# Tech Spec Guide

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Interlocking Concrete Pavement Institute®

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Design and Installation Professionals frequently turn to interlocking concrete pavements and permeable interlocking concrete pavements because they offer lower initial and life cycle costs and provide environmentally sustainable solutions.

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Tech Spec 6

Interlocking Concrete Pavement Institute®

# Operation and Maintenance Guide for Interlocking Concrete Pavement

Interlocking concrete pavement (ICP) provides an attractive, durable, low maintenance pavement system. However, like any pavement system, if one of the elements fails to perform, the entire system can be compromised. Performance issues can arise from inadequate design, inappropriate materials, ineffective construction techniques or absence of proper maintenance. This Tech Spec provides best practices for maintenance and illustrates actions that should be taken when the system underperforms. The methods utilized apply to commercial and residential interlocking concrete pavement applications. Following the guidance provided in this Tech Spec can help ensure the optimum performance.

This Tech Spec does not address maintenance of permeable interlocking concrete pavement (PICP) systems. This is provided in ICPI *Tech Spec 23–Maintenance Guide for Permeable Interlocking Concrete Pavements*.

## Preventive Maintenance

ICPI recommends that interlocking concrete pavement systems should receive routine preventive maintenance in the spring and fall to ensure optimum performance, just like any other type of pavement.

**Remove surface debris**

This can be done using a mechanical street sweeper, as shown in Figure 1, or push broom depending on the size of the area. A spring sweeping to remove any remaining deicing chemicals and winter sand and a fall sweeping to remove accumulated dirt and leaves are recommended. A power washer or leaf blower can do this very effectively but be careful not to remove the joint sand.

**Top up joint sand as required**

During normal use, the sand filled joints receive sediment and debris from traffic. This settles into the top of the joints and helps hold the sand in place. Installations exposed to driving winds, concentrated runoff flows, or excessive cleaning, may result in some joint sand loss, which can be replenished with dry masonry sand. If the joint sand has dropped more that 1/2 in. (12 mm), measured similar to Figure 2, top up the joint sand immediately. While effective when the joint is filled, using polymeric sand for topping up joints is not recommended.

- After removing surface debris, the pavement surface should be dry.


*Figure 1. Typical street sweeper used to remove surface debris from large ICP areas in the spring and fall.*

*Figure 2. Refill joints with dry masonry sand if loss is greater than 1/2 in. (12 mm).*

*Figure 3. It is easier to remove oils stains from pavers that have been sealed.*

*Figure 4. Shovel snow diagonal to the paver pattern to prevent catching edges.*

*Figure 5. Shoes on plows need to be adjusted so the blade is not pushed across the surface and limits scratching the pavers.*

- Using a wide push broom, spread dry masonry sand back and forth over the paver surface allowing it to fall into the joints and fill them to the bottom of the paver chamfers.
- When all joints are filled, remove excess sand from the surface.

**Use of stabilized joint sand**

During construction, stabilized sand can be used instead of masonry sand to reduce the potential for joint sand loss. Sealers can also help hold the sand in the joints. These are applied over the entire paver surface as a liquid and allowed to soak and cure in the joints. Further details are provided in ICPI *Tech Spec 5–Cleaning, Sealing and Joint Sand Stabilization of Interlocking Concrete Pavement*.

**Apply sealers for easier stain removal**

Sealers reduce intrusion of water, stains, oils, and dirt into paver surfaces as shown in Figure 3. Sealers are useful around

*Table 1: Sample form used to inspect an interlocking concrete pavement.*

| **a. Aesthetic (Visual)** | | **High Severity** | **Medium Severity** | **Low Severity** |
|---|---|---|---|---|
| i. | Efflorescence | | | |
| ii. | Dirt and Stains | | | |
| iii. | Weeds and Ants | | | |
| iv. | Color Fading | | | |
| v. | Minor Abrasion and Wear Including Scratches | | | |
| vi. | Chips, spalls, pock marks | | | |
| **b. Structural** | | | | |
| i. | Damaged Pavers | | | |
| ii. | Depressions | | | |
| iii. | Edge Restraint | | | |
| iv. | Excessive Joint Width | | | |
| v. | Faulting | | | |
| vi. | Heave | | | |
| vii. | Horizontal Creep | | | |
| viii. | Joint Sand Loss/Pumping | | | |
| ix. | Missing Pavers | | | |
| x. | Patching | | | |
| xi. | Rutting | | | |

*Figure 6. Radiant heating can be installed under the paver surface to melt snow and ice in the winter.*


*Figure 7. To conserve energy, the snow melt system is only installed directly under the high traffic areas where it is needed.*

barbeques, trash receptacles, fast food restaurants, driveways, other areas subject to stains, and where oil drippings are not wanted. Application of a sealer follows stain removal, efflorescence removal, and overall surface cleaning. Further detail is provided in ICPI *Tech Spec 5–Cleaning, Sealing and Joint Sand Stabilization of Interlocking Concrete Pavement*.

**Inspect for distress**

As part of the routine preventive maintenance inspection, check for the various distresses identified in the Types of Distress and Remedies section. . If a distress is noted, schedule additional maintenance that remedies the distress and restores the pavement to optimum performance. Inspection be conducted twice a year. Once in Spring during or immediately after a rain event and again in late Summer or early Fall. The rain on the pavement surface will readily identify rutting, settlement and ponding, as well as run-on from adjacent vegetated areas. Table 1 is provided as a template that can be used to record the results of an inspection.

## Winter Maintenance

Given durable aggregates and high densities, concrete pavers can offer outstanding resistance to freeze-thaw and deicer deterioration. The texture of the concrete paver surface with slight surface variations created by the joints can contribute to reduced slips and skids during winter conditions. The amount of slip resistance depends on the surface texture and joint widths.

**Snow Shovels/Snow Blowers/Snowplows**

Snow can be removed from interlocking concrete pavers using shovels, snow blowers or snowplows like any other type of pavement. Experience indicates easier snow removal by shoveling and plowing in a direction diagonal to the joints to prevent catching the edge of the pavers as shown in Figure 4. Prior to the winter season, heaved or slightly lifted units creating lippage of greater than $1/8$ in. (3 mm) should be repaired. With more powerful equipment like plows, excessive lippage and working parallel / perpendicular to the joints may lead to chipping the paver edges. In extreme cases where lippage is not addressed, pavers may be removed which would require further maintenance.

Snow blowers and snowplows can have shoes under them that skid across the pavement surface and raise the blade just above the pavement surface. See Figure 5. Over time, these shoes wear and need to be adjusted to ensure the blade rides at a height that removes as much snow as possible without catching paver edges. Excessive snow blowing and snow plowing operations can embed metal filings from worn shoes into the paver surface that can lead to rust stains. These can be removed with rust removal cleaners. See *ICPI Tech Spec 5–Cleaning and Sealing interlocking Concrete Pavement–A Maintenance and Protection Guide*. Synthetic shoes are available which prevent rust staining created by shoe wear.

As with any pavement, snow removal operations can scratch the paver surface. This could be more noticeable on textured or smooth (polished) pavers. Removing debris from the pavement surface before the snow season can reduce scratching. Using plastic snow shovels or synthetic blades edges should be considered in areas where the appearance of the paver surface is important.

**Winter Sanding**

Sand applied to improve slip and skid resistance also helps keep the joints filled thereby reducing preventive maintenance. ICPI recommends removing excess sand from the pavement surface in the spring. If left on the pavement surface year after year, sand can lead to excessive surface abrasion and wear. This may accelerate colour changes and overall deterioration of the paver units.

*Figure 8. Use deicing chemicals sparingly and remove any excess after it has completed its job.*

### Snow and Ice Melt Systems

These systems are an effective way to prevent snow and ice accumulation. Electric and hydronic snow melt systems can be incorporated into interlocking concrete pavement systems. See Figure 6 and 7. Further information can be found in ICPI *Tech Spec 12–Snow Melting Systems for Interlocking Concrete Pavements*.

### Deicer Use

Deicer chemicals that help prevent, reduce, or eliminate ice buildup as well as slips, falls and loss of vehicular control are often essential in many winter climates. Deicers mixed with ice and snow can increase damage to concrete. Pavers made with low absorption aggregates and high densities tend to have higher resistance to degradation caused by deicers. These properties help limit deicers from entering a concrete paver. In addition, a high cement content helps a paver resist damage from the stress of expanding ice. Units manufactured with these characteristics typically yield a high density and low absorption, as well as high compressive strength, thereby increasing winter durability.

ASTM C936 *Standard Specification for Solid Concrete Interlocking Paving Units* includes freeze-thaw durability criteria and resistance to deicing salts. ASTM C936 references the test method ASTM C1645 *Standard Test Method for Freeze-thaw and De-icing Salt Durability of Solid Concrete Interlocking Paving Units*. ASTM C936 includes an optional lower freezing temperature in ASTM C1645 for regions of the United States that experience severe freezing conditions based on a climatic zone map. The optional testing in 3% saline and the lower freezing temperature for these regions is equivalent to that required in the Canadian concrete paver standard, CSA A231.2 *Precast Concrete Pavers*. To obtain a copy of ASTM C936 or ASTM C1645 visit www.astm.org. The CSA standard is available from www.csagroup.org.

A key to successfully using deicing materials on unit concrete pavers is using only as much as needed to do the job, not as shown in Figure 8. This maximizes their benefits while minimizing damage to the concrete pavers and surrounding environment. The following guidelines can help limit the exposure of deicing chemicals while maintaining a safe environment:

- Apply sand first to increase traction, then apply deicers as needed. Sand should not be applied to permeable interlocking concrete pavements.
- Rock salt (sodium chloride, NaCl) is the least damaging to concrete materials and should be used whenever possible.
- If a more effective, quicker acting deicer is necessary, consider the judicial use of calcium chloride.
- Magnesium chloride and CMA are not recommended because they can chemically degrade all types of concrete, significantly increasing potential damage. The potential for damage from CMA increases with the amount of magnesium in the formulation.
- Do not over apply deicing chemicals; follow the recommended dosage.
- Do not use deicing chemicals in place of snow removal but reserve them for melting ice formed by freezing precipitation or freezing snow melt.

*Figure 9. Efflorescence is only an aesthetic concern and can be removed with cleaners specifically formulated for this task.*

*Table 2. Common deicer affect on ICP*

| Deicer | Effective Temperature [1] °F [°C][2] | Potential Freeze Thaw Degradation of Concrete | Additional Potential of Chemical Degradation of Concrete | Comments |
|---|---|---|---|---|
| NaCl<br>Sodium Chloride | 15 [ -9] | Least Among Deicing Salts | Minimal | Least damaging deicer; use whenever possible. |
| $CaCl_2$<br>Calcium Chloride | -2 [-19] | Minimal to Moderate | Moderate | Use judicially if a more effective, quicker acting deicer is needed. |
| CMA<br>Calcium Magnesium Acetate | 19 [-7] | Moderate | Moderate to Significant | Not recommended. Potential for damage increases with the amount of magnesium in the formulation |
| $MgCl_2$<br>Magnesium Chloride | -8 [-22] | Moderate to Significant | Significant | Not recommended. Highest potential for damage. |

[1]Effective temperature is lowest practical temperature of the deicer defined as the lowest temperature at which the relative melting potential (MP) is 0.7 as calculated in reference 1 below.

[2]Information adapted from National Cooperative Highway Research Program Report 577 "Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts" ©2007 Transportation Research Board

- Once loosened, snow, ice and excess deicing salts should be promptly removed by plow or shovel to avoid a buildup in concentration of the deicing chemical(s). If excess snow, ice and deicing salts is to be stored on-site do not store on concrete paver pavement.
- Protect vegetation and metal from contact with deicing chemicals as most can impair vegetation and corrode metals.

ICPI recommends adequate pavement slopes (typically a minimum of 2%) to facilitate surface water drainage and to help remove deicing materials. While not essential, reduction of water entering jointing sand can be further enhanced with joint sand stabilization materials and/or sealers.

Table 2 compares common deicing chemicals and their effective temperatures to their impact on degradation of the concrete.

## Distress Types and Remedies

Some distresses are aesthetic in nature and others affect the structural integrity of the pavement system. Identifying the type of distress points to repairs that can return the pavement to a high-performance level.

### Aesthetic (Visual)

Aesthetic distresses typically do not affect the structural performance of the interlocking concrete pavement system.

#### *Efflorescence*

Efflorescence is a white haze that may appear on the surface of pavers sometime after installation as seen in Figure 9. It forms from Portland cement reacting with water. This reaction creates water-soluble calcium hydroxide (lime). When water enters the microscopic capillaries in the pavers, calcium hydroxide is dissolved and carried to the paver surface, where it reacts with the carbon dioxide in the air to become calcium carbonate. This forms a white haze on the surface of the pavers when the water evaporates. The appearance of efflorescence stops when the calcium hydroxide supply is exhausted.

Efflorescence is not a structural, but rather an aesthetic concern. The white haze may give the impression that the color of the pavers is fading but this is not the case. Efflorescence may occur randomly or be concentrated in certain areas. Dark colored pavers show efflorescence more than lighter colored ones.

Most paver producers put chemical additives in the concrete to reduce the likelihood of efflorescence occurring. In most cases the additives prevent efflorescence. However, completely eliminating the chance of efflorescence isn't possible because it's a natural by-product of curing concrete.

If efflorescence occurs, it can be removed with cleaners specifically made for concrete pavers. Careless or improper cleaning can result in damage and discoloration to paver surfaces. Contact the paver supplier for further information

*Figure 10. Excessive scratching from a snow plow can lead to rust stains.*

*Figure 11. Pressure washers are commonly used to clean ICP. When using be careful not to remove joint sand.*

*Figure 12. From the underside of the pressure washing attachment, it is possible to see the rotating pressure wand, which sprays the pavement surface.*

on commercially available cleaners. ICPI *Tech Spec 5–Cleaning and Sealing interlocking Concrete Pavement–A Maintenance and Protection Guide* provides additional details.

***Dirt and Stains***

Numerous companies sell products designed specifically to clean concrete pavers. Some are general cleaners and some are specific to the type of stain being removed. As an example, there are cleaners designed to remove only rust stains like those shown in Figure 10. Pressure washers, shown in Figure 11, are a commonly used tool used to clean pavers. Professionals use specialized equipment shown in Figure 12 to maximize the cleaner's effectiveness and minimize any damage to the pavement.

Concrete pavers generally aren't damaged by petroleum products, but oil stains from vehicles can be difficult to remove.

*Figure 13. Joint sand stabilization could have been used to reduce the affects of weeds and ants.*

*Figure 14. Cleaning the ICP surface can remove fine particles lodged in the pores of the concrete surface to rejuvenate the color.*

*Figure 15. Coarse debris like winter sand should be removed from the paver surface to reduce abrasion.*

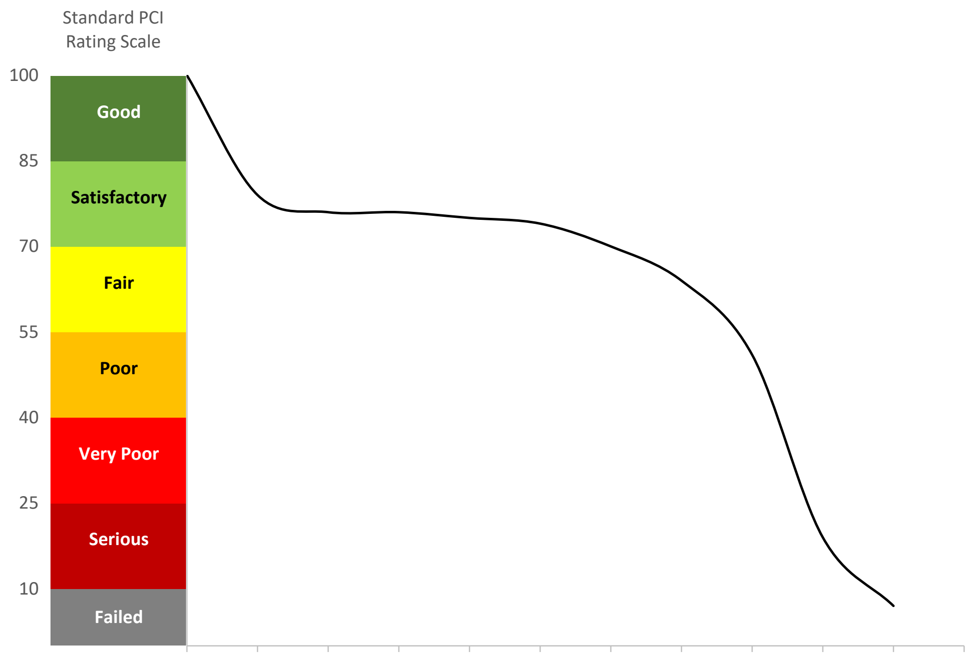


*Figure 16. Pavement Condition Index Surveys can be used to predict when maintenance might be required.*

Oil stains should be treated as soon as possible. The longer they remain on the surface, the deeper they penetrate making them harder to remove.

First, wipe oil from the surface and apply liquid detergent. Allow it to soak for several minutes, scrub, then rinse the pavers with hot water. Several treatments may be necessary to remove particularly stubborn stains. For best results use cleaners specially made for removing oil stains from concrete pavers. Keep in mind that due to their modular nature, replacing stained pavers might be simpler and less expensive than attempting to removed stubborn stains.

Cleaning and sealing concrete pavers can make removing stains easier, since sealers prevent stains from soaking into the surface. The sealers may need to be reapplied from time to time due to wear and weather. Concrete pavers should be cleaned prior to sealer application to obtain the best performance and appearance. It is generally recommended that pavers be sealed after any efflorescence issues are under control. If there are concern about the reoccurrence of efflorescence, use of a "breathable" sealer is recommended.

Removing oil and many other stains is discussed in ICPI *Tech Spec 5–Cleaning and Sealing Interlocking Concrete Pavement—A Maintenance and Protection Guide*. The paver supplier can provide information on cleaners and sealers specifically made for concrete pavers.

### *Weeds and Ants*

Contrary to some views, weeds don't grow from the bedding sand, base, or subgrade. Weeds can germinate between pavers from windblown seeds lodged in the joints. See Figure 13. Weeds can be removed by hand or killed using steam or a herbicide. Take care in using herbicides so that adjacent vegetated areas are not damaged. Use biodegradable products that won't damage other vegetation or pollute water supplies when washed from the pavement surface. Besides stabilizing the joint sand, sealers can prevent seeds from germinating, and prevent ants from entering.

### *Color Fading*

Color in concrete pavers is achieved by adding pigment to the concrete mix during production. The cement in the concrete mix holds the pigments in place. Normal wear from traffic or weather gradually erodes the cement and pigment particles, exposing more of the aggregate and sand, causing a color change over time. Like all pavements, concrete pavers receive dirt from foot or tire traffic which changes the surface color. See Figure 14. Cleaning and sealing the surface of the concrete pavers can moderate the rate of color change. Besides enhancing the pavers' color, sealers can help prevent dirt from lodging in their surface.

### *Minor Abrasion and Wear Including Scratches*

Over time traffic will cause wear and abrasion of the paver surface just like all other pavements. As mentioned in the winter maintenance section, sand or gravel left on the paver surface year after year can lead to accelerated abrasion and wear shown in Figure 15. As noted in the section on Preventive Maintenance, a routine maintenance program should include removal of surface debris to minimize surface wear and abrasion.

## Structural

ASTM E2840 *Standard Practice for Pavement Condition Index Surveys for Interlocking Concrete Roads and Parking Lots* provides descriptions of distresses, severities and deduct values for calculating a pavement condition index (PCI), a fundamental tool for managing pavement preservation. This standard can be used to calculate a Pavement Condition Index (PCI) which is a value between 0 (very bad) and 100 (perfect) for an interlocking concrete pavement surface. Figure 16 shows how a typical pavement's PCI value will reduce over time. The severity and extent of eleven distresses (some unique to interlocking pavements) and deduct curves indicate the functional and operational condition of the pavement surface while providing clues to structural integrity. Moreover, the PCI establishes the pavement deterioration rate and helps forecast preservation activities, especially rehabilitation timing. Although not typically used in residential applications, the distresses in ASTM E2840 can be useful for identifying performance problems in residential interlocking concrete pavements.

The following list provides information about the eleven interlocking pavement distresses identified in ASTM E2840 and provide guidance for repair.

*Figure 17. Damaged pavers can be caused by excessive movement of the base or excessive concentrated loads applied to the surface.*

### *Damaged Pavers*

*Description*: Damaged pavers distresses such as chips, cracks, or spalls. Damage may indicate inadequate support causing shear breakage, etc. Figure 17

*Identification*: One or more chips, cracks, or spalls. Cracked pavers with little to no opening generally will not affect performance.

*Repair*: Replace with new pavers, compact, refill joint sand, compact.

*Figure 18. Depressions are caused by settlement of the base or subgrade and are easily spotted by the puddles formed after rain events.*

### *Depressions*

*Description*: Depressions are lower areas than those around it. Depressions are caused by settlement of the underlying subgrade or granular base, often from inadequate compaction. Other factors can be a saturated base or soil, excessive bedding sand thickness deformed from wheel loads, or washed out bedding and joint sand. Loose or inadequate edge restraints will cause pavers to move apart. Settlement is common on utility cut patches and adjacent to road hardware. Depressions can cause roughness in the pavement, and when filled with water, can cause hydroplaning of vehicles or slippery ice patches in the winter.

*Identification*: Depression are measured by placing a 3 m (10 foot) straight across the depression and measuring the high depth from it to the pavement.

Changes in shades of color on a pavement surface can give the impression of differential elevation where none exists. The apparent depth of differential elevation is often exaggerated by shadows in the early morning and late afternoon, as well as the chamfer on the paver edges. Standing water and stains can be used to visually identify depressions, like Figure 18, however, the boundaries and depth should be established using the straight edge or string line. Be careful to distinguish heaves from depressions.

*Repair*: Identify source (typically not load-related): Bedding, base or subgrade and repair per rutting distress described below. Pavers in uneven areas with low severity depressions can be removed, the settlement adjusted, and the units reinstalled with no wasted paving materials or unsightly patches.

***Edge Restraint***

*Description*: Edge strips and curbing are restraints that provide lateral support for pavers. Lateral restraint is considered essential to resisting movement, minimizing loss of joint and bedding sand, and preventing paver rotation as seen in Figure 19. Edge strips/curbs can comprise prefabricated metal or plastic supports, concrete curbs, etc. This distress is accelerated by repeated traffic loading.

*Identification*: Loss of lateral restraint is characterized by widening of the paver joints at the outer pavement edge or at the transition of pavement types. Pavers at the perimeter can exhibit vertical and horizontal rotation as well as local edge settlement. The distress is most notable within 0.3 to 0.6 m (1 ft to 2 ft) of the pavement edge.

*Repair*: Repair/replace edge restraint/curb & adjacent pavers, compact, refill joint sand, compact.

***Excessive Joint Width***

*Description*: Excessive joint width means the joints between pavers have widened. Excessive joint width can occur from several factors including poor initial construction, lack of joint sand, poor edge restraint, adjacent settlement/heave, lateral movement of the pavers, etc. As joints get wider, the layer becomes less stiff and can lead to overstressing the substructure layers.

*Identification*: Optimal paver spacing is typically specified as 1.5 to 3 mm (0.05 to 0.12 inches). Significant variation in joint width will highlight excessive joint width as shown in Figure 20. As joints get wider, the individual blocks may show signs of rotation.

*Repair*: Identify reason for paver joint movements. Remove the pavers and remediate the cause. Reinstate pavers to specified joints widths, compact, refill joint sand, compact.

***Faulting***

*Description*: Faulting happens when the elevation of adjacent pavers differs or have rotated. Faulting can be caused by surficial settlement of the bedding sand, poor installation, pumping of the joint or bedding sand. Local roughness can reduce the ride quality. Faulting can pose a safety hazard for pedestrians.

*Identification*: Faulting is characterized by small areas of individual units standing slightly proud above their neighbors. This can bee seen in Figure 21. This distress is often associated with more severe distresses such as settlement, heave, rutting, etc.

*Figure 19. Lack of an effective edge restraint has allowed the pavers to separate and compromise the structural capacity of the ICP.*

*Figure 20. Variation in the joint width is a typical present in ICP with excessive joint width.*

*Figure 21. Faulting can be seen as a line of pavers being lifted above the neighboring units.*

*Figure 22. Heave is typically seen near structures that have moved due to freeze-thaw action.*

*Figure 23. Horizontal Creep is easily spotted in ICP areas that were constructed straight, but over time develop a wave in the pattern.*

*Figure 24. Joint sand loss should be repaired when the void created is greater than 1/2 in. (12 mm).*

*Repair*: Faulting may be corrected by resetting the blocks. However, faulting may be caused by differential base movement. In this case repair base, replace bedding, reinstate pavers, compact, refill joint sand, compact.

***Heave***

*Description*: Heaves exhibit elevations higher than surrounding areas. Heaves are typically caused by frost heave of the underlying soils as shown in Figure 22. Heaves can also occur because of subgrade instability and can also occur in conjunction with settlement / rutting.

*Identification*: Visual examination is not always a reliable technique for detection of heaves, especially for low severity depressions. The most reliable method is using a 3 m straight edge.

*Repair*: If from frost, install frost-resistant subbase materials. Consult w/ geotechnical engineer if not frost related.

***Horizontal Creep***

*Description*: Horizontal creep is the longitudinal displacement of the paving pattern caused by repeated braking, accelerating, or turning tires.

*Identification*: Regardless of the paver pattern, the pavement surface should have a uniform pattern. Shifting of the joints or pattern signify horizontal creep as seen in Figure 23.

*Repair*: Remove and reinstate pavers in original laying pattern. Apply steel, anti-creep reinforcement under the pavers in severe cases. Compact, refill joint sand, compact.

***Joint Sand Loss/Pumping***

*Description*: Joint sand loss/pumping typically includes removal of some or all joint sand, an essential component of interlock and pavement stiffness. Joint sand loss can occur from pressure washing, saturated bedding sand that pumps under traffic loading, etc.

*Identification*: Surface of the joint sand is well below the paver chamfer or the top of the paver if there is no chamfer as shown in Figure 24. Stains on the pavers indicate a saturated bedding layer.

*Repair*: Provide bedding layer drainage, replace with washed bedding sand, provide bedding layer drainage, reinstate pavers, compact, refill joint sand with ICPI recommended material, compact.

***Missing Pavers***

*Description*: Missing pavers, as the name implies, refers to sections of pavement without pavers resulting from removal or disintegration/damage. Missing pavers compromise the integrity of the pavement structure and promote surface roughness like potholes in flexible pavements.

*Figure 25. Missing pavers should be replaced as soon as possible to avoid damage to the surrounding units.*

*Figure 26. Patching compromises the structural integrity of ICP and occurs when proper maintenance techniques are not followed.*

*Identification*: One or more missing pavers as illustrated in Figure 25.

*Repair*: Replace with new pavers

#### *Patching*

*Description*: Patching includes missing pavers replaced with a dissimilar material. Patch quality can compromise the integrity of the pavement structure and promote surface roughness.

*Identification*: Sections of dissimilar materials such as asphalt, etc as shown in Figure 26.

*Repair*: Remove the patch materials and replace with new pavers. May require establish a new bedding layer.

#### *Rutting*

*Description*: Rutting is a surface depression in the wheel path. Rutting is typically caused by settlement of the underlying subgrade or granular base under repetitive wheel loads. Rutting can cause roughness in the pavement and when filled with water can cause hydroplaning of vehicles.

*Identification*: Locate rutting by visual assessment and measure rutting with a straight edge. See Figure 27. Rutting in a single wheel path is usually quite evident. However, depressions caused by static wheel loads are measured as rutting.

*Repair*: Minor rutting typically occurs in bedding from excessive fines in the bedding sand and lack of surface and/or bedding drainage. Check slopes, drainage, and sand durability. Major rutting often indicates insufficient base thickness/stiffness loads – repair/ replace base, install bedding, reinstate pavers, compact, refill joint sand, compact.

## Restoration

This section provides steps to remove pavement layers to address the underlying issue and reinstate the pavement.

### Evaluate the Design

Before reconstructing what was originally constructed, consider the structural design and determine appropriateness for the application. This is particularly important if any distress is present that cannot be explained. Specific details reviewed include:

- Paver aspect ratio
- Paver laying pattern
- Base thickness
- Adequate slope and drainage

*Figure 27. Rutting occurs when the underlying layers settle. The extent of rutting is easily measured by laying a straight edge across the rut.*

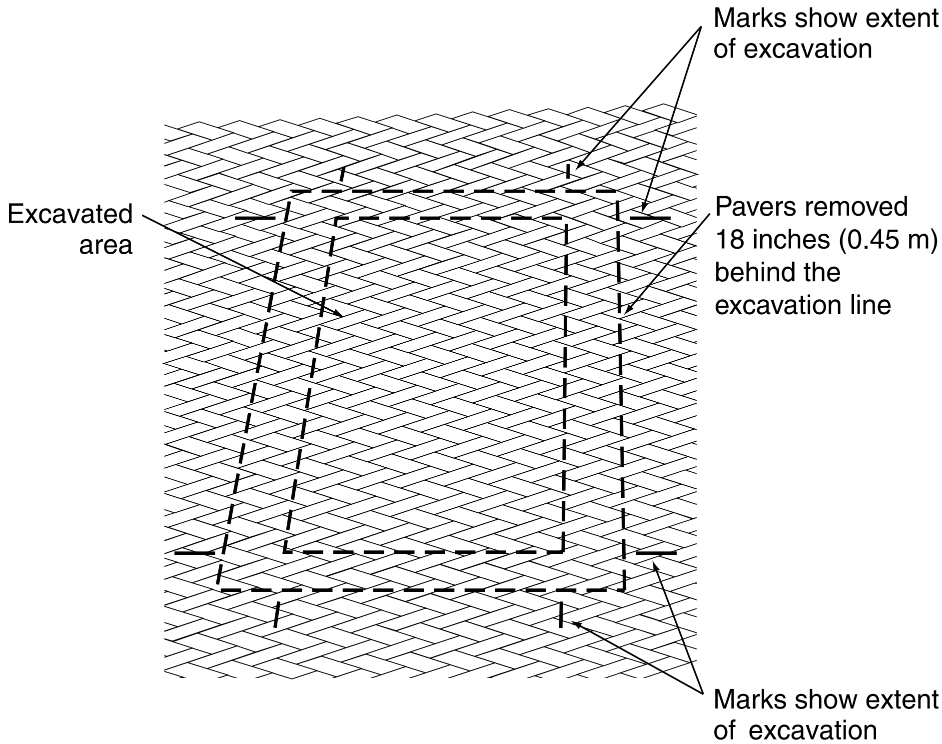


*Figure 28. Mark limits of excavation and remove pavers at least 18 in. (450 mm) beyond those limits.*

### Disassembly

Concrete pavers can act as a zipper in the pavement that facilitate underground repairs by removal and reinstatement of the same concrete pavers. Unlike asphalt or poured-in-place concrete, segmental pavement can be opened and closed without using jack hammers on the surface and with less construction equipment. This results in no ugly patches and no reduction in pavement service life. In addition, no curing means fast repairs with reduced user delays and related costs.

Repair of a segmental pavement system might not require removal of the entire pavement area. It is possible only the area showing signs of distress would need to be repaired. It might also not be necessary to remove the full depth of the system. Depending on the type of distress identified, it might only be necessary to remove the top layers and leave the lower layers intact. The section on Distress Types and Remedies provides guidance on disassembly and reinstatement.

The following step-by-step procedure covers how to "unzip and zip" interlocking concrete pavement. This procedure applies to any interlocking concrete pavement, including pedestrian areas, parking lots, driveways, streets, industrial, port and airport pavements.

#### *Identify Area to be Excavated*

The location and depth of existing utilities need to be established prior to excavating. Many localities have one telephone number to call for obtaining marked utility locations. Set cones, traffic signs, or barricades around the area to be excavated according to local, state, or provincial standards. Determine and mark the area of pavers to be removed. Remove pavers at least 18 inches (0.45 m) wider on each side of the trench opening. This shoulder around the opening should consist of undisturbed bedding sand. It will be used as a guide for reinstating the sand and pavers later (Figure 28).

Paint or crayon should be used to mark the area of pavers for removal. The trench area can be marked on the pavers as well. Paint may be necessary to establish a more permanent marking than crayon, especially if there is vehicular traffic,

During the disassembly process it may be appropriate to confirm the materials being removed meet specifications and thicknesses. The ICPI *Construction Tolerances and Recommendations for Interlocking Concrete Pavements* guide is an excellent reference to confirm construction details.

### Hire an ICPI Certified Concrete Paver Installer

ICPI Certified Concrete Paver Installers receive training about the most effective and efficient materials and methods recommended for the construction of segmental concrete pavement systems. Certified installers are recommended for restoration of concrete paver installations. A Certified Concrete Paver Installer's credentials can be confirmed at www.ICPI.org.

An experienced crew can reinstate pavers with little or no cutting, aligning reinstated pavers with existing joint lines, pattern, and spacing between the units.

Although existing pavers can be reused in reinstatement, there may be projects where it is more cost effective to remove and replace the area with new pavers. Stabilized joint sand may be difficult to remove from the pavers and recycling the pavers may be more cost-effective. An experienced paver installation contractor can provide guidance on cost-effective approaches for each reinstatement project.

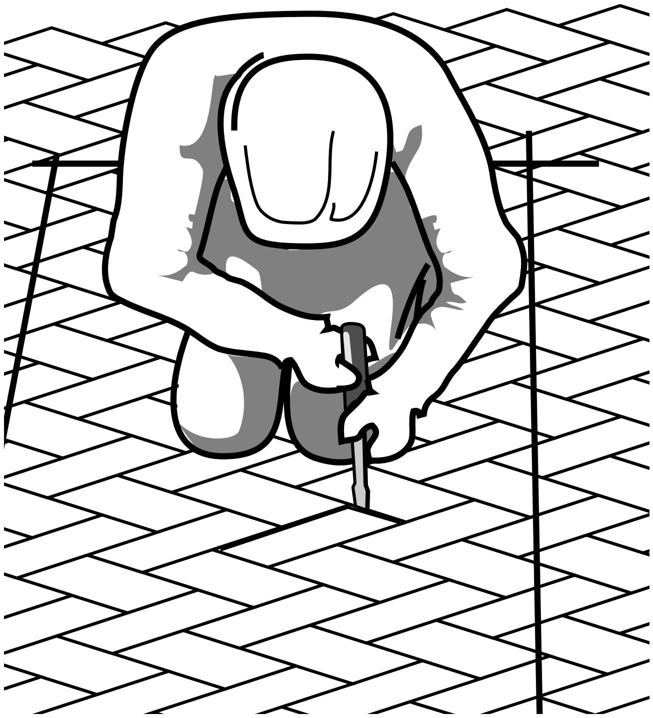

*Figure 29. Remove sand from joints surrounding first paver to be removed with a putty knife or screwdriver.*

*Figure 30. A paver extractor can be used to grab the first paver and wiggle it out.*

or if there will be an extended period between marking and excavation. The same paving units will be reused, so in some instances paint on them may not be desirable, especially if there is little traffic to wear it away over time.

***Remove Joint Sand***

Scrape the sand from the joints around the first paver using a putty knife or small trowel (Figure 29). If joint sand stabilizer was used, it will take more effort to remove the paver.

Alternately, a pressure washer can be used to dislodge the joint sand around the first pavers to be removed.

***Pavers***

Locate the first paver to be removed. This is typically at one end of the marked area. Use a paver extractor to remove the first paver and subsequent ones (Figure 30). They are designed to clamp the paver tightly. These work most efficiently in removing the first paver if some of the joint sand is removed before clamping and pulling. Water can be applied to lubricate the joint sand to facilitate extraction.

Alternately, it is possible to carefully pry each side of a paver upward with one or two large screwdrivers. Begin prying on the short ends of the paver. The paver will rise a small distance with each prying (Figure 31). When the paver is high enough to grasp, wiggle it loose, pulling upward. If necessary, pry with a screwdriver using one hand while pulling upward with the other. Sometimes, one end of the paver can be pulled above

*Figure 31.A pair of slot screwdrivers can also be used to wiggle out the first paver. Care must be used to slowly work the unit out and not damage the surround paver edges.*

the others so a pry bar can be inserted under it. The paver can then be pried out.

If the pavement has been subject to vehicular traffic for a length of time, the pavers may be tightly locked together and the first paver may need to be broken for removal. A small sledgehammer (3 lb. maul) applied to an appropriate chisel will break a paver into small pieces. Protective eye goggles should be worn during this procedure. Remove all broken pieces from the space until the bedding sand is completely exposed. Pneumatic hammers or cutting saws are generally not required for this process.

After the first paver is removed, surrounding pavers can be loosened and pried out (Figure 32). Grab the pavers by the short end, as it offers less resistance than the long side. Remove pavers to the marks on the pavement for the opening.

Sand sticking to the sides and bottoms of pavers can interfere with their reinstatement and compaction into the bedding sand. Scrape off sand from each unit as it is being removed. A small trowel, wide putty knife, wire brush, or another paver works well. Again, if stabilized joint sand has been used, it will take more effort to remove the sand sticking to the paver.

The direction of removal should consider where pavers are going to be stacked. Stack the pavers neatly near the opening, out of the way of excavation equipment such as backhoes or dump trucks. If the pavers need to be removed from the site, stack them on wooden pallets and secure them tightly so there is no loss during transit.

Equipment used to move pallets with pavers should be capable of lifting more than 3,000 lbs. (1,365 kg). If the pavers need to be moved only a short distance, then stack them directly on a paver cart at the opening and set them nearby. They will then be ready for pickup by the paver cart when reinstated.

For every project, a small stockpile of spare pavers should be stored and used for repairs during the life of the pavement. Weathering, wear, and stains may change the appearance of removed pavers compared to spares kept in storage for repairs. When pavers are removed, all undamaged units should be retained for future reinstatement. Pavers from the stockpile that replace damaged or broken units should be scattered among the pattern of the existing reinstated pavers. This will reduce the visual impact of color variations.

***Bedding***

The removed pavers will reveal compacted bedding sand. It may be removed and reused or removed during excavation of the base. For some projects with time constraints, the sand will probably be removed during excavation and not reused.

If the sand is reused, it may need to be loosened with rakes before removal by shoveling. The sand should be neatly stockpiled and kept free from soil, aggregate base, or foreign material. If the sand is mixed with these materials, it should not be reused, and it should be replaced.

Whether or not it is reused, always leave an undisturbed area of sand 6 to 12 in. (15 to 30 cm) wide next to the undisturbed pavers. This area will provide a stable support for temporary edge restraints and for screeding the bedding sand after the base is reinstated.

***Edge Restraint***

If the edge restraint is showing signs of distress. Is loose and not serving it purpose remove the section that is not performing adequately. When removing, consider how the reinstated edge restraint will connect back into the remaining edge restraint.

***Install Temporary Bracing***

Install temporary bracing with wood, plastic, or metal edge restraints around the perimeter of the opening. Using 2x4s placed on their side around the opening and braced with more 2x4s can be very effective. This is recommended practice. If the restraints are to be spiked in they can be pinned to the base using metal spikes (Figure 33), but damage to the base created by removing the spikes will need to be repaired during the reinstatement process. Bracing helps keep the undisturbed pavers in place during excavation and fill activities and will enable reinstatement of units into the existing laying pattern without cutting them to fit.

*Figure 32. A pick or pry bar can be used to reach under the pavement edge and pry units out.*

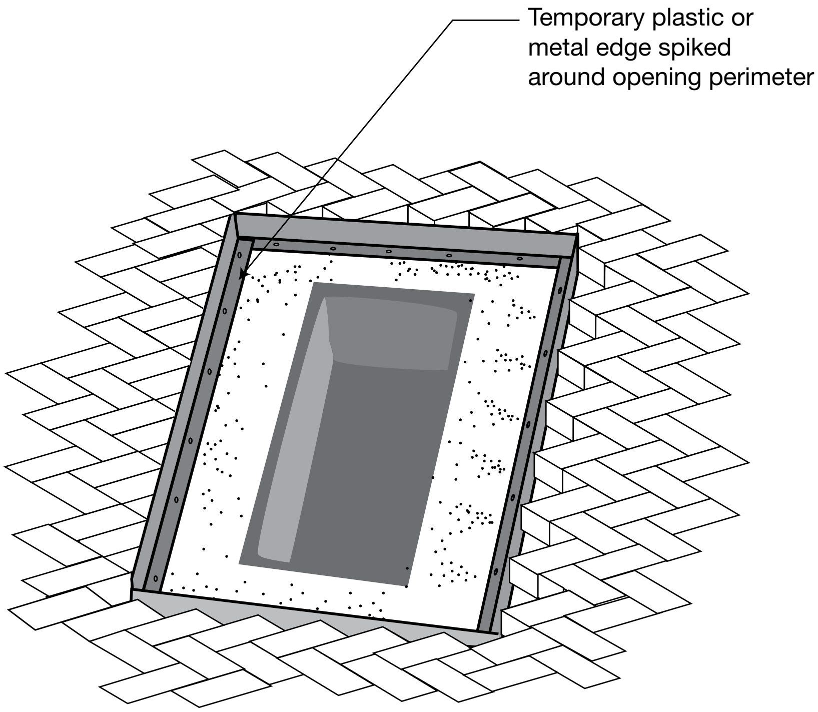


*Figure 33. Temporary bracing should be installed along the edges created by the opening in the pavement to ensure the pavers around the perimeter do not move and reduce the size of the opening which would make reinstatement more difficult.*

***Base and Subgrade***

If aggregate base material is removed, it may be possible to stockpile it near the opening for reuse. Keep the aggregate base material separate from excavated subgrade soil. Any soil removed should be replaced with base material unless local regulations require reinstatement of the native soil. The final shape of the excavated opening should offset from the bracing. (Figure 34). This helps prevent undermining and weakening of the adjacent pavement. Follow local codes for trenching requirements and the use of shoring, as it may need to be inserted to prevent collapse of the trench sides.

**Reinstatement**

Before placing any materials, it would be useful to review ICPI *Tech Spec 2–Construction of Interlocking Concrete Pavement* and *Construction Tolerances and Recommendations for Interlocking Concrete Pavements* to ensure materials to be placed and methods used agree with industry best practices.

***Subgrade***

After the repairs are complete, soil at the bottom of the trench should be compacted prior

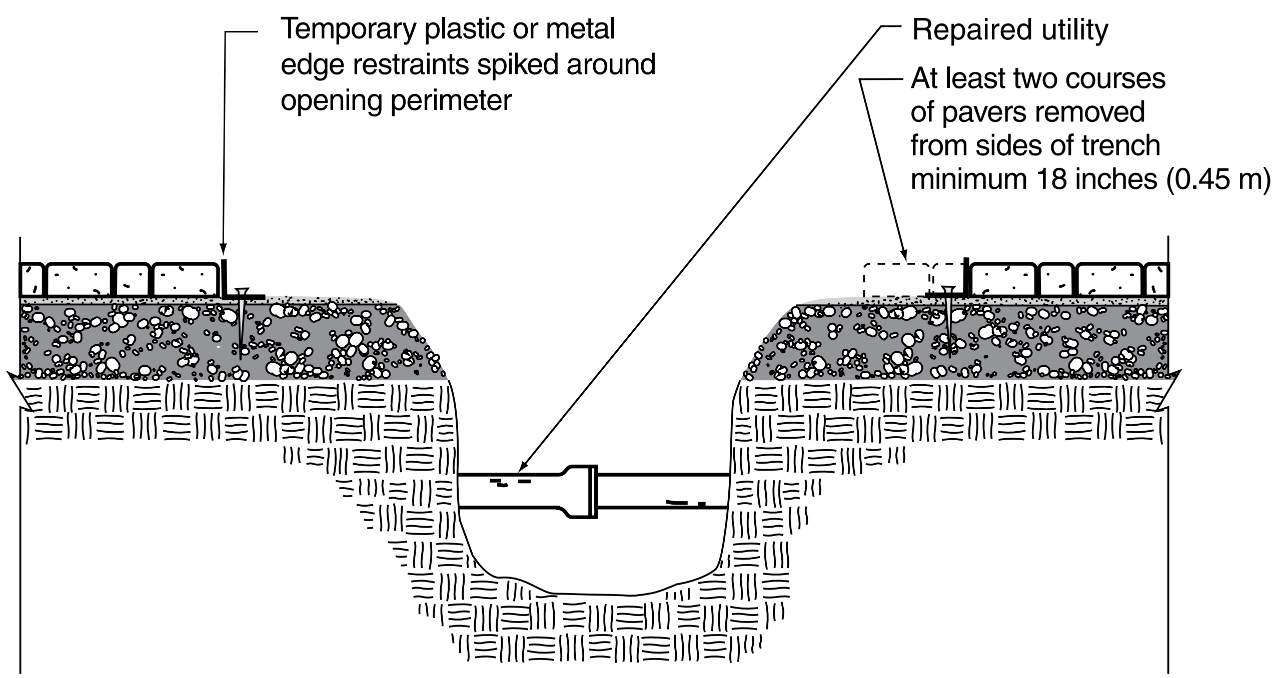


*Figure 34. This figure shows how the layers are peeled back to allow access under the pavement for repair work.*

*Figure 35. The subgrade should be re-established with a material that can be fully compacted and have little potential for settlement.*

to placing and compacting the base material. Repairs typically use the same base material that was removed. A crushed stone aggregate base should be placed and compacted in 4 to 6 inch (100 to 150 mm) lifts (Figure 35). If the excavated base material was stabilized with asphalt or cement, it should be replaced with similar materials.

Monitoring density of the compacted soil subgrade and base is essential to reinstating any pavement, including interlocking concrete pavements. It will help prevent rutting and premature failure. A dynamic cone penetrometer is an effective means for monitoring the density of each lift while working in the opening. If the soil or base material is too dry during compaction, a small amount of water can be sprayed over each lift prior to compacting. This will help achieve maximum density. A nuclear density gauge is recommended for checking the density of the completed compaction of the soil and base layers. A qualified civil engineer should monitor compaction for conformance to local standards.

If there are no local standards for compaction, a minimum of 98% standard Proctor density is recommended for the soil subgrade, and a minimum of 98% modified Proctor density for the base. Compaction equipment companies can provide guidelines on equipment selection and use on the soil and the base. For further guidance on compaction see ICPI *Tech Spec 2–Construction of Interlocking Concrete Pavements.*

***Geotextile***

Placing a geotextile between the subgrade and base can prevent the subgrade from contaminating the base aggregate and reducing the system's long-term performance. Consult *Tech Spec 22–Geosynthetics for Segmental Concrete Pavements* for details of the selection of an appropriate material.

***Base***

The final elevation of the compacted base at the opening perimeter should match the bottom of the existing undisturbed sand layer that surrounds the opening (Figure 36). The elevation of the middle of the base fill placed in the opening should be slightly higher than its perimeter to compensate for minor settlement. ICPI *Tech Spec 4–Structural Design of Interlocking Concrete Pavement for Roads and Parking Lots* and ASCE 58-16 can provide guidance on the minimum recommended base thickness.

Controlled low-strength materials (CLSM) (sometimes called slurry mix, flowable fill, or unshrinkable fill) can be used in some applications as a replacement for unstabilized base materials (1). The fill can be made from aggregate bound with fly ash, pozzolans, or cement. Because it is poured from a truck, the fill will form around pipes and underground structures where soil or base backfill and compaction are difficult. Low-strength

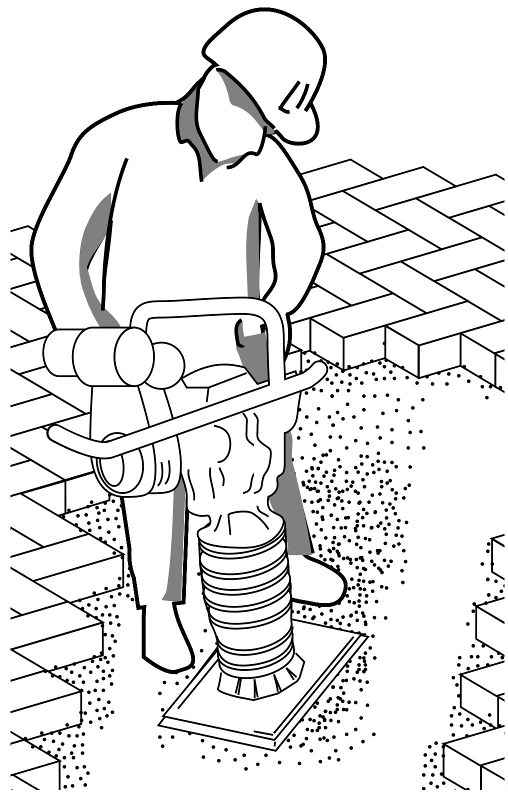

*Figure 36. The base should be reconstructed using a dense graded aggregate and fully compacted to minimize settlement.*

*Figure 37. "Flowable Fill" can provide a subgrade or base with little potential for future settlement and not require compaction.*

fill can be poured into undercuts and under pipes where it is impossible to fill and compact aggregate base. The material is also self-leveling (Figure 37).

Low strength flowable fill requires a short curing time and can be used in freezing weather. It requires no compaction and with some mix designs, can be opened to traffic in 24 hours. Low-strength fill is stiffer than aggregate base and offers higher resistance to settling and rutting. This reduces deterioration of the pavement surface over time. To facilitate re-excavation, flowable fill should be made with a small amount of cement. Check with suppliers on the strength of in-place fill that is at least two years old, and on ease of excavation of these sites. The strength of the fill should not exceed 300 psi (2 MPa) after two years of service. Low-strength fill has been used successfully in Toronto and London, Ontario; Colorado Springs, Colorado; Cincinnati, Ohio, Kansas City, Missouri; Peoria, Illinois; and many other municipalities. It is generally more cost-effective than using aggregate base by reducing job time and future pavement repairs. Local ready-mix suppliers can be contacted for available mixes, strengths, installation methods and prices. See ICPI *Tech Spec 7–Repair of Utility Cuts within Interlocking Concrete Pavements* for further information on low-strength fill.

***Edge restraint***

Ensure the edge restraint is constructed according to the details provided in ICPI *Tech Spec 3–Edge Restraints for Interlocking Concrete Pavements* and the system selected is recommended for the application.

***Remove Temporary Bracing***

Once the base has been reinstated it is appropriate to remove the temporary bracing. Repair any damage to the base this process might create.

***Bedding***

During the foregoing procedures, it is likely that the pavers and bedding sand around the opening were disturbed especially if no temporary edge restraints were placed to secure the pavers. If so, then remove an additional two rows of pavers, or back to an undisturbed course. Clean sand off of these pavers and set them aside with the others. Be sure there is at least 8 in. (200 mm) of undisturbed bedding sand exposed after removal of the course(s) of pavers. This area of undisturbed sand can be used to guide screeding of fresh bedding sand over the compacted and leveled base. Prior to screeding, carefully remove any temporary edge restraints so that adjacent pavers remain undisturbed.

Place a straight edge or string line across the paver surface on either side of the opening. Measure down at several points along the string line to confirm the base follows the grade of the surrounding paver surface, with a slight crown near the center to account for future consolidation of the newly compacted base (Figure 38 and 39). It may be necessary to remove a few

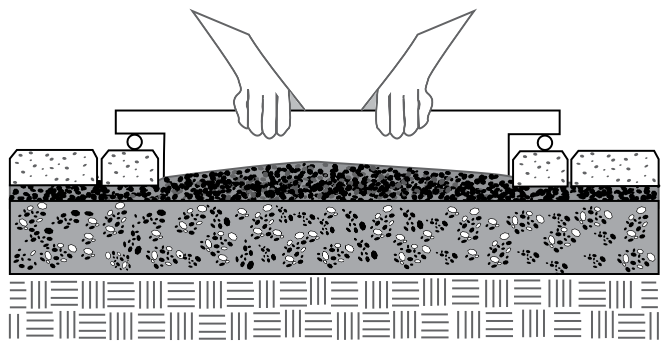

*Figure 38. Screed rails are placed on the surrounding paver surface and the screed bar is notched to provide the correct depth and crown for the bedding .*

*Figure 39. Alternately screed bar can be placed on the re-established base.*

*Figure 40. Pavers salvaged during the disassembly can be brought back and placed according to the original pattern. Care needs to be taken to ensure any remaining sand on the bottom or sides of the pavers is remove before placement.*

*Figure 41. An alignment bar and string line can be useful to tweak the pattern and make it line up with the surrounding undisturbed paver.*

courses of pavers to straighten the edge of the pavers. Low areas should be filled with base material and compacted. Do not use the bedding sand to compensate for low places in the surface of the base.

Use a string line to determine the undisturbed bedding sand thickness by measuring from the string line to the base surface then subtract the paver thickness. This should be ap-

*Figure 42. Paver are compacted into the loose bedding sand. Joint sand is then swept and vibrated into the joints until they are filled to complete the repair.*

proximately 5/8 in. (16 mm). Set screed rails below the string line the thickness of the pavers minus 50% of the undisturbed bedding sand thickness. The additional thickness of the bedding sand will account for compaction and sand moving into the joints. Screed sand to ensure uniform thickness is placed over entire base surface.

It may be necessary to confirm this is the correct bedding thickness by placing pavers and compacting. The paver surface should be 1/16 to 1/8 in. (2 to 3 mm) above the adjacent paver surface to account for further consolidation.

Further information regarding bedding sand is available in ICPI *Tech Spec 17–Bedding Sand Selection for Interlocking Concrete Pavements in Vehicular Applications*.

***Pavers***

Pull and secure string lines across the opening along the pavement joints every 6 to 10 ft. (2 to 3 m). By following the string lines, joints of reinstated pavers will remain aligned with undisturbed ones. Lay the remaining pavers in the original laying pattern from the smaller end of the opening, generally working "uphill," i.e., from a lower elevation of the pavement to the higher one (Figure 40). Minor adjustments to the alignment and spacing of joints can be made with alignment bars (Figure 41), pry bars or large screw drivers. Adjust prior to compacting the pavers.

Compact pavers with at least two passes of a minimum 5,000 lbf. (22 kN) plate compactor. The path of the plate compactor should overlap onto the undisturbed pavers (Figure 42).

***Joint Sand***

Spread dry joint sand and compact again until the joints can no longer accept sand (Figure 14). Sweep away excess sand. The elevation of the reinstated pavers after compaction should be no higher than 1/8 in. (2 mm) at the edges and 3/16 in. (5 mm) at the center. Traffic and minor settlement will compact the pavers to a level surface. After a short period of time, the repaired area will be undetectable (Figure 15).

Applications prone to joint sand loss like steep slopes, concentrated surface water flow and continually windy areas are good candidates for joint sand stabilization. If an area is reinstated in such applications, then the use of a joint sand stabilization is recommended. See *ICPI Tech Spec 5–Cleaning and Sealing Interlocking Concrete Pavements* for advice on joint sand stabilization. Additional information about joint sand is included in ICPI *Tech Spec 17–Bedding Sand Selection for Interlocking Concrete Pavements in Vehicular Applications*.

***Surface Treatment***

At the end of the reinstatement process, it may be appropriate to clean and possibly seal the reinstated and surrounding undisturbed pavers. Information on this process is available in ICPI *Tech Spec 5–Cleaning, Sealing and Joint Sand Stabilization of Interlocking Concrete Pavement.*

## References

Refer to the latest published ASTM and CSA standards and ICPI Tech Specs.

ASTM – American Society for Testing and Materials International, Conshocken, PA. www.astm.org

ASCE – American Society of Civil Engineers, Structural Design of Interlocking Concrete Pavements for Municipal Streets and Roadways. Reston, VA. www.ASCE.org

CSA – Canadian Standards Association, Rexdale, ON. www.csagroup.org

ICPI – Interlocking Concrete Pavement Institute, Chantilly, VA. www.ICPI.org

a. ICPI Construction Tolerances and Recommendations for Interlocking Concrete Pavements
b. ICPI Tech Spec 2, 3, 4, 5, 12, 13, 17, 22

*Controlled Low Strength Materials* (CLSM), ACI 229R-94, American Concrete Institute, Farmington Hills, Michigan, 1994.

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