AQUAPave®

Permeable On-Site Stormwater Source Control System


AQUAPave®
A Paving System We
Can All Live With

The Problem

Increasing urbanization generates excess stormwater runoff from impervious surfaces. What were once farmers' fields or native forests are now subdivisions, shopping malls and roadways. This strains stormwater drainage systems, overloading them during periods of heavy rain. As a result, downstream areas are encountering more frequent and intense flooding. In addition, groundwater elevations are dropping and streams are experiencing increased bank erosion and sedimentation.

With respect to water quality, heavy metals, hydrocarbons, nutrients, rubber, dust and sediment collect on impervious surfaces during dry weather. These accumulations are flushed away during the next rainstorm and enter downstream watercourses. The "first flush" is the initial period of a rainstorm where pollutant concentrations are highest. These pollutants enter streams, lakes, and bays affecting the quality of receiving waters for drinking, recreation, and fishing. Treasured fish species such as salmon, and other eco-systems are negatively impacted by these events.

The Solution - AquaPave® Permeable On-Site Stormwater Source Control System

Regulatory agencies have responded to the problem by requiring developers to utilize Best Management Practices (BMPs) to deal with stormwater on-site; in short, no impacts are to be imposed on downstream receptors. The U.S. Environmental Protection Agency has recognized permeable pavements as a BMP suitable for improving stormwater management.

The **AquaPave®** Permeable On-Site Stormwater Source Control System is an important first effort to reduce excess stormwater runoff quantities and improve water quality. The **AquaPave®** system allows commonly recurring rainstorms to infiltrate through a permeable concrete pavingstone surface into a clear crushed open-graded aggregate base before being released into storm sewers or watercourses. Known as permeable interlocking concrete pavement, the system acts as an infiltration facility for the storage, treatment, and improvement of released water.

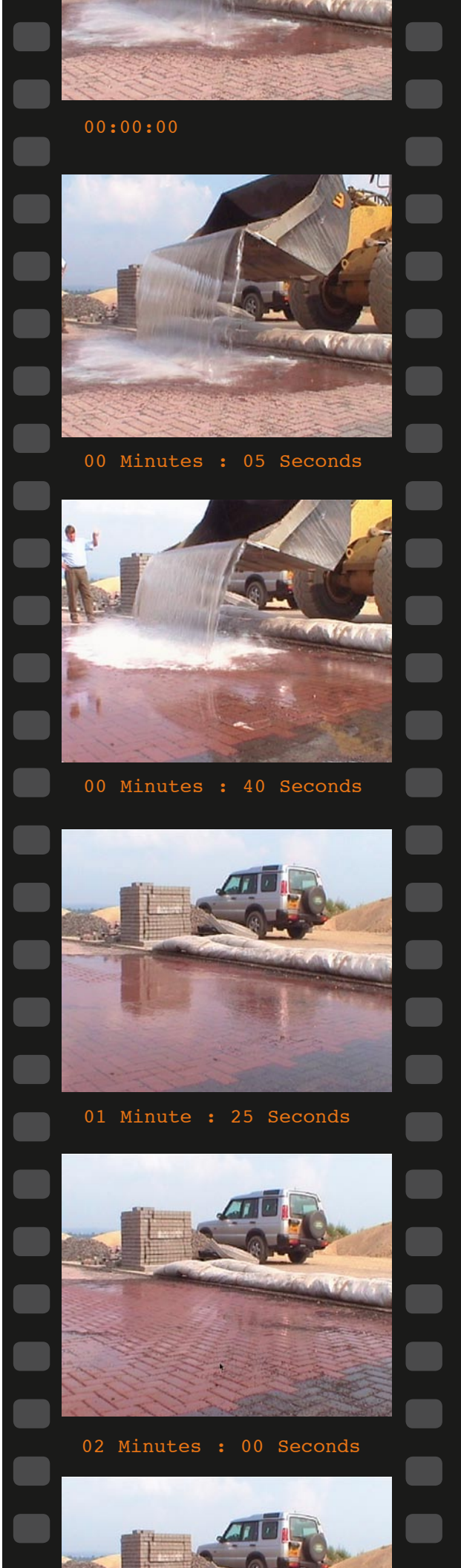
All **AquaPave®** pavers and slabs provide drainage through vertical channels and allow water through the surface at a rate of approximately 2.5 litres/sec/m^2. This is reduced to 1.25 litres/sec/m^2 due to the effects of the geotextile. If the soil subgrade and underlying geology are suitable, some or all of the water can infiltrate directly into the subgrade, thereby substantially reducing outflow rates. Alternately, the surface water can be temporarily stored in the sub-base before being slowly released into the receiving water system. The **AquaPave®** system helps to clean and improve the quality of runoff water by filtration through the base and microbial action. In many instances, the outflow can be re-used for irrigation of domestic and commercial landscapes.

Applications

Consisting of permeable interlocking concrete pavers and a clear crushed open-graded aggregate base, the **AquaPave®** Permeable On-Site Stormwater Source Control System is suitable for parking lots, residential driveways, commercial entrances, overflow parking areas, boat ramps, sidewalks, plazas, and low-speed residential roads.

Most municipalities strive to manage runoff from a range of storms with the intent of reducing runoff volumes and peak flows to those from pre-development conditions. In addition, many U.S. cities must obtain permits from the National Pollutant Discharge Elimination System (NPDES) administered by state and federal agencies. The applications for permits must include post-construction BMPs for the reduction of runoff and pollutants. As an effective BMP, the **AquaPave®** Permeable On-Site Stormwater Source Control System can be part of a municipality's stormwater management plan and help achieve compliance with the NPDES regulations.

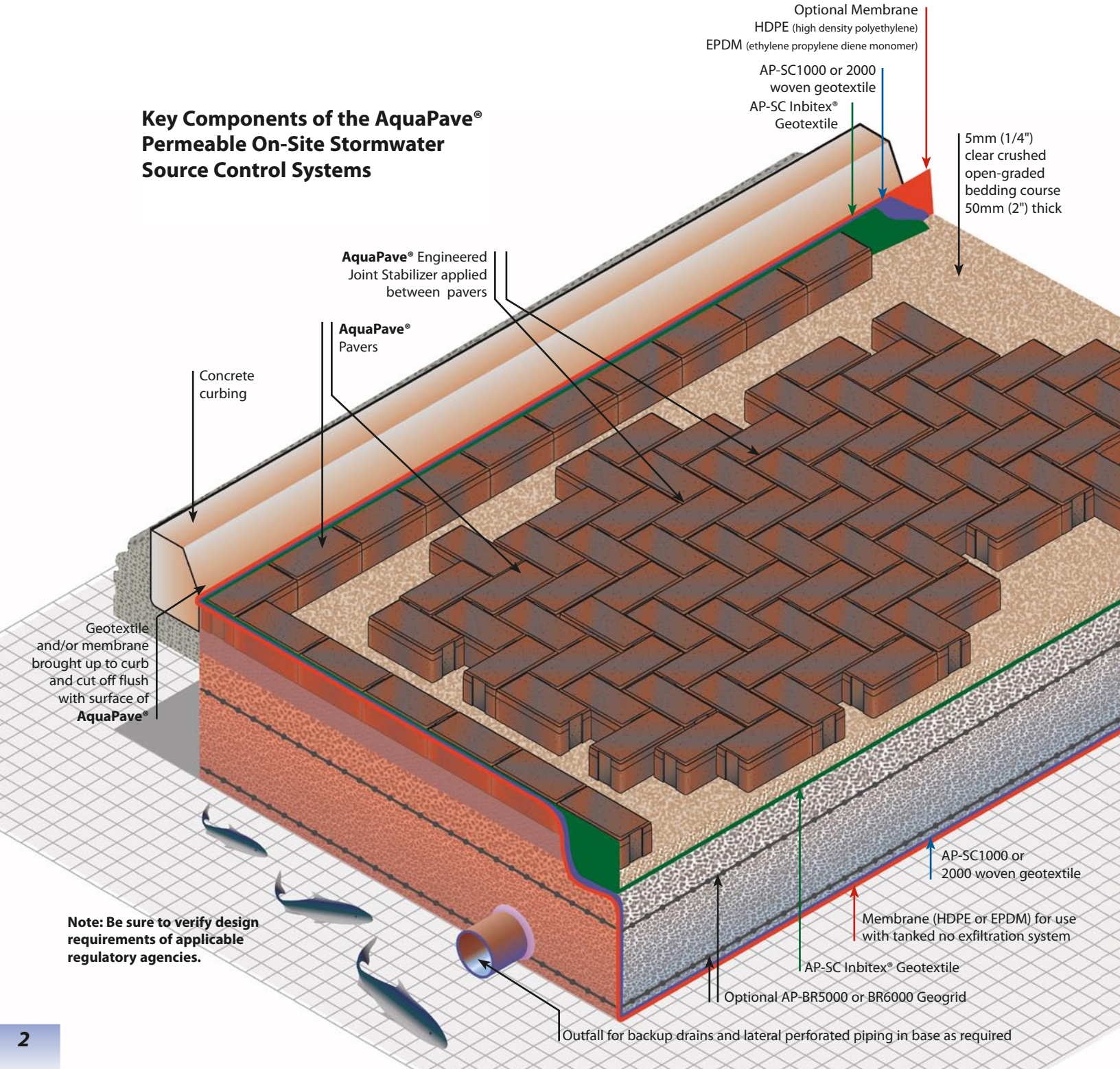
Photos at right demonstrate the drainage capability of a typical AquaPave® installation over a two minute period.



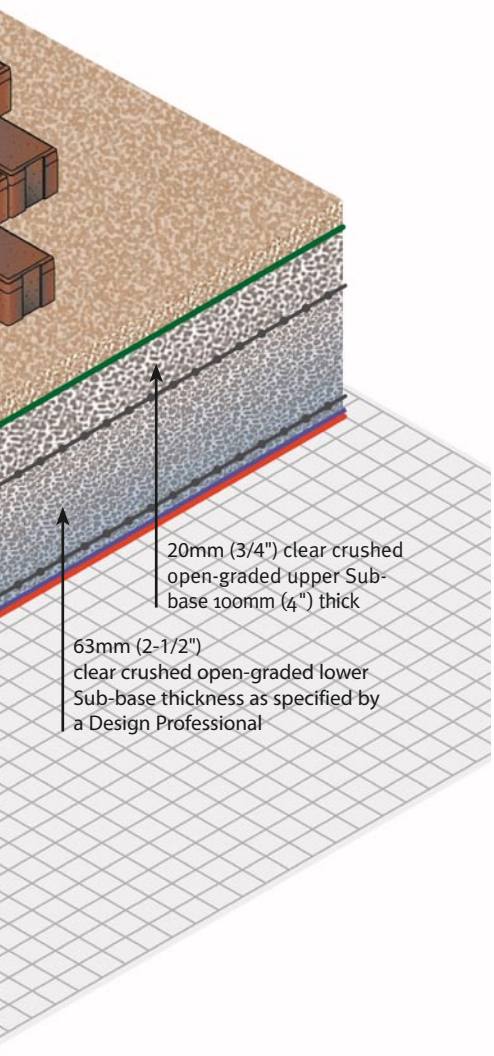
When designing an AquaPave® system, the following conditions need to be determined by a qualified design professional:

1. The range of design storms and antecedent moisture conditions that will be managed by the system. These are commonly recurring rain storms.
2. The total area contributing to the **AquaPave®** system. Typically this is no greater than a 2:1 ratio based on the standard design as shown below.
3. The amount of water that will enter the system and be stored in the base, treated, filtrated, and/or released over a specific time, typically between 24 and 72 hours.
4. The long-term infiltration capacity of the soil subgrade.
5. Exfiltration options for the base is guided by the determinations in 1 through 4.
   Exfiltration options (shown in detail on page 4) include:
   Full Exfiltration into the soil subgrade with no underlying drain pipes.
   Partial Exfiltration, i.e., some infiltration into the soil subgrade and some detention with drainage through underlying pipes.
   No Exfiltration where an impermeable liner captures the stored runoff and prevents its infiltration to the soil. This is a detention facility with drainage through underlying pipes.
6. Means to handle rainstorms that exceed the storage capacity of the base.
7. If a vehicular application, the base thickness required to support the anticipated traffic loads.

Key Components of the AquaPave® Permeable On-Site Stormwater Source Control Systems



Note: Be sure to verify design requirements of applicable regulatory agencies.



AquaPave® Interlocking Concrete Paver
The unique design of the patented AquaPave® interlocking concrete pavers are the vertical slots and other design characteristics that allow surface water to infiltrate through to the sub-base. These unique characteristics can be applied to any paver shape, providing an unlimited number of possibilities. The in-stock paver sizes, thicknesses and colors are shown on page 5 – for specialty colors, shapes or sizes, call Brown's Concrete at 1-800-461-4888.

AquaPave® Engineered Joint Stabilizer
AquaPave® Engineered Joint Stabilizer is placed in the spaces (joints) between the pavers to help enhance the interlock, therein creating a more stable and secure surface.

Since gradation, texture and durability are critical to the long-term performance of the Engineered Joint Stabilizer and in turn the entire system, Brown's Concrete supplies prebagged AquaPave® Engineered Joint Stabilizer for your convenience. Contact Brown's for more information on available package sizing.

Bedding Course
The Bedding Course provides four main functions: it beds the pavers during installation; it helps initialize interlock among the pavers; it provides a structural component for the system; and, it facilitates drainage of water that infiltrates through the joints. To ensure proper performance, the bedding course material needs to be a 5mm (1/4") clear crushed open-graded aggregate. This aggregate must be manufactured to ensure proper performance; natural rounded material is not permitted. The source material must be of sufficient durability as to withstand the expected traffic loading.

AP-SC Inbitex® Geotextile
AP-SC Inbitex® is a thermally bonded non-woven geotextile that was specifically developed to work within the AquaPave® system to optimize the cleaning of water entering the sub-base. The various characteristics have been combined to create a unique geotextile that not only provides separation between the bedding course and sub-base, but also aids in the development of naturally occurring microbes. These microbes are vital to the bio-degradation of captured pollutants and overall cleansing of the water. The AP-SC Inbitex® also provides these microbes refuge during periods of drought.

For optimal performance, the AP-SC Inbitex® is to be laid out horizontally immediately below the bedding course. Along the perimeter, the geotextile is to be brought up vertically with the curb and cut off flush with the surface of the AquaPave® pavers. Contact Brown's Concrete for available roll sizes of AP-SC Inbitex®.

Sub-base and AP-BR5000/BR6000 Geogrid
The sub-base has two main functions: it provides the structural foundation upon which the pavers rest; and, it provides sub-base storage capacity. Specifications for the upper and lower sub-base materials are included on Page 16 – Tables 2 and 3 respectively. Where additional structural support is required, the Design Professional may select to augment the sub-base with one or more layers of AP-BR5000 or AP-BR6000 Geogrid.

AP-SC1000/SC2000 Woven Geotextile
The purpose of the woven geotextile is to prevent mixing of the imported sub-base material with the native subgrade material. To prevent native material from migrating into the sub-base from the sides of the system, the woven geotextile needs to be brought up the curb and cut off flush with the AquaPave® pavers.

Membrane
For "No Exfiltration Systems" (see page 4 for details), it may be necessary to install an HDPE (high density polyethylene) or EPDM (ethylene propylene diene monomer) membrane to prevent the migration of water into the existing sub-grade. As with the woven geotextile, the membrane must encapsulate the entire system.

Although the membrane is subject to selection by the Design Professional, the material must at a minimum be inert to biological degredation and resist naturally encountered chemicals, alkalis and acids.

Typical Systems and Exfiltration Options *(Modify to site conditions)*

The following is intended to serve as a reference guide only for designing an AquaPave® system, and is not intended to replace an actual site specific design as prepared by the Design Professional.

Step 1 – Evaluate Existing Conditions

1. Determine the hydraulic conductivity and structural strength of the subgrade soils. Reference ICPI Tech Spec 4 for assistance.

Step 2 – Conduct a Water Balance

1. Identify the total area contributing to the AquaPave® system, including the paved area and the surrounding run-on area. When using our standard design specifications, the run-on area should not be greater than the paved area.
2. Select the intensity and duration of the design storm to be used, and calculate the resulting antecedent moisture conditions (for each applicable soil type within the contributing area) that will be managed by the system.
3. Calculate the infiltration rate, and total amount, of water entering the system.
4. Compare the infiltration rate to the hydraulic conductivity of the soil sub-grade. Determine the resulting storage requirements of the sub-base (if any).

Step 3 – Sub-base Design

1. Calculate the structural design thickness of the sub-base subject to the subgrade strength, anticipated loading, and design life.
2. Compare the previous to the design thickness based on storage capacity of the base (approximately 30% of the base volume).
3. Select the greater of the two. In the case of the structural design being greater, consider re-evaluating design using geogrid.

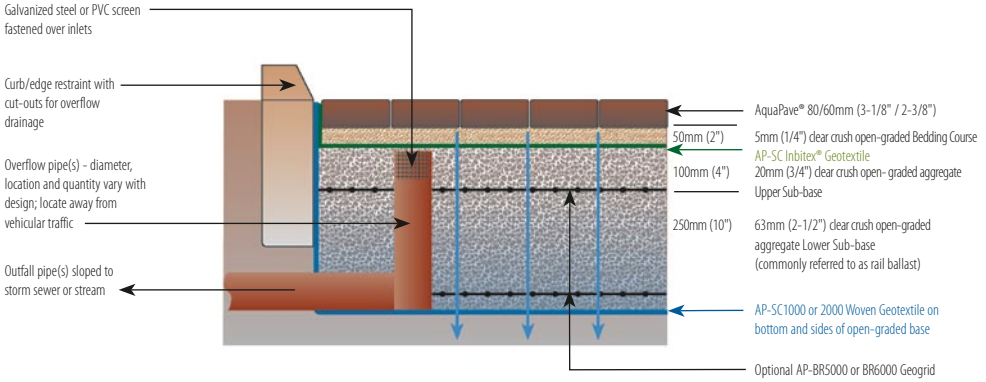
Step 4 – Verify Overflow Drainage

1. Verify the location and elevation of the available storm drain(s) or watercourse(s).
2. Compare these to the proposed elevation of the outfall pipe.

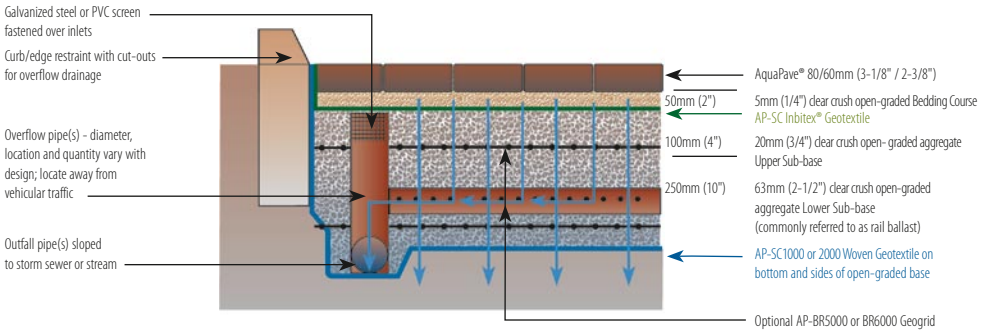
If the infiltration rate of the soil subgrade, with or without the allowable storage volume within the base material, exceeds the infiltration rate of the system, then a "Full Exfiltration System" can be used (Note: Full Exfiltration System refers to exfiltration from the system itself).

For permeable soils in which the infiltration rate of the soil subgrade is lower than the infiltration rate of the system, even after allowing for storage within the base material, a "Partial Exfiltration System" can be used. Where a tanked system is desired, a "No Exfiltration System" can be used.

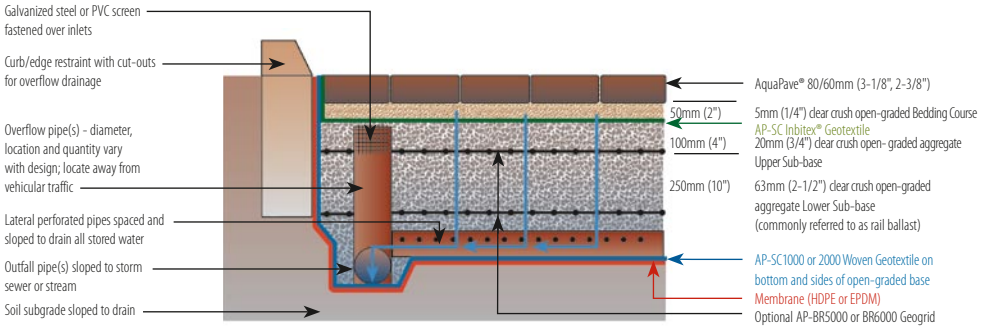
Full Exfiltration System



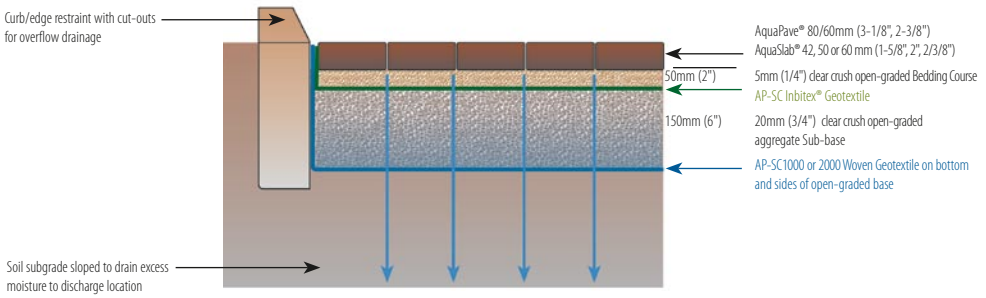
Partial Exfiltration System



No Exfiltration System



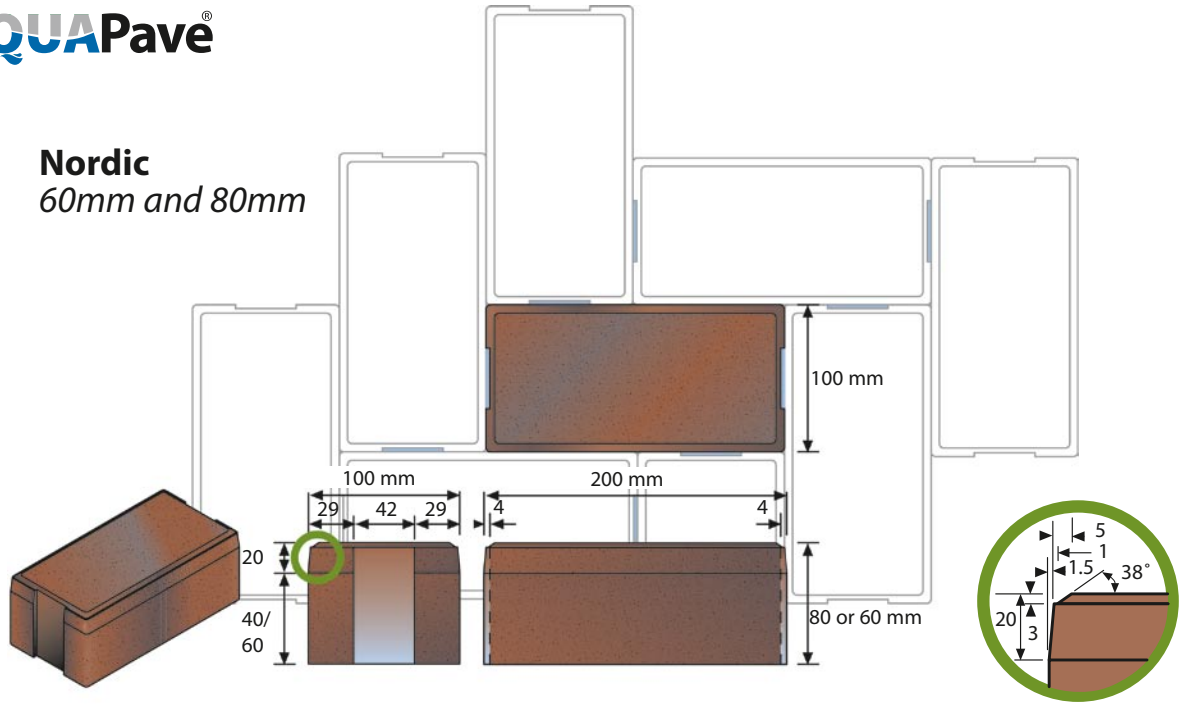
Typical Residential Driveway/Sidewalk Construction



On all designs:
- Open-graded base thickness varies depending on water management and/or structural requirements.
- For pedestrian sidewalks or residential driveway applications only the 20mm clear crushed open-graded aggregate, upper sub-base is required. This should be a minimum of 6".

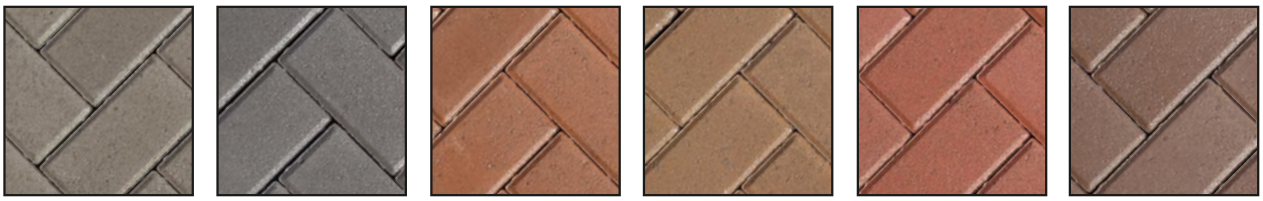
AQUAPave®

Nordic
60mm and 80mm



While the colours shown here are represented as accurately as possible, they should only be used as a guide.
Actual samples should be viewed before making a final colour selection.
Colour blends should be installed from 2 or 3 bundles for best results.

Nordic Colors



Granite | **Charcoal** | **Salmon** | **Tan** | **Red** | **Brown**

Blackwood Range
Granite/Charcoal

Robinson Range
Tan/Charcoal

Laurentian Range
Buff/Brown

Fairbanks Range
Salmon/Charcoal

Timmins Range
Salmon/Brown

Autumn Range
Red/Charcoal

Custom colours are available on special order. Please call Brown's Concrete at 1-800-461-4888 for details

Brown's Concrete Products Limited offers AquaPave® Nordic as its standard use shape. The AquaPave® Nordic 60mm is suitable for single family residential driveways and pedestrian areas. The AquaPave® Nordic 80mm is intended for areas subject to constant vehicle traffic such as parking lots and low speed roads. AquaPave® Nordic pavers need to be laid in a 90º or 45º herringbone pattern, to accommodate machine lay installations, the 80mm pavers are oriented in a 45 degree herringbone pattern on the pallets.

For projects in Canada, paving units will meet CSA A231.2-06, Precast Concrete Paving. For projects in the United States, paving units will meet ASTM C936, Standard Specifications for Solid Concrete Interlocking Paving Units.

Specialty Shapes

As mentioned previously, the unique design of the patented AquaPave® interlocking concrete pavers are the vertical slots and other design characteristics that allow surface water to infiltrate through to the sub-base. These unique characteristics can be applied to any paver shape, providing an unlimited number of possibilities.

For sufficiently large sized projects, it is possible to manufacture a specialty shape upon request. However, please note that at least 6 months notice would be required to allow for the mold to be ordered and obtained.

Benefits

Lower Construction Costs

In conventional drainage design, infiltration and detention facilities are separate from impervious parking lots and pedestrian areas. **AquaPave®** On-Site Stormwater Source Control System combines the parking, infiltration and detention facilities into one location, allowing more space on the site for income-generating buildings. With the water detention facilities located below ground, we eliminate public safety concerns associated with the accidental drownings of children. This also eliminates the breeding areas for insect born diseases such as West Nile Virus.

For some designs there will also be cost savings through the reduction or elimination of typical stormwater management infrastructure, including collection works, water retention ponds, treatment systems (e.g. oil/water separators), and associated appurtenances.

Considering the ever increasing cost of oil, **AquaPave®** is becoming comparable in unit price to other traditional paving systems. Couple this with the increased design life equivalent and you have a superior, more aesthetically pleasing surface at a lower cost. With its flat continuous surface, **AquaPave®** accepts pavement marking materials such as paint and thermal plastic tapes.

Reduction of Runoff

With an open surface area of about 2%, the openings can infiltrate as much as 354 in./hr (9000 mm/hr or 9000 litres/m²/hr). The infiltration rate of the clear crushed open-graded aggregate used for the bedding and base is similar. For design purposes, a conservative 90% reduction in efficiency is generally assumed for infiltration facility design, due to the build-up of sediment over years of service. When considering a 90% reduction of initial infiltration as a typical design assumption, the **AquaPave®** On-Site Stormwater Source Control System will still capture, treat, infiltrate, and filter rainstorms over 35.4 in./hr (900 mm/hr or 900 litres/m²/hr). This includes the commonly recurring storms, which generate the most pollution.

Recharging the Groundwater Table

With "Full Exfiltration" and "Partial Exfiltration" systems, some if not all of the rain water that falls on the paved area is allowed to infiltrate into the ground and recharge the local groundwater table. Groundwater is not only a primary source of drinking water, but it also maintains the base flow characteristics of our watercourses between precipitation events.

Roof Water Management

Roof water can be discharged into the sub-base. With gravity fed drainage it is recommended that the water is introduced into the sub-base by means of a sump with a manhole cover adjacent to the paved area. Any debris can be easily caught and cleared. The water is then dispersed within the system via a permavoid distribution tank or perforated outlet pipe. With siphonic drainage, a special chamber is used to disperse the water within the sub-base.

Pollutant Category Source	Solids	Nutrients	Bacteria	Dissolved oxygen demands	Metals	Oils (PAHs)* SOCs*
Soil erosion	•	•		•	•	
Cleared vegetation	•	•		•		
Fertilizers		•				
Human waste	•	•	•	•		
Animal waste	•	•	•	•		
Vehicle fuels & fluids	•			•	•	•
Fuel combustion		•			•	
Vehicle wear	•			•	•	
Industrial/household chemicals	•	•	•	•	•	•
Industrial processes	•	•	•	•	•	•
Paints & preservatives				•	•	•
Pesticides				•	•	

Common sources of pollution in urban stormwater runoff

PAHs = polynuclear aromatic hydrocarbons

SOCs = synthetic organic compounds

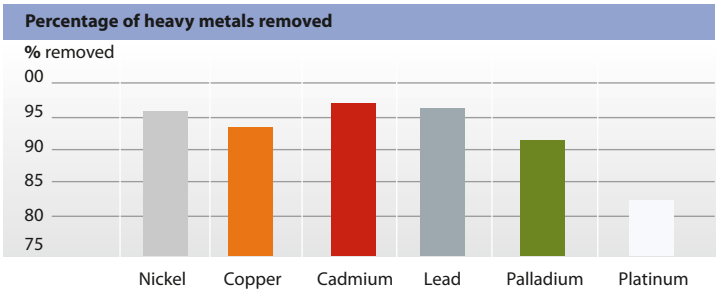
ref. 1

Pollutant	0.5 in. (13mm) of Runoff per Impervious Acre	1.0 in. (25mm) of Runoff per Impervious Acre	2-year Design Storm Treatment
Total suspended solids	60-80	80-100	80-100
Total phosphorous	40-60	40-60	60-80
Total nitrogen	40-60	40-60	60-80
Biological oxygen demand	60-80	60-80	80-100
Bacteria	60-80	60-80	80-100
Metals	60-80	60-80	80-100

Projected average annual pollutant removal capability of infiltration areas in percent

Note: These rates are not based on actual data since monitoring what enters and leaves any infiltration facility is difficult to measure. This data is based on land application of pollutants and their treatment through soils.

ref. 2



Data provided by the kind permission of Dr. Chris Jefferies and Fiona Napier. Urban Water Technology Centre, University of Albertay, Dundee.

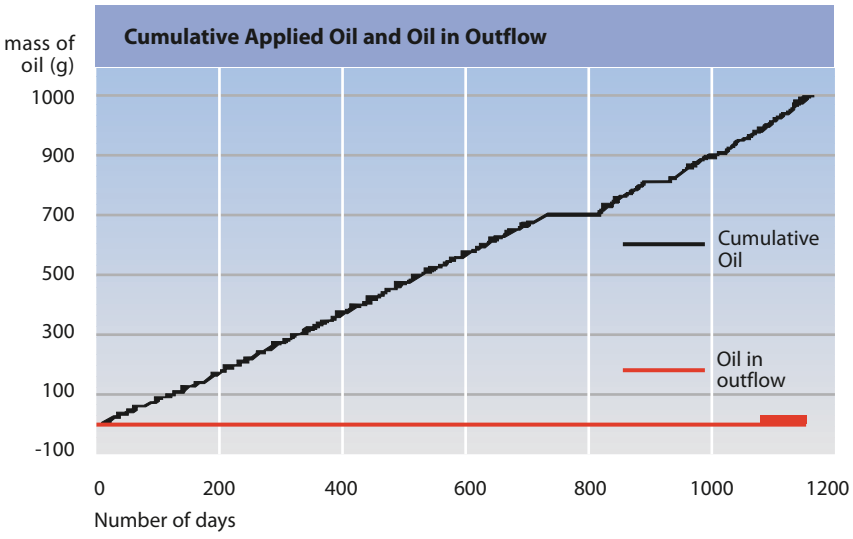
ref. 3

Management of Oil Contaminates

"The runoff from parking lots represents the biggest single source of tonnages of oil going into the ocean" – *Brian Giroux, Port Hardy Forum on the Development of Off-shore Oil Exploration & Drilling.*

Oil drippings and related hydrocarbons are typically digested within the base through filtering and microbial action. Research by Coventry University, England on microbial action has shown that the **AquaPave®** system is capable of bioremediation at the rate of 70 grams (0.15 lbs.) of oil per square metre (approx. 11ft^2) per year. Severe hydrocarbon contamination can be dealt with by feeding the affected areas with slow release fertilizer.

In addition, the pH of water exiting the system can be raised slightly which assists in buffering lower pH acid rain.



Courtesy of Stephen Coup, Coventry University *ref. 4*

Filtering and Treatment of Pollutants

Studies of permeable interlocking concrete pavement have shown substantial reduction of non-point source pollutants in runoff. The clear crushed open-graded aggregate base has a storage volume of at least 30%. This storage capacity enables a decrease in peak flows and treatment of pollutants, especially nutrients and total suspended solids prior to drainage of the water from the base through drain pipes. Substantial reductions of metals can occur in full or partial base exfiltration designs where the water enters silt and clay soils.

Pedestrian Friendly

The **AquaPave®** patented design was created to accommodate all types of pedestrian traffic. Unlike other permeable pavements, the **AquaPave®** system does not incorporate loose aggregates on its surface, making it safer and more comfortable to walk on, even with high heels. The result is a flat smooth walking surface for customers and employees, completely free of water build up. **AquaPave®** is ideal for high foot traffic areas like building entrances, parking lots, inspection areas, and bike paths.

LEED® Green Building Rating System

The Leadership in Energy and Environmental Design (LEED®) rating system uses a point system to recognize environmentally conscious site and building designs. LEED® is a design guideline used by some agencies for certification. It is a voluntary, consensus-based rating system to encourage sustainable construction sites, and buildings. In the USA it is administered by the U.S. Green Building Council (www.usgbc.org) and in Canada by the Canadian Green Build Council (www.cagbc.org). More information can also be obtained in ICPI Tech Spec 16 (Achieving LEED® Credits with Segmental Concrete Pavement).

The **AquaPave®** Permeable On-site Stormwater Source Control System can be eligible for earning points under LEED®. For example, SS Credit 6.1 offers 1 point for stormwater management on building sites where the existing impervious surface is greater than 50%. The LEED® requirement is that runoff rate and quantity be reduced by at least 25%. The **AquaPave®** system can reduce runoff rates and quantities from common storms by as much as 100%.

Another opportunity is MR Credit 5.1 (1 to 2 points) that requires a minimum of 20% of building materials manufactured within a radius of 800 km (500 miles). MR Credit 5.2 earns an additional point if 50% of the regionally manufactured materials are extracted, harvested or recovered within this same radius. Most **AquaPave®** projects will be within this distance from the manufacturer's plant, earning these credits.

There is also SS Credit 6.2 (1 point), Stormwater Management Treatment. (Additional LEED® points are available, see page 13 under Water Harvesting.)

Access for People With Disabilities

AquaPave® paving units have gaps less than 13 mm wide, which meet the recommendations of the Americans with Disabilities Act Accessibility Guidelines *(ADAAG)*. Since **AquaPave®** does not need to be sloped to drain, access for the disabled can be made easier. **AquaPave®** provides a safe, smooth surface free of loose aggregates ensuring a reliable footing for the elderly or disabled using canes, crutches, walkers, or wheelchairs.

Slip and Skid Resistance

The ADAAG recommends that the slip resistance, expressed as a minimum coefficient of friction, be 0.6 for accessible routes and 0.8 for ramps. Testing conducted on behalf of the ICPI has verified that pavers, with the exception of pavers with polished surfaces, meet these guidlines. Vehicular skid resistance tests have demonstrated that stopping distances are shorter at speeds up to 40 MPH than either asphalt or typical concrete surfaces. Since the surface of the **AquaPave®** system consists of concrete pavers, the same resistance to skidding and shorter stopping distances can be expected. Couple this with the rapid infiltration of water, and the result is a reduction in accidents and increased safety.

Performance

Design Life

AquaPave® has a design life equivalent to that of conventional interlocking concrete pavers, typically 30 to 40 years. Should the pavers become damaged or cracked, they can be removed and replaced with new ones. The infiltration rate, storage capacity, and pollution reduction performance of the base depends on the amount of sediment that enters it. Therefore, control of sediment entering the system during and after construction is vital to continuing infiltration performance. When outside sources of sediment are kept from the pavement, a minimum of 20 to 25 year life can be expected. When the rate of outflow is significantly diminished, the **AquaPave®** pavers are removed, the clear crushed open-graded bedding and the Inbitex® geotextile are replaced, and the **AquaPave®** pavers reinstated.

Infiltration facilities and permeable interlocking concrete pavements such as **AquaPave®** are conservatively designed with the assumption of a 90% reduction in the infiltration rate. Using this as a worse case scenario, 10% of the initial infiltration rate of 354 inches (9000 mm) per hour would be 35.4 inches (900 mm) per hour. This infiltration rate would still be 18 times greater than 2 in. (50 mm) per hour system infiltration rate, typical to many designs.

Professor John Argue of the Urban Water Resources Centre at the University of South Australia in Adelaide has conducted extensive research on the siltation of the pavers and bedding layer. His research assumed rainfall of 22.8 inches (580 mm) per year with a loading of 200 parts per million of silts. This is a sediment loading similar to what would be found in an established urban catchment. His conclusion was that even after a thirty year life, the permeability of the surface was only reduced by 25%. *(For a copy of this research, please contact us)*

Design Considerations & Maintenance

All pavement systems require regular maintenance. With the **AquaPave®** system, sediment that collects in the surface openings should be removed by vacuuming a minimum of twice a year. It is recommended that this take place in the early spring and late fall during a dry period. In most cases this operation is already a part of a regular maintenance program. **AquaPave®** surfaces can be cleaned by pressure washing without risking damage to its components or dislodging and spreading loose aggregates like in other permeable paver systems. This makes it ideal for high foot traffic areas such as mall entrances and sidewalks.

Although there is a sizable factor of safety in terms of infiltration capabilities through the pavers, there is always the chance that sheeted ice or packed snow between plowing events could plug the system; should this occur, some surface water runoff would be expected. Every project should therefore have one or more separate spillways cut into the concrete curbs to allow for these conditions.

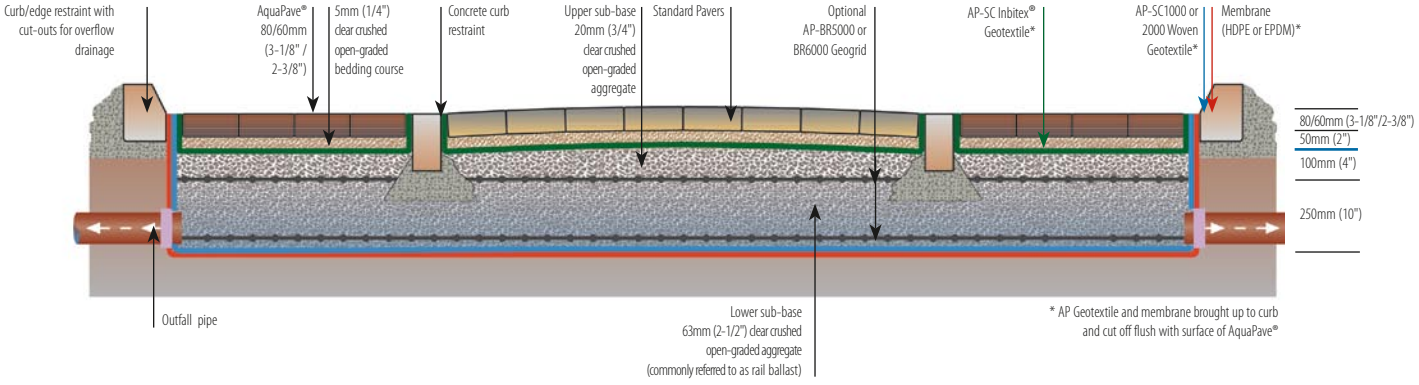
Design consideration should also be given to ensuring that soft landscaping is retained to prevent migration of softscape materials (e.g. topsoil) into the **AquaPave®** surface. Doing so will significantly help to maintain the integrity of the system.

AquaPave® doesn't incorporate loose aggregates or turf as an integral component of its system, therefore, mechanical snow removal methods are very effective on its flat continuous surface. Other types of permeable pavements may have to rely on chemical deicing due to their shaped top surface. This may be counter to the water handling portion of the installation.

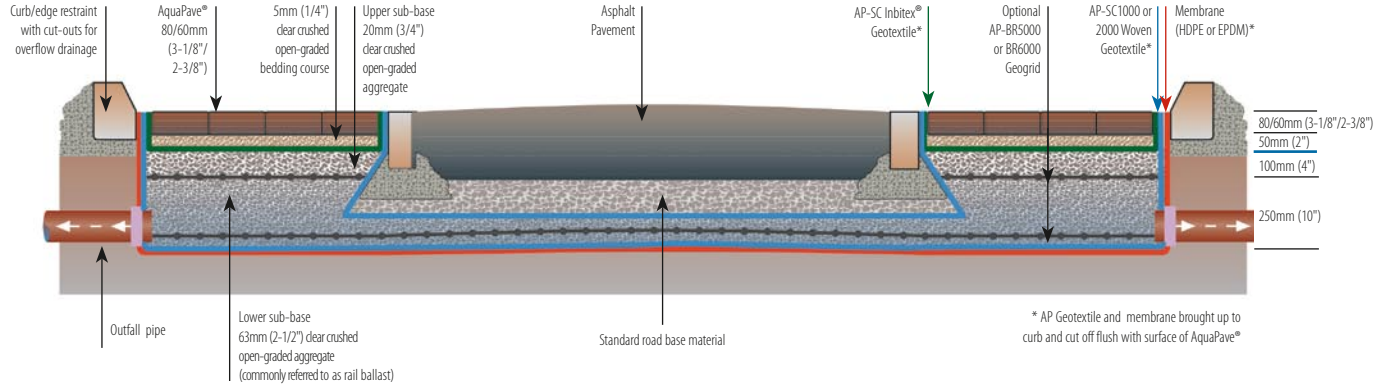
Settlement up to 25 mm (1 in.) in the surface, as in all segmental interlocking systems, can be easily corrected. First, remove the area of pavers affected, then fill and compact the clear crushed open-graded aggregate used under the paving units. **AquaPave®** can then be reinstated and compacted with a plate compactor. Likewise, broken pavers can simply be removed, replaced and compacted. Unlike other paving systems, **AquaPave®** can be immediately reopened for use.
Heaving from freezing water in the crushed stone base is generally not a concern. There is typically sufficient void space within the aggregate to accommodate the 10% expansion in the volume of water when it freezes.

An observation well is recommended in all installations of the **AquaPave®** Permeable On-Site Stormwater Source Control System. The well is typically a 150 mm (6 in.) diameter perforated pipe, placed near the lowest elevation of the pavement, out of the way of vehicular traffic. The top of the well can be under the pavers, hidden from view and covered with a secure lid. The well enables monitoring of outflow and sedimentation after storms, as well as an opportunity to sample and test water quality. Outflow should be monitored at least once a year after a large storm. Every project should have separate overflow drains or spillways to accommodate the saturation conditions that occur in high intensity and/or long duration rain storms.

AquaPave® In Conjunction With Conventional Interlocking Concrete Pavers



AquaPave® In Conjunction With Asphalt Pavement



All conversions from Metric to Imperial are approximate. Illustrations are not to scale.

Water Harvesting

Typically, filtered and treated water exiting the **AquaPave®** On-site Stormwater Source Control System can be re-used for non-potable uses such as domestic or commercial irrigation. In fact, some schools and youth hostels are currently using this non potable water for the flushing of lavatories. This conserves and economizes on water usage and charges in some localities.

These practises may also qualify for additional LEED® points under Water Efficiency:

- 1 point WE credit 1.1
- 1 point WE credit 1.2
- 1 point WE credit 2
- 1 point WE credit 3.1
- 1 point WE credit 3.2

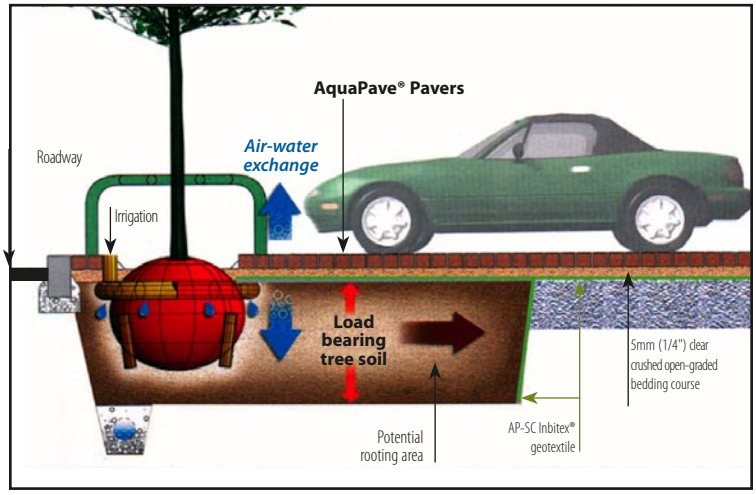
Sanders Garden World, an example of using reclaimed water from a tanked system to provide plant irrigation.

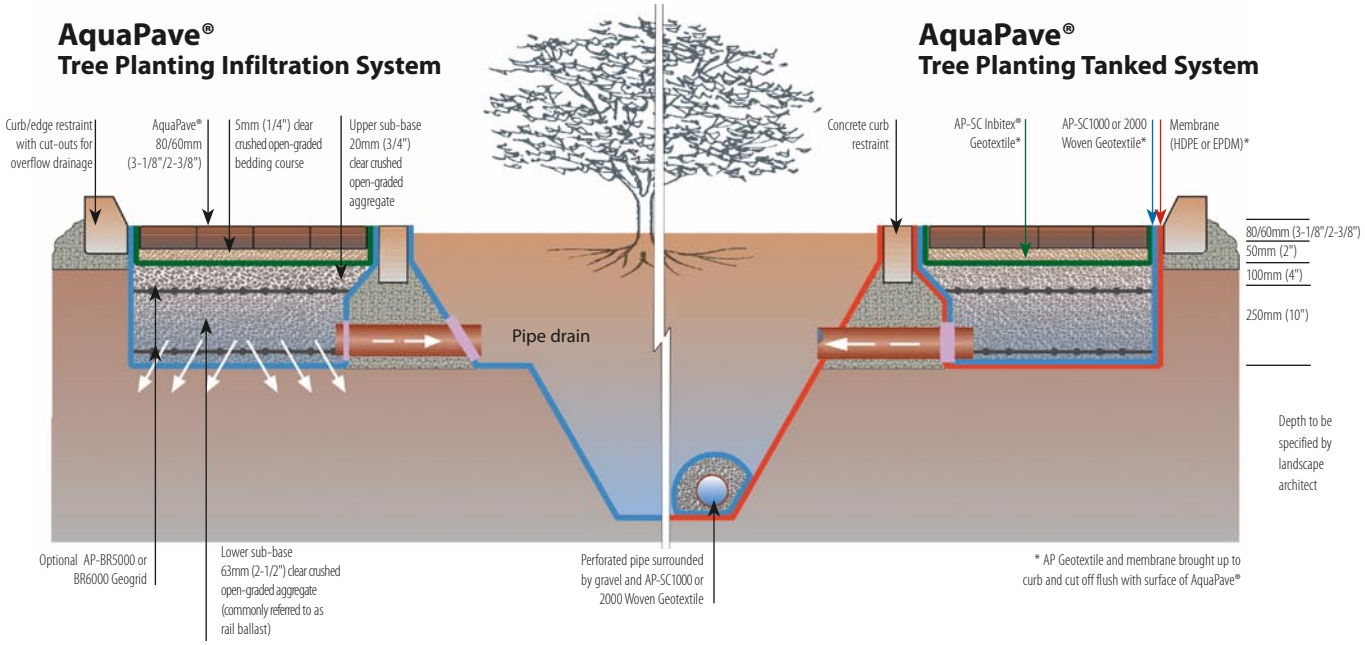
Root System Maintenance

Availability of air and water to the root systems of existing or newly planted vegetation, particularly trees, is key to their survival and growth. When building near trees, the previous BMPs were to install a grate around the perimeter of the tree to allow for direct infiltration, or to install a subgrade irrigation system.

It has been proven that the **AquaPave®** system can be used successfully with load bearing tree soils. This allows the pavers to be installed right up to the border of the tree pit, which increases the available parking area, while still allowing air and water to reach the root structure. This practise is not possible with conventional paving.

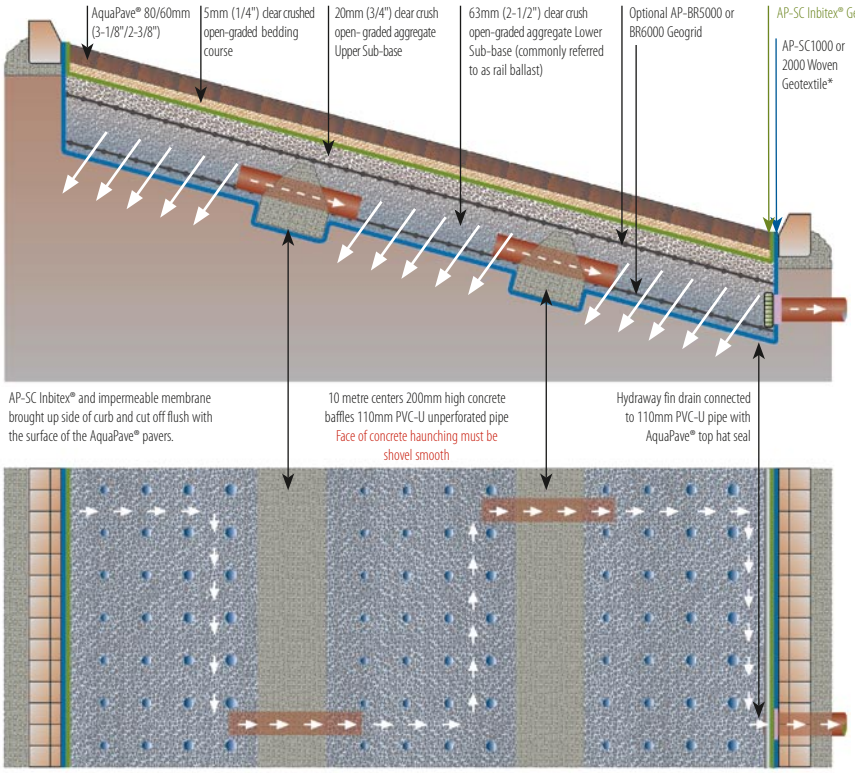
In applications where additional water is desired within the root system, it is possible to divert the overflow from a "Partial Exfiltration" or "No Exfiltration" system to the root zone (see below, left side), or even create an artificial tanked system (see below, right side).





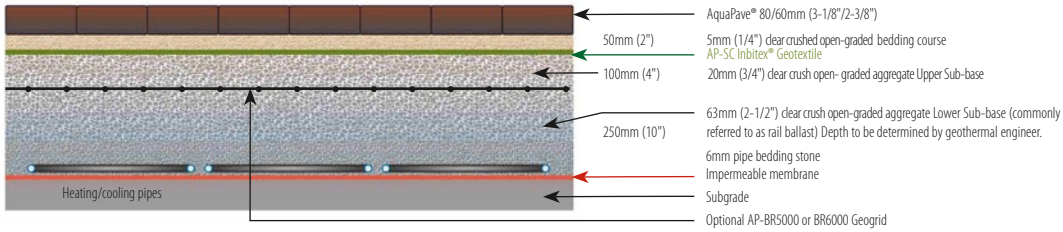
All conversions from Metric to Imperial are approximate. Illustrations are not to scale.

AquaPave® With Exfiltration System on a Slope



*Where a tanked system is desired, place an impermeable membrane (HDPE or EPDM) on the AP-SC1000 or 2000 Woven Geotextile**

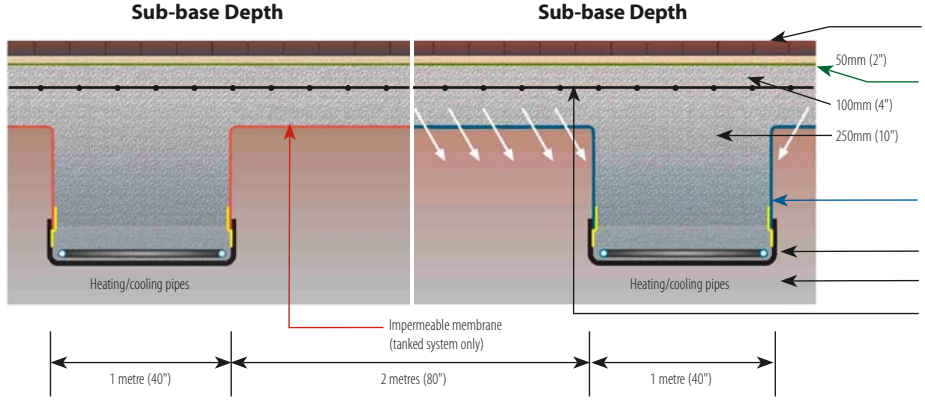
AquaPave® With A Standard Tank Stormwater Geothermal System

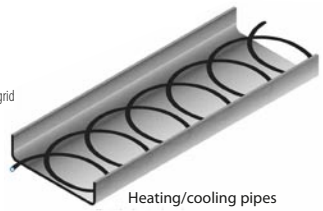


Heating/cooling pipes

AquaPave® With A Tank Stormwater Geothermal System With Added Sub-base Depth

AquaPave® With An Exfiltration Geothermal System With Added Sub-base Depth





Heating/cooling pipes

Note: When incorporating a geothermal system in conjunction with your AquaPave system, be sure to consult with your local geothermal engineer for site specific specifications in your region.

All conversions from Metric to Imperial are approximate. Illustrations are not to scale.

GUIDE SPECIFICATIONS FOR CONSTRUCTION OF AQUAPAVE® PERMEABLE STORMWATER MANAGEMENT SYSTEM

SECTION 32 14 13.19
AquaPave® Permeable Interlocking Concrete Pavement

Note: This guide specification is for the construction of an AquaPave® permeable interlocking concrete paver system which is designed to allow for the infiltration, detention and release of stormwater from a permeable, open-graded base. Components covered under this specification include AP-SC Woven Geotextile, permeable clear crushed open-graded sub-base, Inbitex® Geotextile, Bedding Layer, AquaPave® Pavers and Joint Stabilizer, which are generic to all AquaPave® Systems. Additional specifications are required where drain pipes, geogrid and/or an impermeable liner are used. The text below must be edited to suit specific project requirements. It will require review by a qualified civil or geotechnical engineer, or landscape architect familiar with the site conditions and local materials. Edit this specification as necessary to identify the design professional in the General Conditions of the Contract. This guide specification is intended for use in the U.S. or Canada and should be edited to fit terms and standards appropriate to each region.

PART 1 GENERAL
1.01 SUMMARY
A. Section Includes
1. AquaPave® Permeable concrete pavers.
2. AquaPave® Engineered Joint Stabilizer.
3. Clear crushed open-graded aggregate Bedding Course.
4. Inbitex® Geotextile.
5. Clear crushed open-graded sub-base materials.
6. AP-SC Woven Geotextiles.
7. [Impermeable liner].

Note: Curbs will typically be precast or cast-in-place concrete. Plastic edging with steel spikes can be used if the spikes are driven into substantial soils and are not driven into any of the open-graded drain rock or pierce any portion of the water containment system. Plastic edging should not be used where wheel loads are within 2.5 feet of the restrained edge. In areas of severe freeze-thaw cycles plastic edge restraints are not recommended.

1.02 RELATED SECTIONS

A. Section [-]: Curbs.
B. Section [-]: Stabilized aggregate base.
C. Section [-]: [PVC] Drainage pipes.
D. Section [-]: Impermeable liner.
E. Section [-]: Edge restraints.
F. Section [-]: Drainage pipes and appurtenances.
G. Section [-]: Earthworks/excavation/soil compaction.

1.03 REFERENCES
A. American Society of Testing Materials (ASTM)
1. C 33, Specification for Concrete Aggregates.
2. C 13, 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 936, Standard Specification for Solid Interlocking Concrete Pavers.
5. C 979, Specification for Pigments for Integrally Colored Concrete.
6. 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.
7. 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.
8. D 1883, Test Method for California Bearing Ratio of Laboratory-Compacted Soils.
9. D 2488, Description and Identification of Soils (Visual/Manual Procedure)
10. D 4873, Guide for Identification, Storage and Handling of Geotextiles
11. D 6928, Standard Test Method for Resistance of Course Handle and transport material to avoid segregation, contamination and degradation. Aggregates to Degradation by Abrasion in the Micro-Deval Apparatus

B. Canadian Standards Association (CSA)
1. A231.2-06, Precast Concrete Pavers.
2. A231.1-06, Precast Concrete Paving Slabs.
3. A23.2A, Sieve Analysis of Fine and Coarse Aggregates.

1.04 SUBMITTALS
A. In accordance with Conditions of the Contract and Submittal Procedures Section.
B. Site Plan - indicate the following: area of AquaPave® Paver installation; perimeter conditions; stormwater run-on area; and, layout, patterns and color arrangements.
C. Installation details – provide details for each of the following: junction with other materials; expansion and control joints; layout, pattern, and relationship of paving joints to fixtures; geotextile panel installation drawing; and, project formed details.
D. AquaPave® Engineered Joint Stabilizer, Bedding Course and Sub-base (upper and lower):
1. Sieve analysis of aggregates per [ASTM C 136] [CSA A23.2A].
2. Durability of aggregates using Micro-Deval Degradation per [ASTM D 6928] [CSA A23.2A].
3. Percentage of angular and sub-angular particles per [ASTM D 2488].
E. Site soils report including: in-situ density test reports; soil classification(s); infiltration rate(s) measured on-site under compacted conditions; and recommendations on suitability of native soils 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 extremes of color expected in the finished installation. Note that accepted samples become the standard of acceptance for the work of this Section.
3. Laboratory test reports certifying compliance of the concrete pavers [slabs] with [ASTM C 936] [CSA A231.1-06] [CSA A231.2-06].
4. Manufacturer's material safety data sheets for the safe handling of the specified materials and products.
I. Geotextiles:
1. Manufacturer's product catalog sheet with specifications.
2. One 0.5 x 0.5 m (18 x 18 in.) panel of each geotextile for inspection and testing. The sample panels shall be uniformly rolled and shall be wrapped in plastic to protect the material from moisture and damage during shipment. Samples shall be externally tagged for easy identification. External identification shall include: name of manufacturer;product type; product grade; lot number; and physical dimensions.
J. Paver Installation Subcontractor:
1. Statement of Installer Qualifications: Submit list of comparable projects completed by installer. Include list of completed projects with project names, addresses, names of Architect/Engineer and Owners with contact information, and dates of construction.
2. Copy of current 'ICPI Concrete Paver Installer Certification School' Certificate for the site supervision personnel.
3. A letter of assurance from the manufacturer stating that the site supervising personnel is an Approved AquaPave® Installer.

1.05 QUALITY ASSURANCE
A. Installer Qualifications: Engage an experienced installer who has successfully completed permeable pavement installations similar in design, material, and extent indicated for this project.
B. Field-constructed Mock-up:
1. Install 3 x 3 m (10 x 10 ft) area with Geotextiles, Sub-base, Bedding Course, AquaPave® Engineered Joint Stabilizer and Pavers.
2. Use area to determine surcharge of the bedding layer, joint sizes, lines, laying pattern(s), color(s), and texture of the job.
3. Use the area as the standard to judge the remaining work.
4. Subject to acceptance by the owner, mock-up may be retained as part of the finished work.
5. If mock-up is not retained, remove and dispose of mock-up.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Concrete Pavers:
   1. Coordinate delivery of paving stones to minimize interference with onsite works, and normal use of buildings, roads and structures adjacent to works.
   2. Deliver concrete pavers to the site palletized for transfer by forklift or clamp lift. Maintain manufacturer's original, unopened, undamaged packaging with identification labels intact.
   3. Unload pavers at job site in the location designated by the Installer Subcontractor and in such a manner that no damage occurs to the product or existing construction.

B. Imported Soils:
   1. Handle and transport material to avoid segregation, contamination and degradation.
   2. Keep different materials sufficiently separated as to prevent mixing. Do not dump or store one material on top of another unless it is part of the installation process.
   3. Cover material with waterproof covering if needed to prevent exposure to rainfall or removal by wind. Secure the covering in place.

C. Geotextiles:
   1. Geotextiles shall be delivered, stored and handled in accordance with [ASTM D-4873].
   2. Maintain manufacturer's original, unopened, undamaged packaging with identification labels intact.
   3. The geotextiles shall be kept dry and wrapped in waterproof wrapping such that it is protected from UV light and the elements during delivery and storage.

D. The Installer shall check all materials delivered to the site to ensure that the correct materials have been received and are in good condition prior to signing off on the manufacturer's packing slip.

1.07 ENVIRONMENTAL REQUIREMENTS

A. Do not install in heavy rain, or snow.
B. Do not install frozen Bedding Course, Joint Stabilizer or Sub-base materials.
C. Do not install on frozen soil subgrade.

1.08 MAINTENANCE

A. Extra materials: Provide [Specify area] [Specify percentage] additional material for use by owner for maintenance and repair.

PART 2 PRODUCTS

2.01 PAVING UNITS

A. Manufactured by Brown's Concrete Products
   Phone: 1-800-461-4888 Fax: 1- 705-522-2732
   AquaPave® Nordic: [Color]
   200 mm x 100 mm x 60 mm thick
   200 mm x 100 mm x 80 mm thick

Note: ASTM C 936 or CSA A231.2-06 applies to AquaPave® pavers. CSA A231.1-06 applies to AquaSlab® HydraPressed slabs.

B. Meet [ASTM C 936] [CSA A231.2-06] [CSA A231.1-06]. Freeze-thaw requirements may be waived in applications with no freeze-thaw conditions.
   1. When testing 3-1/8 in. (80 mm) thick units for conformance to [ASTM C 936], compressive strength tests shall be corrected by multiplying the results by 1.18.

C. Manufactured in a plant where paving products are certified by ICPI as having passed manufacturer designated [ASTM] [CSA] requirements.
D. Color(s): [Specify from selection in manufacturers' product literature].

2.02 CLEAR CRUSHED OPEN-GRADED BEDDING COURSE AND SUB-BASE MATERIALS

Note: The bedding and sub-base materials are an integral part of the AquaPave® system design. When designing an AquaPave® system, compliance with the following points must be strictly observed.

A. Aggregates to be clean, non-plastic, and free from deleterious or foreign matter.
B. Micro-Deval Degradation of less than 8%. Soft Aggregates such as Limestone cannot be used as they will lead to total system failure.
C. Percentage of angular and sub-angular particles greater than 90%. Do not use rounded river gravel. Sub-base and bedding materials must be clear crushed open-graded aggregates.
D. Gradation criteria

Note: Dx is the particle diameter 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. D15 upper and lower sub-base aggregate /D50 bedding aggregate < 5.
   2. D50 upper and lower sub-base aggregate /D50 bedding aggregate > 2.

E. LA Abrasion <40, minimum CBR of 80%.

Note: The following gradations in Tables 1, 2 and 3 can be used for the clear crushed open-graded bedding course and sub-bases. Check gradations against the above criteria.

Table 1
Grading Requirements for Clear Crushed Bedding Course (ASTM No. 8)

Sieve Size	Percent Passing
12.5 mm (1/2 in.)	100
9.5 mm (3/8 in.)	85 to 100
4.75 mm (No. 4)	10 to 30
2.36 mm (No. 8)	0 to 10
1.16 mm (No. 16)	0 to 5

Table 2
Grading Requirements for Clear Crushed Upper Sub-Base (ASTM No. 56)

Sieve Size	Percent Passing
37.5 mm (1-1/2 in.)	100
25 mm (1 in.)	90 to 100
19 mm (3/4)	40 to 85
12.5 mm (1/2 in.)	10 to 40
9.5mm (3/8 in.)	0 to 15
4.75mm (No. 4)	0 to 5

Table 3
Grading Requirements for Clear Crushed Lower Sub-Base (ASTM No. 2)

Sieve Size	Percent Passing
75 mm (3 in.)	100
63 mm (2-1/2 in.)	90 to 100
50 mm (2 in.)	35 to 70
37.5 mm (1-1/2 in)	0 to 15
19 mm (3/4 in.)	0 to 5

2.03 GEOTEXTILES

A. AP-SC1000, or 2000 and Inbitex® as supplied by:
   Brown's Concrete Products PH: 1-800-461-4888

2.04 AquaPave® ENGINEERED JOINT STABILIZER

A. Pre-bagged AquaPave® Engineered Joint Stabilizer as supplied by:
   Brown's Concrete Products PH: 1-800-461-4888

PART 3 EXECUTION

3.01 EXAMINATION

Note: Compaction of the soil subgrade may be necessary to achieve stability under vehicle loads. Compaction, however, will reduce the permeability of soils. In such cases, laboratory and on-site testing for density and soil permeability should be conducted. These can help establish a relationship between compacted density and anticipated design permeability after compaction. An experienced civil or geotechnical engineer familiar with local soil conditions should be consulted for determining project standards for the percentage of soil Proctor density and test methods for permeability. When soil compaction is required, standard Proctor density per ASTM D 698 for pedestrian and driveway areas is recommended. Modified Proctor density per ASTM D 1557 is recommended for vehicular areas. 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. These conditions may require the use of drain pipes within open-graded bases. Compaction on the "open aggregate base" for pedestrian and residential driveway areas, a minimum 97% standard Proctor density per ASTM D 698 is recommended. For vehicle and high traffic areas, a minimum 97% modified Proctor density per ASTM D 1557 is recommended.

A. Subgrade:
   1. Verify that subgrade surface is free from standing water, uniform, even, free of any organic material or sediment, debris, ready for installation of AP-SC 1000 or 2000 geotextile.
   2. Verify correct gradients and elevations of subgrade surface, particularly where backup drains are to be located.
   3. Verify compaction density and soil permeability.
B. Edge Restraints:
   1. Verify location, type, installation and elevations of edge restraints around the perimeter to be paved. Ensure the side of the edge restraint adjacent to the paver is perpendicular to the bedding course. This will ensure a tight fit, eliminating a future trip hazard.
C. Beginning of installation means acceptance of subgrade and edge restraints.

3.02 INSTALLATION

Note: Geotextile is placed on the compacted soil subgrade under the clear crushed open-graded lower sub-base. The geotextile is applied to the bottom and sides of the excavation with overlapped joints a minimum of 30cm (12 in.) Overlap is a function of CBR, 30 to 45cm (12 to 18in.) for CBR 3.0 and above, 60 to 90cm (24 to 36 in.) for CBR 1.0 to 3.0, for CBR values below 1.0 they should be sewn. Please consult manufacturers' specifications and your Geotechnical Engineer. Overlaps should follow down slope with drainage. All drainpipes, observation wells, overflow pipes, and impermeable liner (if applicable) should be in place per the drawings either prior to or during placement of the base, depending on their location. The open-graded base is typically compacted in 10 to 15 cm (4 to 6 in.) thick lifts with a minimum 10 T (10 ton) static roller. Care must be taken not to damage drainpipes during compaction and paving. There should be at least 4 passes with no visible movement in the base material when compaction is complete. Absolutely 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. Keep area where pavement is to be constructed free from sediment during entire job. Geotextiles sub-bases and bedding materials contaminated with sediment shall be removed and replaced with clean materials.
B. Place geotextile on the bottom and sides of the excavated area with a minimum down slope overlap of 30cm (12 in.). Allow for enough geotextile to exceed the final elevation of the AquaPave® surface. After final compaction the excess geotextiles should be cut flush with the finished surface.
C. Place and spread the clear crushed open-graded lower sub-base without wrinkling or folding the geotextile. To prevent damage to the geotextile, track vehicles must not be used to spread the initial base course.
D. Do not damage drainpipes, overflow pipes, observation wells, or any inlets and other drainage appurtenances during installation.
E. Spread, moisten and compact clear crushed open-graded lower and upper sub-bases in 10 to 15 cm (4 to 6 in.) lifts with a minimum 10 T (10 ton) vibratory roller.
F. For each lift, make at least two passes in the vibratory mode then at least two in the static mode until there is no visible movement of the material.
G. The elevation of the final surface of the clear crushed open-graded upper sub-base should not deviate more than ±13 mm (± 1/2 in.) over a 3 m (10 ft.) straightedge.
H. Place the Inbitex® geotextile over the clear crushed open-graded upper sub-base following the panel installation drawings. Ensure a minimum down slope overlap of 30cm (12 in.).
I. Spread, moisten and lightly compact the bedding material course. Use a Plate Compactor on this course. No visible movement should occur in base material when compaction is complete.
J. Loose screed the Bedding Course.
K. Lay the AquaPave® in the pattern(s) shown on the drawings. Maintain straight pattern lines.
L. Fill gaps at the edges of the paved area with cut units, ensuring no cut unit is less than one third its original size.
M. The use of Guillotine or Paver Splitters is not acceptable. Cut pavers with a masonry saw only. Do not allow slurry from the cuts to adhere to the surface of the pavers.
N. Compact and seat the pavers into the bedding material using a low amplitude, 75-90 Hz plate compactor capable of at least 5,200 lbs. (23 kN) centrifugal compaction force. After the first pass with the vibrating plate compactor remove and replace any damaged pavers.
O. Apply a dressing of Brown's Concrete Products' AquaPave® Engineered Joint Stabilizer to the surface and sweep into the joints. Approximately 3kg/m2 (6.6lbs/10 ft2) will be required. Fill joints and sweep off excess material before continuing compaction. Two or three more passes with the compactor will be required.
P. Do not compact within 1 m (3 ft) of the unrestrained edges of paving units.
Q. Remove excess aggregate by sweeping pavers clean.
R. All pavers within 1 m (3 ft) of the laying face must be left fully compacted at the completion of each day.
S. The final surface elevations shall not deviate more than ±10 mm (±3/8 in.) under a 3 m (10 ft) long straightedge.
T. The surface elevation of pavers shall be 3 to 6 mm (1/8 to 1/4 in.) above adjacent drainage inlets, concrete collars, or channels to allow for future settlement.

3.03 FIELD QUALITY CONTROL

A. After sweeping the surface clean, check final elevations for conformance to the drawings.
B. The top surface of the pavers shall extend 3 to 6 mm (1/8 to 1/4 in.) above the final elevations after compaction to compensate for possible minor settling. (see 3.02 T)
C. Lippage: No greater than 3 mm (1/8 in.) difference in height between adjacent pavers.

3.04 PROTECTION

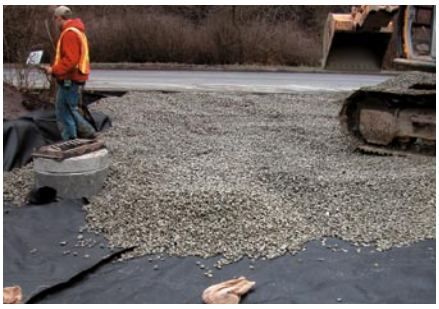
A. After work in this Section is complete, the Contractor shall be responsible for protecting the work from damage and sediment due to subsequent construction activity on the site.
B. Design consideration should be taken to ensure that soft landscaping is retained to prevent migration of softscape materials on to the AquaPave® surface. This will significantly help to maintain the integrity of the system.

End of section

Standard AquaPave® University of Victoria, Engineering Building

Typical AquaPave® Installation at the University of Victoria, Engineering Department

1. Placing the AP-SC1000 or 2000 woven geotextile with the specified overlap.

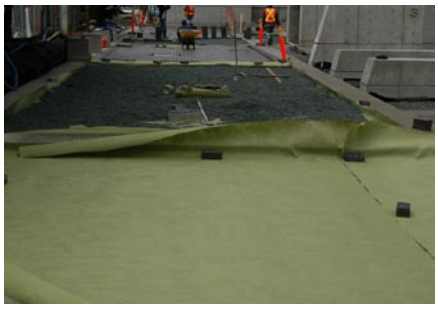


2. Placing and spreading of the clear crushed open-graded lower sub-base aggregate without wrinkling or folding the geotextile.

3. Compaction of the lower sub-base.

4. Placing and spreading the clear crushed open-graded upper sub-base.

5. Compaction of the clear crushed open-graded upper sub-base.



6. Placing the AP-SC Inbitex® geotextile.

7. Placing and spreading of the 5mm clear crush bedding material.

8. Compaction of the 5mm clear crushed open-graded bedding material.

9. Loose screeding of the 5mm clear crush open-graded bedding course.

10. Placing the AquaPave® pavers.

11. Initial compaction of the AquaPave® pavers.

12. Spreading and sweeping in of the AP Engineered Joint Stabilizer.

13. Close-up view of the joints with AP Engineered Joint Stabilizer applied before final compactions.

14. Final compactions of the AquaPave® pavers.

15. Close-up view of the joints with AP Engineered Joint Stabilizer applied after final compactions.

AquaPave® Installation Using Mechanical Laying Equipment, Burnaby, BC

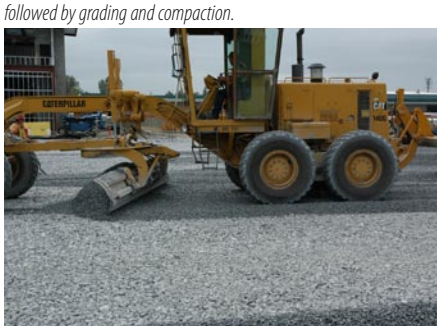
1. Excavation of sub-grade, removing any organic material.

2. AP-SC 1000 geotextile is rolled out and fastened to sub-grade .

3. Clear crushed open-graded aggregate lower sub-base is placed, followed by grading and compaction.

4. Paver restraints are placed.

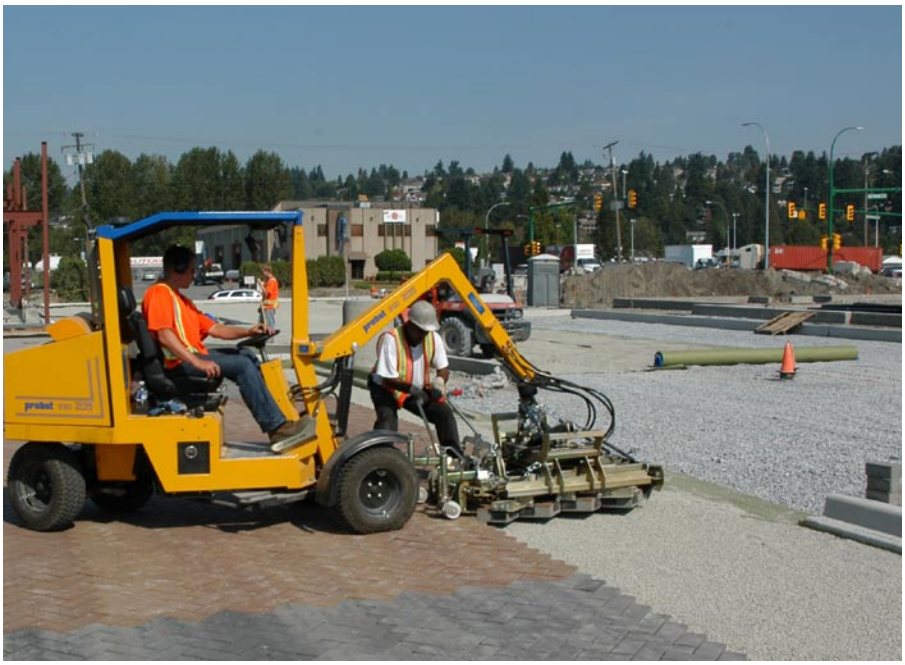
5. Clear crushed open-graded aggregate upper sub-base is placed.



6. Upper sub-base is then graded to elevation and compacted.

7. SC Inbitex® is placed followed by the 5mm clear crushed open-graded bedding course .

8. AquaPave® pavers are delivered to site, prearranged on pallets .



9. AquaPave® is placed using mechanical laying equipment, this can increase production to 8,000-10,000 sq. ft. per day with a standard crew.

10. All cuts must be made with a masonry saw.

11. AP Engineered Joint Stabilizer is applied and swept into place.

12. After final compaction the paved area is available for immediate use.

Glossary of Terms

Antecedent A preceding occurrence or cause or event.

Bioremediation Use of living organisms to clean up oil spills or remove other pollutants from soil, water, or wastewater.

CBR California Bearing Ratio. An empirical test used for estimating the bearing value of highway sub-bases and subgrades.

Detention An enforced delay.

Detention Pond A pond that temporarily stores stormwater runoff and subsequently releases it at a slower rate than it is collected by the drainage facility system.

Eco-System A system made up of a community of animals, plants, and bacteria and the physical and chemical environment with which it is interrelated.

Exfiltration A gradual escape of fluid.

LEED® Leadership in Energy & Environmental Design. It is a voluntary rating system that is used to evaluate a project in relation to its use of "green building" technology.

Impervious Incapable of being passed through or penetrated.

Inbitex® Inbitex® is a thermally bonded nonwoven geotextile. Inbitex® has been specifically developed to optimize the cleansing of water entering the system. The various characteristics have been combined to create a unique geotextile that aids in the development of naturally occurring, and offers them refuge during periods of drought.

Infiltrate To pass, or cause (a fluid) to pass, through small gaps or openings; filter.

Infiltration Rate The rate, usually expressed in inches per hour, at which water percolates or moves down through the soil profile.

In-situ To treat in place.

Non-Point Pollution Source Pollution that enters any waters from any dispersed land based or water-based activities and does not result from discernible, confined, or discrete conveyances. Collectively, this is the largest source of stormwater pollution.

Observation Well A perforated pipe inserted vertically into an open-graded base used to monitor its infiltration rate.

One Hundred Year Storm A very unusual rainfall event that occurs once every 100 years and has a 1% chance of occurring in a given year.

One Year Storm A rainfall event that occurs once a year or has a 100% chance of occurring in a given year.

Outfall Point of water disposal to a stream, river, lake, tidewater, or artificial drain.

Peak Discharge The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

Permeable Open to passage or penetration, especially by fluids.

PICP Permeable Interlocking Concrete Pavements.

Pretreatment The removal of materials such as solids, grit, grease, and scum from flows prior to physical, biological, or physical processes to improve treatability.

PSC Permanent Stormwater Control Plan. A plan which includes permanent BMP's for the control of pollution from stormwater runoff after construction and/or land distributing activity has been completed.

Retention Pond A pond that is either designed to hold water for a considerable length of time and then release it by evaporation, plant transpiration, and/or infiltration into the ground; or to hold surface and stormwater runoff for a short period of time and then release it to the surface and stormwater management system.

Void Ratio Ratio of the volume of void space to the volume of solid particles in a given mass.

References:

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6. John Argue of the Urban Water Resources Centre at the University of South Australia

Patents:

The system and products described in this brochure are covered by patents issued or pending in the following countries:
Australia, Canada, European Patent Convention, Great Britain, New Zealand, Singapore, South Africa and the United States of America.


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