name of product group, family, series, etc.].
      a. Material Standard: Comply with CSA A231,2.
      b. Color [and finish]: [Specify color.] [Specify finish].
      c. Color Pigment Material Standard: Comply with ASTM C 979.

Note: Concrete pavers may have spacer bars on each unit. Spacer bars are recommended for mechanically installed pavers. Manually installed pavers may be installed with or without spacer bars. Verify with manufacturers that overall dimensions do not include spacer bars.

      d. Size: [Specify] mm x [Specify] mm x [Specify] mm thick.

2.02 PRODUCT SUBSTITUTIONS

A. Substitutions: No substitutions permitted.

2.03 CRUSHED STONE FILLER, BEDDING, BASE AND SUBBASE

A. Crushed stone with 90% fractured faces, LA Abrasion < 40 per ASTM C 131, minimum CBR of 80% per ASTM D 1883.
B. Do not use rounded river gravel.
C. All stone materials shall be washed with less than 1% passing the 0.080 mm sieve.
D. Joint/opening filler, bedding, base and subbase: conforming to ASTM D 448 gradation as shown in Tables 1, 2 and 3 below:

Note: No. 89 or finer gradation may be used to fill permeable pavers with narrow joints.

Table 1
ASTM No. 8 Grading Requirements
Bedding and Joint/Opening Filler

Sieve Size	Percent Passing
12.5 mm	100
9.5 mm	85 to 100
4.75 mm	10 to 30
2.36 mm	0 to 10
1.16 mm	0 to 5

Table 2

ASTM No. 57 Base Grading Requirements	
Sieve Size	Percent Passing
37.5 mm	100
25 mm	95 to 100
12.5 mm	25 to 60
4.75 mm	0 to 10
2.36 mm	0 to 5

Table 3
Grading Requirement for ASTM No. 2 Subbase

Sieve Size	Percent Passing
75 mm	100
63 mm	90 to 100
50 mm	35 to 70
37.5 mm	0 to 15
19 mm	0 to 5

E. Gradation criteria for the bedding and base:

Note: D_x is the particle size at which x percent of the particles are finer. For example, D15 is the particle size of the aggregate for which 15% of the particles are smaller and 85% are larger.

1. D_{15} base stone /D_{50} bedding stone < 5.
2. D_{50} base stone/D_{50} bedding stone > 2.

2.04 ACCESSORIES

A. Provide accessory materials as follows:

Note: Curbs will typically be cast-in-place concrete or precast set in concrete haunches. Concrete curbs may be specified in another Section. Do not use plastic edging with steel spikes to restrain the paving units.

1. Edge Restraints
   a. Manufacturer: [Specify manufacturer.].
   b. Material: [Pre-cast concrete] [Cut stone] [Concrete].
   b. Material Standard: [Specify material standard.].

Note: See ICPI publication, Permeable Interlocking Concrete Pavements *for guidance on geotextile selection. Geotextile use is optional.*

2. Geotextile Fabric:
   a. Material Type and Description: [Specify material type and description.].
   b. Material Standard: [Specify material standard.].
   c. Manufacturer: [Acceptable to interlocking concrete paver manufacturer]]

PART 3 EXECUTION

3.01 ACCEPTABLE INSTALLERS

A. [Specify acceptable paver installation subcontractors.].

3.02 EXAMINATION

Note: The elevations and surface tolerance of the soil subgrade determine the final surface elevations of concrete pavers. The paver installation contractor cannot correct deficiencies *excavation and grading of the soil subgrade with additional bedding materials. Therefore, the surface elevations of the soil subgrade should be checked and accepted by the General Contractor or designated party, with written certification presented to the paver installation subcontractor prior to starting work.*

A. Acceptance of Site Verification of Conditions:
   1. General Contractor shall inspect, accept and certify in writing to the paver installation subcontractor that site conditions meet specifications for the following items prior to installation of interlocking concrete pavers.

Note: Compaction of the soil subgrade should be determined by the project engineer. If the soil subgrade requires compaction, compact to a minimum of 95% standard Proctor density per ASTM C 698. Compacted soil density and moisture should be checked in the field with a nuclear density gauge or other test methods for compliance to specifications. Stabilization of the soil and/or base material may be necessary with weak or continually saturated soils, or when subject to high wheel loads. Compaction will reduce the permeability of soils. If soil compaction is necessary, reduced infiltration may require drain pipes within the open-graded sub base to conform to local storm drainage requirements.

      a. Verify that subgrade preparation, compacted density and elevations conform to specified requirements.
      b. Provide written density test results for soil subgrade to the Owner, General Contractor and paver installation subcontractor.
      c. Verify location, type, and elevations of edge restraints, [concrete collars around] utility structures, and drainage pipes and inlets.
   2. Do not proceed with installation of bedding and interlocking concrete pavers until subgrade soil conditions are corrected by the General Contractor or designated subcontractor.

3.03 PREPARATION

A. Verify that the soil subgrade is free from standing water.
B. Stockpile joint/opening filler, base and subbase materials such that they are free from standing water, uniformly graded, free of any organic material or sediment, debris, and ready for placement.
C. Edge Restraint Preparation:
   1. Install edge restraints per the drawings [at the indicated elevations].

3.04 INSTALLATION

Note: The minimum slope of the soil subgrade should be 0.5%. Actual slope of soil subgrade will depend on the drainage design and exfiltration type. All drainpipes, observation wells, overflow pipes, geotextile (if applicable) and impermeable liner (if applicable) should be in place per the drawings prior to or during placement of the subbase and base, depending on their location. Care must be taken not to damage drainpipes during compaction and paving. No mud or sediment can be left on the base or bedding aggregates. If they are contaminated, they must be removed and replaced with clean materials.

A. General
   1. Any excess thickness of soil applied over the excavated soil subgrade to trap sediment from adjacent construction activities shall be removed before application of the [geotextile] and subbase materials.
   2. Keep area where pavement is to be constructed free from sediment during entire job. [Geotextiles] Base and bedding materials contaminated with sediment shall be removed and replaced with clean materials.
   3. Do not damage drainpipes, overflow pipes, observation wells, or any inlets and other drainage appurtenances during installation. Report any damage

immediately to the project engineer.

B. Geotextiles
    1. Place on [bottom and] sides of soil subgrade. Secure in place to prevent wrinkling from vehicle tires and tracks.
    2. Overlap a minimum of 0.6 m in the direction of drainage.

C. Open-graded subbase and base
    1. Moisten, spread and compact the No. 2 subbase in 100 to 150 mm lifts [without wrinkling or folding the geotextile. Place subbase to protect geotextile from wrinkling under equipment tires and tracks.]
    2. For each lift, make at least two passes in the vibratory mode then at least two in the static mode with a minimum 10 T vibratory roller until there is no visible movement of the No. 2 stone. Do not crush aggregate with the roller.
    3. The surface tolerance of the compacted No. 2 subbase shall be ±65mm over a 3 mm straightedge.
    4. Moisten, spread and compact No. 57 base in 100 mm lift over the compacted No. 2 subbase with a minimum 10 T vibratory roller until there is no visible movement of the No. 57 stone. Do not crush aggregate with the roller.
    5. The surface tolerance the compacted No. 57 base should not deviate more than ±25 mm over a 3 m straightedge.
    Note: In-place density of the base and subbase may be checked per ASTM D 4254. Compacted density should be 95% of the laboratory index density established for the subbase and base stone.

D. Bedding layer
    1. Moisten, spread and screed the No. 8 stone bedding material.
    2. Fill voids left by removed screed rails with No. 8 stone.
    3. The surface tolerance of the screeded No. 8 bedding layer shall be ±10 mm over a 3 m straightedge.
    4. Do not subject screeded bedding material to any pedestrian or vehicular traffic before paving unit installation begins.

E. Permeable interlocking concrete pavers and joint/opening fill material
    1. Lay the pavers [paving slabs] in the pattern(s) and joint widths shown on the drawings. Maintain straight pattern lines.
    2. Fill gaps at the edges of the paved area with cut units. Cut pavers subject to tire traffic shall be no smaller than 1/3 of a whole unit.
    3. Cut pavers and place along the edges with a [double-bladed splitter or] masonry saw.
    4. Fill the openings and joints with [No. 8] stone.

    Note: Some paver joint widths may be narrow and not accept most of the No. 8 stone. Use joint material that will fill joints such as washed ASTM No. 9 or No. 10 stone. These smaller stone sizes are recommended for filling joints in pedestrian applications that use 60 mm thick pavers.
    5. Remove excess aggregate on the surface by sweeping pavers clean.
    6 Compact and seat the pavers into the bedding material using a low-amplitude, 75-90 Hz plate compactor capable of at least 18 kN centrifugal compaction force. This will require at least two passes with the plate compactor.
    7. Do not compact within 2 m of the unrestrained edges of the paving units.
    8. Apply additional aggregate to the openings and joints, filling them completely. Remove excess aggregate by sweeping then compact the pavers. This will require at least two passes with the plate compactor.
    9. All pavers within 2 m of the laying face must be left fully compacted at the completion of each day.
    10. The final surface tolerance of compacted pavers shall not deviate more than ±10 mm under a 3 m long straightedge.
    11. The surface elevation of pavers shall be 3 to 6 mm above adjacent

drainage inlets, concrete collars or channels.

3.05 FIELD QUALITY CONTROL

A. After sweeping the surface clean, check final elevations for conformance to the drawings.
B. Lippage: No greater than 3 mm difference in height between adjacent pavers.

Note: The minimum slope of the finished pavement surface should be 1%. The surface of the pavers may be 3 to 6 mm above the final elevations after compaction. This helps compensate for possible minor settling normal to pavements.

C. The surface elevation of pavers shall be 3 to 6 mm above adjacent drainage inlets, concrete collars or channels.

3.06 PROTECTION

A. After work in this section is complete, the General Contractor shall be responsible for protecting work from sediment deposition and damage due to subsequent construction activity on the site.

END OF SECTION

ANNEX 2
LEED AND BELGARD SUBTERRA STONE

LEED and Belgard Permeable Paving Stone Systems

The Leadership in Energy and Environmental Design (LEED) was originally developed for the U. S. Department of Energy. LEED utilizes a point rating system to recognize sustainable site and building design. Many organizations were involved in developing the rating system and certification program. The LEED program is administered by the U. S. Green Building Council www.usgbc.org . Currently, many municipal projects that are city owned or city funded are mandating LEED point objectives, while private sector projects are pursuing LEED credits points on a voluntary basis.

Belgard permeable concrete paving stone systems can earn credit points in the LEED rating system. The following listed LEED credit *summaries* represent possible point contributions. Please refer to the ICPI (Interlocking Concrete Pavement Institute) www.icpi.org Tech Spec Number 16 for a complete description and detailed explanation of the below listed LEED Credit references. LEED Credits for new projects and major renovations earn points from six broad rating categories and of these six, the two primary categories that pertain to permeable concrete paving stones are ***Sustainable Sites (SS)*** and ***Materials and Resources (MR)***.

LEED credit *summaries*

MR Credit 4.1: 1 point for Recycled Content 10% (post-consumer & ½ pre-consumer)

MR Credit 4.2: 1 point (in addition to Credit 4.1) for Recycled Content 20% (post-consumer & ½ pre-consumer)

Use materials with recycled content such that the sum of post-consumer recycled content plus one-half of the pre-consumer content constitutes at least 10% (based on cost) **Credit 4.1** of the total value of the materials in the project and 20% (based on cost) **Credit 4.2** of the total value of the materials in the product.

MR Credit 5.1: 1 point for Regional Materials (10% Extracted, Processed & Manufactured Regionally)

MR Credit 5.2: 1 point (in addition to Credit 5.1) for Regional Materials (20% Extracted, Processed & Manufactured Regionally)

Use building materials or products that have bee extracted, harvested or recovered, as well as manufactured within 500 miles or the project site for a minimum of 10% (based on cost) **Credit 5.1** of the total materials value and 20% (based on cost) **Credit 5.2** of the total materials value.

SS Credit 6.1: 1 point for Storm Water Design: Quantity Control

Storm water management of a building site where the existing impervious area is greater than 50% and the runoff rate and quantity is reduced by at least 25%. Belgard permeable concrete paving stone systems can reduce runoff to zero for the most frequent storms.

SS Credit 6.2: 1 point for Storm Water Design: Quality Control

A treatment system designed to remove 80% of the average annual post development total suspended solids (TSS), and 40% of the average annual post development total phosphorus (TP).

SS Credit 7: 1 point for Heat Island Effect: Non-roof

Landscape and exterior designs that reduce heat island effect would entail the use of light colored / high albedo materials with a reflectance of at least 0.3 for 30% of the sites non-roof impervious surfaces, i.e., pavements. Manufacturing permeable concrete paving stones in light or natural colors that can register an albedo of at least 0.3 will meet this requirement.

Belgard

Permeable Concrete Paving Stone Systems