OAKS LANDSCAPE PRODUCTS

tech note

number L3

INSPECTION, MAINTENANCE & REPAIR OF PERMEABLE PAVEMENTS
(Last Updated November 2017)

Permeable Interlocking Concrete Pavements (PICP) couple an attractive and functional pavement structure with a recognized low impact development (LID) stormwater management solution. However, it is important for owners to monitor the condition of these systems and rectify any signs of clogging or distress in order to ensure proper performance and fully optimize the pavement's lifespan.

The following table summarizes our recommended regular and semiannual inspection programs, which are elaborated upon in Sections 1 and 2 respectively. Section 3 discusses the potential reasons behind more serious problems (i.e. where remedial maintenance is required), and how to evaluate the situation to determine the required remedial maintenance action(s).

REGULAR INSPECTIONS	ACTION
a) Ensure signage is in place and visible.	Improve visibility or replace as required
b) Inspect perimeter vegetation	Install temporary sediment controls as required until vegetation re-established.
c) Inspect paver surface for dirt and debris.	Clean as required.
d) Inspect paver surface for stains	Clean as required.
e) Inspect paver surface for weeds and moss	Remove weeds and moss as required.
f) Inspect paver surface for ponding.	Remediate clogged joints (see Section 2a)
g) Check for damaged pavers.	Replace paver(s) as needed, especially if a trip hazard exists
h) Evaluate condition of pavement markings	Re-paint as required
i) Conduct environmental compliance testing as required by the Owner/regulatory agency	Record monitoring data and submit samples as required.
SEMI ANNUAL INSPECTION	
a) Vacuum sweep surface debris	
b) Check for lippage between adjacent pavers	Re-set pavers if lippage > 6mm
c) Verify depth of jointing material	Replenish when >12mm from surface
d) Verify surface infiltration rate	Remediate when infiltration rate < 250mm/hr
e) Check for surface elevation changes (depressions/ruts/heaving)	Remediate when elevation change > 13mm as measured using a straight edge.
f) Check for surface movement (Shifting/creep)	Remediate when movement > 13mm or joint material loss evident
g) Check underdrain outlets are clear of debris	Clean out as required.

1) REGULAR INSPECTIONS

Regular inspections, outside of the environmental monitoring, fundamentally involve a walk around the site – no tools are required tools. The objectives are to:

1. Assess the general appearance of the pavement.
2. Prevent potential clogging by ensuring signage is in place and perimeter vegetation is stable.
3. Identify evidence of existing clogging so that the proper maintenance can be conducted.

The following subsections outline what to look out for during each component of the inspection.

a) SIGNAGE

Signage is required to notify users, in particular landscape and winter maintenance crews, that there are use restrictions on the PICP surface. Common things to avoid:

- Storage of landscape or building materials, or snow piles.
- Discharge of grass clippings. When grass cutting, clippings will inevitably end up on the pavement; the landscape contractor should use a leaf blower to clean off the PICP area.
- Fueling of equipment or vehicles. Traditional spill containment practices will not work on PICP, so refueling should be avoided.
- Power washing of equipment or vehicles.
- Application of winter sand.

A good idea is to provide contact information for the Owner's agent on the bottom of the sign in the event of an accidental spill or surface contamination.

During the inspection, one wants to make sure signage is present and visible. Trim or cut any vegetation that may block the sign, or replace the sign immediately if damaged or stolen.

b) PERIMETER VEGETATION

All areas expected to drain onto the PICP surface should either be grassed or paved (e.g. standard pavers, asphalt or concrete). Where bare soil or erosion gullies exist, silt fencing should be installed and maintained adjacent to the PICP surface. The objective is to prevent sediment laden stormwater from flowing onto and contaminating the PICP surface.

Stormwater from areas not expected to be drained onto the PICP surface should be collected using traditional practices, or direct around the PICP surface using conveyance berms.

Planter beds or other similar areas (where the surface material is topsoil) within or adjacent to the PICP surface should not drain directly onto the PICP surface; use an area drain with silt control features or interim sediment trap, with the area drain / trap discharging via underground pipe to the base / subbase aggregates.

c) DIRT AND DEBRIS

Pavement surfaces can regularly be exposed to trash, wind-blown and tracked on dirt, and fallen leaves. Debris and sediment accumulates in low laying areas, between the joints, or around the perimeter of the pavement. Regular cleaning will help the pavement keep its original appearance.

Areas to focus on, or things to look out for:

- Around trees. Leaves should not be allowed to accumulate long enough that they start to decay.
- Transition points from conventional (i.e. impermeable) drive surfaces. Sediment, including winter sand, can be tracked onto the PICP by vehicles, and will accumulate in the drive lanes and parking stalls.
- Surface water run-on areas. Any sediment contained in the run-on water will accumulate within the first few feet of the PICP pavement.
- Snow pile storage areas. The use of winter sand is discouraged. Do not store snow piles containing winter sand (when used), including snow from other impermeable surfaces, on the PICP surface.
- Adjacent to silt fencing. As previously mentioned, silt fencing is required between the PICP pavement and any bare soils or erosion gullies; inspect adjacent to the silt fencing to make sure it is working properly.

In the spring, the inspector should also look for accumulations of residual de-icing agents; some de-icing agents can chemically damage the pavers and should therefore be cleaned off as soon as possible.

Depending on the severity of the dirt accumulation, vacuum sweeping as discussed in Section 2a, or possibly even remedial maintenance as discussed in Section 3g, may be required. The source of the sediment should also be verified so that potential preventative measures can be implemented.

d) STAINS

Any pavement surface is subject to stains or marking, be it due to general trafficking or contamination from other sources. Ideally cleaning takes place as soon as the stain or marking appears, but this may not be realistic in commercial, industrial or municipal applications. Using a sealer will delay how long it takes for the stain to set, but if the deleterious material is not removed within a reasonable period of time the stain will eventually set into the concrete.

"*ICPI Tech Spec 5 - Cleaning, Sealing and Joint Sand Stabilization of Interlocking Concrete Pavement*" lists stain removal recommendations for several specific items like blood, food drippings, creosote, wood rot, and paint, amongst others. Below are recommended practice for some of the most common stains. The following are general rules of thumb when cleaning stains:

- Use only environmentally safe products as the cleaning agent will infiltrate into the permeable pavement system with the wash water.
- Start removal of stains at the low end of the pavement and work up the slope in manageable sections. This way the surface remains dry ahead of the cleaner-soaked areas, allowing better visibility of the stain to be removed.
- Where the cleaning agent/stain remover may run onto vegetated areas, saturate the vegetation with water prior to cleaning; this will minimize the absorption of cleaner and reduce the risk of damage to the vegetation.
- When pavers have stains too difficult to remove, replace them with the same type of unit – refer to "*ICPI Tech Spec 6 - Reinstatement of Interlocking Concrete Pavements*". There may be a difference in colour from the surrounding pavers, even if the replacement paver(s) was taken from attic stock; this variation should eventually disappear. If the colour variation is unacceptable or attic stock is not available, then consider adding an accent or border to the pavement area of a different colour – use the pavers removed to accommodate the accent or border as replacement for the stained units.

Rust Stains: To remove a rust stain, the surface should be wetted and the affected area treated with an acid based concrete cleaner (no stronger than an equivalent 5% Hydrochloric acid solution or similar). Be aware that the acid in cleaners can adversely impact concrete; it can leave a slightly roughened surface or leach out some of the pigment from the concrete, so care must be taken. After application of the cleaner any residue should be washed off the surface of the concrete with copious quantities of water to avoid staining and dilute the chemical. All manufacturers' instructions must be strictly followed and after cleaning is completed, any chemical residue should be properly disposed of.

Oil Stains: Oil penetrates readily into concrete, but it should not stain if any spillage is removed promptly with an absorbent material (e.g. paper towels or cloth). Do not wipe as this will drive the oil into the concrete and spread the contamination over a larger area. If the stain persists, a cleaner suitable for the purpose should be used in accordance with the manufacturers' instructions. Alternatively the surface can be scrubbed with a strong detergent and the residue washed away with hot water. However, care must be taken as this method might also result in the leaching out of some pigment from the concrete product and discolouration due to surface abrasion.

Bitumen Stains: Bitumen does not penetrate concrete readily. The bitumen should be left until it has cooled. It can then be removed using a paint scraper or similar mechanical device. If it is particularly resistant, the use of ice to make the bitumen brittle may be required, prior to scraping it from the paving. Any residue should be removed with an abrasive powder and finally the whole area rinsed with clean water. Certain proprietary

cleaning agents are also available to remove bitumen, but these should first be tested on an inconspicuous area of the paving.

Chewing Gum: Chewing gum is one of the most difficult substances to remove from any surface. Newly discarded gum can be scraped off using a scraper. Hardened gum can be removed by chiselling it off the surface of the paving, using a hot water/steam cleaner or by chemical means. There are contract cleaning companies who specialise in this type of cleaning, and it is recommended that they be contacted directly for further details.

Scuff marks from vehicle tires: These can normally be removed by steam cleaning or by scrubbing the area with hot water and a strong detergent.

e) WEEDS AND MOSS

It is important to understand that weeds grow when soil accumulates in the joints, then seedlings fall on top of, and germinate into, this soil. The regular cleaning of dirt and debris outlined previously should prevent weeds and moss from occurring.

Similarly, moss, lichens and algae should not grow on concrete unless the area is heavily shaded, is under a tree or is not adequately drained. Ensuring proper drainage during the original installation will help avoid moss growth.

Should young weeds or moss begin to appear, remove them as soon as they are noticeable. Ideally this can be accomplished using a screwdriver or nail to dig down into the joint and remove the root system.

For established weeds, one may need to use an organic solution to destroy the plant. Vinegar mixed with dish detergent, or boiling water, are two environmentally friendly alternatives; by pouring these over the infected areas, one can kill already existing organics and prevent new ones from sprouting. Use of more aggressive weed killers is at the discretion of the owner.

For established moss, lichens and algea, treat the area with a solution of 20% dish soap and 80% water. If this does not work, use a proprietary cleaner suitable for the purpose.

f) SURFACE PONDING

As mentioned previously, pavement surfaces can regularly be exposed to trash, wind-blown and tracked on dirt, and fallen leaves. Debris and sediment can accumulate in the joints which can impede, if not prevent, surface infiltration. Surface ponding is an indicator of clogged joints; vacuum sweeping as discussed in Section 2a, or possibly even remedial maintenance as discussed in Section 3g, may be required.

g) DAMAGED PAVERS

PICPs are a flexible pavement system consisting of individual concrete paver units; occasional one or more of these individual units can be damaged while being moved around during transportation or installation. Ideally any defective units will be identified and removed by the contractor, but sometimes the deficiency is not noticed until after the pavers are installed and the entire pavement is completed. Individual, or clusters of, pavers can also become damaged after installation due to impacts (e.g. dropping heavy materials or stabilizer pads on the surface), heavier than intended traffic using the area, or chemical exposure. The intent of the regular inspection is to identify cracked, chipped, spalled or deteriorating pavers that are either aesthetically unpleasant or could present a trip hazard to pedestrians.

To remove a damaged paver(s), scrape out the jointing material around the first unit, then use a paver extractor (see adjacent) or couple of screwdrivers to pull the paver up. If this does not work, use a hammer and chisel to break up the first paver. Depending on the location of the paver, it may be easier to start at an outside edge and work your way towards the paver. Once you get the first one out, you can get under the other stones to pull them out, making the job much easier.

Prior to reinstating existing pavers, be sure to remove any accumulated sediment from the sides and bottom of the stone, or else it will be very difficult to align them properly.

To reinstate the paver(s), add and screed additional bedding material, install new pavers from attic stock, compact the pavers into the bedding layer, refill the joints and vibrate full. Additional details can be found in "*ICPI Tech Spec 6 – Reinstatement of Interlocking Concrete Pavements*".

Should paver damage re-occur or is excessive, refer to Section 3a which outlines in more detail how to determine the reason(s) for paver damage.

h) PAVEMENT MARKINGS

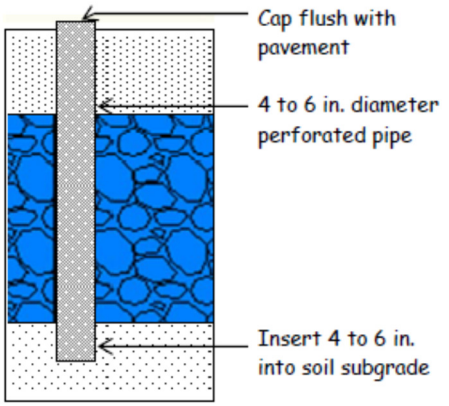
There are two ways of stripe marking a permeable interlocking concrete pavement – using different coloured pavers to create the markings (see adjacent), or painting the markings onto the pavement surface.

In the case of the initial, ensure that there is enough contrast between the main field and line pavers that some fading can be accommodated.

In the case of the latter, re-painting will occasionally need to be done. Use standard line paint used for concrete surfaces.

i) ENVIRONMENTAL COMPLIANCE MONITORING

The frequency and monitoring requirements, when applicable, are specified by the local regulatory agency. Monitoring can include:



- Water level measurements within the base and subbase. Depending on the type of PICP system (full-, partial- or no-exfiltration system), a monitoring well within the pavement field and/or outlet control device at the underdrain outlet would need to be included in the original design. Water levels can either be taken manually with a ruler or water level sensor, or automatically with a pressure sensing datalogger. The purpose of the water level measurements is to verify the system drains within the required post storm event time frame; saturation of the soil subgrades for extended periods of time can jeopardize the structural integrity of the system.
- Water quantity and/or flow rates at the underdrain outlet. This is commonly done when there are quantity or flow restrictions to the receiving stormwater system – for example, some municipalities limit the flow rate to the municipal stormwater collection system to a set volume per hour per unit area of property.
- Water quality at the underdrain outlet. This is commonly done when there are either specified water quality improvement requirements or pollutant discharge limits for the site. Total Suspended Solids monitoring is most commonly called for as it is an easy to measure low cost analysis. Chlorides are monitored along highway corridors where de-icing chemical contamination has traditionally been an issue. Total Nitrogen and/or Total Phosphorus are commonly called for when the receiving waters have a history of associated problems (e.g. algae blooms). In the case of water quality improvements, background comparison samples will also have to be collected; run on from adjacent impervious surfaces or discharge from a nearby stormwater control device to which the PICP system is not connected, are two examples of background water quality sources.
- Discharge temperature. This is commonly done when there is temperature sensitive biota (e.g. trout) in the receiving waters.

Sample containers and collection protocols can be obtained from the analytical lab. A site specific log book should be maintained that records sample dates, results and observations.

2) SEMIANNUAL INSPECTION

Semi-annual inspections for the most part involve taking measurements to verify any deficiencies in the pavement are within acceptable tolerances. For all but the vacuum sweeping and infiltration testing, a measuring tape, straight edge, 12mm diameter rod, and scraper is all that is needed.

a) VACUUM SWEEPING

Vacuum sweeping is recommended at a minimum twice a year, once in the spring and once in the fall. Spring cleaning should focus on removing any residual de-icing agents and winter sand tracked/washed/deposited onto the pavement. Fall cleaning should focus on removing organic debris (residual clippings, leaves) from the pavement area.

Brooming, including with hand brooms or mechanical broom sweepers, is discouraged – brooms tend to spread dirt around (which ultimately promotes clogging of a larger area), and are not successful at getting debris out from within the chamfer of the pavers (see adjacent). A chamfer is a 45 degree beveled edge around the top of a paver unit that helps prevent edge chipping, delineates the individual paving units, and provides a sloped outside edge in the event there is slight height variances between adjacent units.

Pressure washing can be used to break up the surface buildup, but care needs to be taken to ensure the debris is not just blown to another location, or sediment is pushed through the joint material and into the lower aggregates. Direct the water at an angle not greater than 30 degrees and across the diagonal, and use a wide nozzle spray. Please note that some pressure washers even have enough power to expose aggregate on the surface of the pavers; test the nozzle style, distance from the surface and pressure on spare pavers (if available) prior to working on the main pavement area.

The recommended piece of equipment for regular cleaning is a shop vacuum for small areas, or regenerative air sweeper or similar (shown adjacent) for larger areas. Regenerative air sweepers use a blast of air the width of the sweeping head to dislodge material from the surface / joints, making it easier for the suction hose to pull up the debris and deposit it into the debris hopper. A regenerative air is not the same as a true vacuum sweeper (see Section 3g) as the amount of vacuum they produce is much lower.

b) LIPPAGE

Because of the way pavers are manufactured, there can be slight height variations amongst units; CSA A231 Precast Concrete Paving Slabs/Precast Concrete Pavers allows for the measured height of samples to differ by up to +/- 3.0mm from the specified dimension. However, lippage should not be visible on the final pavement surface if the bedding layer is properly screeded (see adjacent) and remains uncompacted until final bedding of the pavers. The recommended method of installation is to layout the pavers on top of the uncompacted bedding layer, then use a vibratory plate compactor to seat them into the bedding layer; this way, height variances between adjacent pavers is adjusted for within the bedding layer and the final pavement surface ends up being level. When a contractors or pre compacts the bedding layer, the bedding layer cannot compensate for any height variances in the pavers so lippage becomes evident on the pavement surface.

During the regular inspection, make sure any lippage does not pose a potential trip hazards for pedestrians. Use a measuring tape to measure any height difference, and if greater than 6mm re-set the pavers. Lippage can also pose a snag issue for snow plows, and can causing damage to both the pavers and snow plow equipment. If lippage problems persist, this may be evidence of a more serious settlement/frost heave problem; refer to Sections 3b to 3d for more details.

c) JOINT MATERIAL

When first installed, jointing material should fill the entire joint to the bottom of the chamfer. However, as the pavement is trafficked, the jointing material can continue to consolidate within the joint (vibration causes the joint material particles to consolidate). Jointing material loss can also occur from a number of factors including: wash out, cleaning, tire suction, vandalism, etc.

On a semi-annual basis, and after severe storm events (especially when flooding occurred), use a putty knife to check the depth of the jointing material – it should never be lower than 12mm below the top surface of the paver.

If required, spread new joint material (typically an ASTM size No. 8, 89 or 9 stone per *ASTM D448 – Standard Classifications for Sizes of Aggregates*

for Road and Bridge Construction) over the pavement area, clean off excess material that does not flow down into the joints, then run over the surface with a small vibrating compactor. Repeat until the joints are full to the bottom of the chamfer.

d) SURFACE INFILTRATION RATE

ASTM C1781 – Standard Test Method for Surface Infiltration Rate of Permeable Unit Pavement Systems was developed as an easily re-producible and low cost method of monitoring the performance of PICP. The test method requires a 12" diameter plastic or metal ring, plumber's putty, a 20 litre pail, and a stop watch. The ring is seated onto the pavement surface using the plumber's putty. Water is slowly poured into the ring such that 10 to 15 mm of water head is maintained above the pavement. The time taken for the entire contents to drain is measured. An equation within the standard is used to convert the time into an infiltration rate expressed in mm per hour.

Testing should be done on potentially problematic areas identified during the regular inspections. Keep records so that changes can be tracked over time.

The recommended minimum infiltration rate is 250 mm per hour – this is still significantly higher than would be needed during even the worst rainfall event, but serves as a good indication that clogging is occurring and remedial maintenance should be done.

e) ELEVATION CHANGES (DEPRESSIONS / RUTS / HEAVING)

A depression is when one or more pavers have sunk and are lower than the surrounding pavers or road features (adjacent photo). Rutting is a surface depression that occurs specifically in wheel tracks (middle photo). Heaving is when one or more pavers have raised and are higher than the surrounding pavers or road surface (lower photo).

With conventional pavements, depressions or ruts are typically identified by surface water ponding, but given that PICP are permeable surface ponding may not be present. Shadows and colour changes are also viewed as evidence of depressions, but actually can give the impression of differential settlement where none exists. It is always best to lay a 3 m long straight edge on the

surface and measure any height variances along the length – elevation changes should not exceed 13mm. Rather than try to use a ruler to measure the variance, find a 12mm diameter rod (dowels are available at most hardware stores) and try to slide it under the straightedge when it is laying flat.

When an elevation change is identified, it is important to determine the reason for the problem prior to initiating remedial action. Additional details are available in Sections 3b through 3d below.

f) SURFACE MOVEMENT (SHIFTING/CREEP)

Perimeter creep exists when the pavers start to shift at or near the outside perimeter of the installation. Joint start to grow and the bond lines no longer line up. Vehicle traffic turning, stopping or starting in the area exasperate the problem once it begins. Additional details on evaluating the reason(s) for and remediating creep is available in Section 3e below.

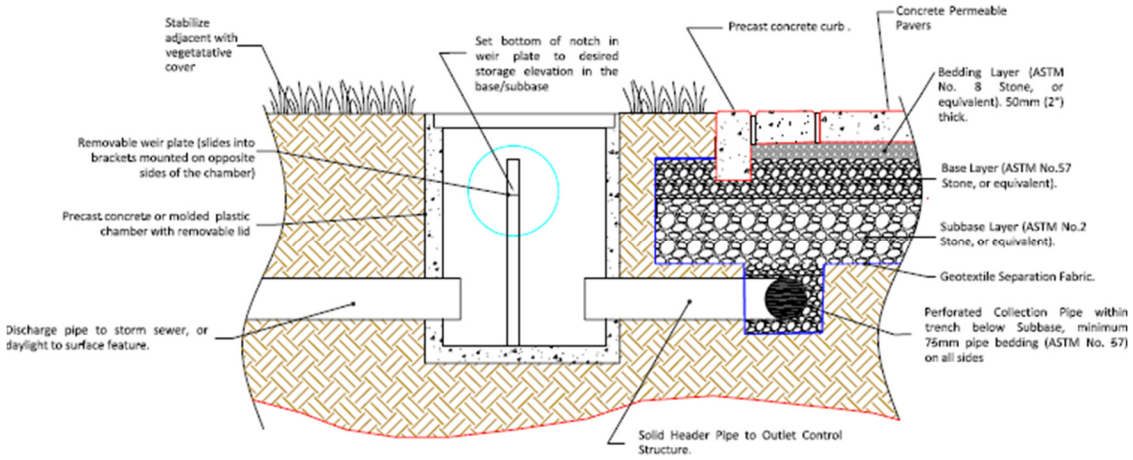
Paver shifting is similar to the previous, but within the pavement field (i.e. not close to the outside perimeter of the pavement). As mentioned previously, PICPs are a flexible pavement system, so some degree of shifting can occur without affecting the pavement performance. However, when movement similar to what is shown adjacent is observed, wherein joint material is being lost in areas, remedial action will be required. Additional details on evaluating the reason(s) for and remediating shifting is available in Section 3f below.

g) UNDERDRAINS

Depending on the site topography and proximity of existing underground stormwater infrastructure, underdrain outlets from the PICP system (where required) can discharge to surface or into a stormwater manhole/catchbasin.

Discharge from underdrains can be very infrequent, so the piping can be prone to animal encroachment and/or vegetative overgrowth at the outlet. Make sure the pipes and outlets are clear of debris and can properly discharge. Screens can be placed on the end of the pipe to prevent animal encroachment.

With underground utility connections, we recommend a monitoring vault be installed where the underdrain extends beyond the PICP boundaries (see below). The water storage volume of the PICP system (and in turn the time required for the system to drain) can be adjusted by modifying the weir plate notch elevation. The chamber also provides a convenient location for water quality sampling and quantity measurements.



3) EVALUATION OF PROBLEMS AND REMEDIAL REQUIREMENTS

a) DAMAGED PAVERS

As mentioned previously, damage to pavers can include cracking, chipping, spalling or general deterioration. The following subsections discuss the most common causes for each of these problems.

Hairline Cracks: Randomly oriented hairline cracks (little to no opening) on the paver surface are typically related to production issues; these pavers should never have made it through production quality assurance or have been installed by the contractor. These pavers are aesthetically unpleasant and will be more susceptible to freeze thaw damage due to the poor general quality; therefore, they should be replaced.

Visible Cracks: Visible cracks that extend across the entire unit are evidence of damage due to product overloading or poor installation practices. For example, the pavers in the adjacent photo were initially selected based on their suitable for a pedestrian walkway; unfortunately the designer neglected to consider the fact that maintenance vehicles would drive over the pavers, and the pavers cracked under load.

When product overloading occurs, the owner should evaluate whether (A) the existing pavers should be replaced with a different product that is suitable for the expected traffic loading, (B) consider an alternate design approach (pervious concrete overlay) that would provide greater flexural support to the existing pavers, or (C) install measures to prevent vehicles from accessing the area (e.g. bollards).

The most common "problematic" installation practice is using the wrong compaction equipment during installation – for example, only roller compactors should be used with larger pavers and slabs; plate tampers can crack the units. Although this type of cracking dose not adversely impact the structural integrity of the pavement, it may not meet the aesthetic expectations of the owner and the broken units will need to be replaced.

Edge Chipping: For pavers with nominal to no chamfers (see adjacent), chipping along the outside edge of the pavers can occur (especially when installed tightly together). As traffic drives over the pavement, the pavement flexes and the outside edges of the pavers can come into contact with one another; the resulting pressure between units can pop edges off one or both of the paver faces. If the problem is wide spread or persists, the owner can consider having the product re-laid with increased joint spacing.

For larger chamfered product (which most permeable pavers are), chipping typically only occurs when two cut pavers are butted tightly up to one another, or a cut paver butts up against a solid object (curb or building). This problem can be avoided by always having a cut edge butt up against an uncut paver; that way there is a chamfered edge next to the cut. If the problem is wide spread or persists this can be an initial indication of pavement movement (see Sections 3b to 3d for more details).

Surface Spalling: Spalling of the paver surface (adjacent) occurs when something like a snow plow strikes an exposed outside edge of the unit and shears off a section of the face. This only occurs when the paver(s) is elevated above the adjacent surface, which can be a result of poor installation or settlement/frost heave. In the case of poor installation, the pavers would need to be lifted and relayed. To assess settlement or frost heave, refer to Sections 3b to 3d for more details.

Deterioration: Deterioration of the paver (adjacent) is indicative of chemical damage from de-icing chemicals; magnesium based de-icers in particular are problematic in that the magnesium chemically degrades the cement paste. The owner should discontinue the use of these deicing chemicals, or at minimum switch to a sodium chloride deicing agent which is not as harmful to the product.

Deterioration of pavers adjacent to road features such as concrete edge restraints (see adjacent), catch basins or manholes is due to settlement of the underlying base and subbase materials. Proper compaction in these areas during installation requires extra effort to achieve, and therefore may not have been accomplished. As the material and pavers settle, the pavers separate and the joint material gets washed out.

Once this occurs, vehicles trafficking the area will cause the pavers to knock together breaking them apart. The pavers would need to be lifted, the base and subbase properly compacted, then the pavers reinstated.

b) <u>DIFFERENTIAL SETTLEMENT (DEPRESSIONS)</u>

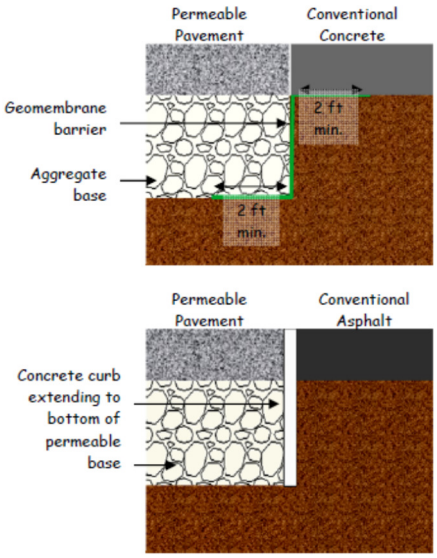
A depression exists when one or more pavers are lower than the surrounding pavers or road features. Depressions are most commonly caused by bedding/base/subbase material migration, or settlement of the underlying base/subbase/subgrade.

Aggregate material migration can occur when the wrong size of aggregates are used for one or more of the bedding, base or subbase, and proper choking between products is not accomplished. For example, if the bedding layer were to contain a large percentage of overly small aggregates, over time these small aggregates would migrate down into the underlying (and larger) base material. The progressive loss of bedding material would cause the overlying pavers to settle.

Aggregate migration can also occur when specified separation geomembrane materials are not used and the base/subbase aggregates blend with the underlying subgrade soils.

Subgrade or granular base/subbase differential settlement can occur:

1. Over poorly installed utility cuts or improperly compacted base/subbase materials,
2. Adjacent to road features (e.g. manholes, building footings) where proper compaction may not have been performed during original construction,
3. Adjacent to conventional pavement when a water containment feature (header curb or geomembrane liner) is not provided to protect the base under the conventional pavement – see adjacent.
4. Over scarified subgrade soils (scarifying is sometimes incorrectly done to try to rectify subgrade compaction impacts during initial construction),
5. When the subgrade soils remain saturated for extended periods of time due to improper design or restricted discharge drainage and soften,
6. When the structural depth of the PICP structure was insufficient for the amount of traffic using the pavement.



For minor subgrade or base settlement, it may be sufficient to lift the existing pavers, level the base and compact, then reinstate the pavers. For severe settlement, total reconstruction of the entire pavement system, including compaction/stabilization of the subgrade, may be needed. Consult with the original designer, or other appropriate professional, to assess the situation before proceeding.

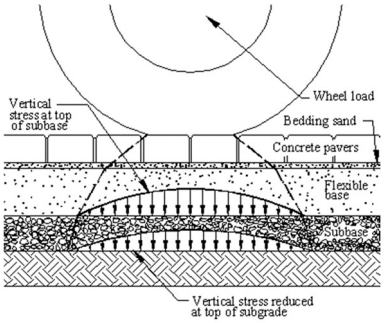
c) RUTTING IN PAVEMENT SURFACE

Rutting is a surface depression that occurs specifically in wheel tracks. With PICP, rutting can commonly be attributed to structure failure of the bedding material through degradation, use of the improper aggregates, or structural failure of the subgrade.

Structure failure of the bedding material occurs when the aggregate particles are not durable enough to withstand the abrasive conditions encountered and break down. To verify this is in fact the case, pull up a series of pavers that span both a rutted and non-rutted area, and observe the difference between the bedding material in these two areas. The presence of a significant smaller aggregate material in the rutted area would be evidence of material degradation. Remediation would involve the replacement of the bedding material and reinstatement of the original pavers – refer to "*ICPI Tech Spec 17 – Bedding Sand Selection for Interlocking Concrete Pavements in Vehicular Applications*" for details on conducting Micro Deval degradation testing on the replacement bedding material

The adjacent photo is from a PICP installation where traditional bedding sand and Granular A, rather than the specified open graded materials, where used. The low infiltration rates of Granular A caused the bedding sand to remain saturated for extended periods of time; the smaller particles in the sand became suspended and, as vehicles drove over the area the slurry was displaced. The wash out of bedding material resulted is settlement in the vehicle tracks. Again, to verify this is in fact the case, follow the same procedure above; the presence of small particles suspended in water, forming a slurry, would be evidence of improper base material (where the proper base material present, any fines would have migrated downwards).

Failure of the subgrade occurs when:



- The depth of the aggregate base is insufficient for the given traffic conditions (the deeper the aggregate base, the higher the stress reduction on the subgrade – see adjacent), and the subgrade starts to break down and/or consolidate. In this case, a more comprehensive review of the original design details and overall re-construction is required. Consult with the original designer, or other appropriate professional, to assess the situation before proceeding.
- The subgrade is remaining saturated for extended periods of time and as a result is softening. Assuming a monitoring vault was used at the outlet, further settlement can be prevented by adjusting the storage water depth of the system by adjusting the height of the weir plate. If monitoring wells are present, install a dedicated water level monitoring device to assess if the adjustments are sufficient.

d) FROST HEAVE

Frost heave is the upwards swelling of soil during freezing conditions caused by an increased presence of ice lenses displacing the soil particles. For frost action to occur three basic conditions must be satisfied: the soil must be frost-susceptible; water must be available in sufficient quantities; and cooling conditions must cause soil and water to freeze. If one of these conditions can be eliminated, frost heaving will not occur.

Obviously cold weather cannot be avoided in Canada, and most PICP are designed to retain water in the base/subbase and infiltrate water into the native subgrade, so the only remaining option is to use non-frost susceptible materials. Frost-susceptibility is related to size distribution of soil particles. In general, coarse-grained soils such as sands and gravels (i.e. the open graded aggregates used in PICP) do not heave. Native clays, silts and very fine sands underneath the PICP will however support the growth of ice lenses. In Ontario, where the frost depth is between 1.0 and 1.6 metres, it is not realistic to use open graded aggregates for the full frost depth. Fortunately research at several PICP test sites in Canada, Sweden and the northern US have shown that this is not necessary; thermal heat transfer properties of open graded materials differ from most soils in that frost depths are shallower, while the large percentage of voids permits convection of latent heat to radiate up from below. The result has been no negligible movement of PICP pavements that have open graded profiles that extend to less than the full frost depth.

Should, under extreme conditions, some movement occur, interlocking concrete pavements being a flexible pavement system can endure a certain amount of frost action without sustaining irreversible damage. However, when the effects of frost heave are permanent, total reconstruction of the entire pavement system, including deepening the road profile to a greater percentage of the frost depth, may be needed.

e) PERIMETER CREEP

Perimeter creep exists when the pavers start to shift at or near the outside perimeter of the installation, and the joints sizes change plus the bond lines no longer line up. Vehicle traffic turning, stopping or starting in the area exasperate the problem.

Perimeter creep occurs due to either a lack of proper edging, or insufficient support of the edging.

In pedestrian or residential driveway applications, plastic or aluminum edging can be used, but under the following conditions:

1. Make sure there are enough spikes installed to hold the edging in place; refer to the manufacturer's instructions for specifics.
2. Spikes should not be driven down into open graded material, topsoil or loose fill as these provide no lateral support.
3. Install dense graded berms in areas

where edging needs to be installed (see previous photo); make sure the material extend at least 150mm beyond the spikes as this is what the spikes lock into to prevent movement.

Remediation involves lifting the pavers that have moved, extending the base (if required), installing the edge restraint directly on the base, and securing the edge restraint using the number, spacing and size of spikes recommended by the manufacturer.

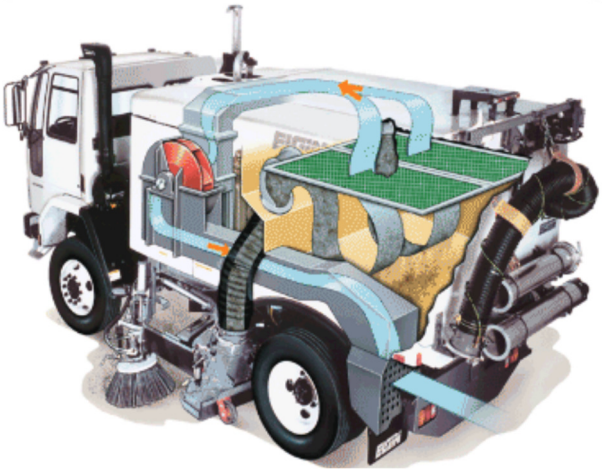
Commercial vehicular applications require a cast in place concrete curb. As long as local municipal standards are followed, there should be no issue with curb movement and paver creep.

f) PAVER SHIFTING

Paver shifting is similar to the previous, but within the pavement field (i.e. not close to the outside perimeter of the pavement). As mentioned previously, PICP are a flexible pavement system, so some degree of shifting can occur without affecting the pavement performance. However, when movement similar to what is shown adjacent is observed, particularly in areas subject to a lot of traffic starting, stopping and turning such as cross walks, remedial action may be required.

Although paver shifting can occur for a number of reasons including, but not limited to, bedding material degradation, and settlement, it is a degree of interlock in the laying pattern of the pavers that controls how extreme the shifting is. Often design professionals like to install pavers in a running bond pattern at crosswalks as this orientation defines a sense of direction; unfortunately running bond has limited interlock. The options are to change the laying pattern (herringbone is preferred), or install header curbs on each side of the crosswalk (shown adjacent) to help secure the pavers in place.

g) CLOGGED JOINTS



To perform remedial maintenance on a PICP surface, a true vacuum truck is required (Elgin Whirlwind shown adjacent or equivalent). The vacuum nozzle (36" x 6" just in front of the rear tires) allows for concentrated suction on a small area of the pavement, which is needed to remove the sediment from between the joints. The

nozzle rides on castor wheels so it will not damage the pavement surface.

Three very important points:

1. The entire pavement surface does not need to undergo remedial maintenance if not required. Clogging is usually specific to certain areas – focus the remedial maintenance on these areas.
2. The equipment operator will have to fine tune the vacuum strength as required to extract the required depth of joint material (typically the first inch to inch-and-a-half); when the vacuum strength is set too high, all the jointing material and even some of the bedding material can be pulled up, while when the vacuum strength is too low, all of the sediment will not be removed.
3. Realize the joint material will also be removed, and will need to be replaced immediately after the area is cleaned.

There is some debate in the industry on whether or not to wet the material down while vacuuming; wetting should help lubricate the material, but silt/clay material can swell and become sticky due to capillary action. According to Elgin, "best results are obtained when it's dry enough for the silt/clay to contract and release its grip on the surrounding material". To reduce the carryover dust through the vacuum fans, the hopper should be preloaded with water.

For particularly difficult (sediment has become embedded into the joints) or hard to reach areas, the rear mounted wandering hose (typically used for catch basin cleaning) can be used as shown in the adjacent photo.

FINAL NOTE

As a final note, this document was prepared as a reference guide to identify, evaluate and rectify various possible pavement problems. Although a lot of content was provided, this is in no way a comprehensive summary – more than one problem may be present, or there could be more than one reason for the given problem. Additional information is available in the "*ICPI Distress Manual*" and "*ASTM E2840 – Standard Practice for Pavement Condition Index Surveys for Interlocking Concrete Roads and Parking Lots*". If questions arise, please do not hesitate to contact Oaks for assistance.