Tech Specs

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Interlocking Concrete Pavement Institute®

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The Interlocking Concrete Pavement Institute (ICPI) is the authority for concrete pavers and slabs in North America, bringing together producers, contractors, dealers/distributors, industry suppliers and designers in an industry-wide effort to create high-quality products and deliver the best results for both residential and commercial customers. ICPI members represent the top segmental concrete paver and slab producers in North America and other countries like South Africa.

Tech Spec 25

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Interlocking Concrete Pavement Institute®

Construction Guidelines for Segmental Concrete Paving Slabs and Planks in Non-Vehicular Residential Applications

This Tech Spec provides installation guidelines for products defined in ASTM C1782 *Standard Specification for Utility Segmental Concrete Paving Slabs* and CSA A231.1 *Precast Concrete Paving Slabs*. While there are no ASTM and CSA product standards yet for for concrete planks (also called linear units), this techical bulletin covers minimum recommended product characteristics, as well as best practices for at-grade construction. As further research into the structural design for paving slab and plank pavement systems is completed the recommendations in this Tech Spec will be updated. Roof applications for paving slabs are covered in *ICPI Tech Spec 14–Segmental Concrete Paving Units for Roof Decks*.

Product Characteristics

Paving slabs—ASTM C1782 defines slabs as having an exposed face area greater than 101 in.^{2} (0.065 m^2) and a length divided by thickness (aspect ratio) greater than four. The minimum thickness is 1.2 in. (30 mm), and maximum length and width dimensions are 48 in. (1220 mm). Units require a minimum flexural strength of 725 psi (5 MPa) with no individual unit less than 650 psi (4.5 MPa). Units must meet dimensional tolerances for length, width, thickness and warpage, as well as a freeze-thaw durability requirements. Tighter tolerances for many sand-set and bitumen-set applications are noted in Table 1 in the section on Construction Guidelines.

In Canada, CSA A231.1 Precast Concrete Paving Slabs defines the dimensional envelope with a face area greater than 139.5 in.^{2} (0.09 m^2) and a length divided by thickness of greater than four. The minimum thickness is 1.2 in. (30 mm), and the maximum length and width dimensions are 39.3 in. (1000 mm). Units must have a minimum flexural strength of 650 (4.5 MPa) with no individual unit less than 600 psi (4.5 MPa). Units must meet dimensional tolerances for length, width, thickness and warpage, as well as a freeze-thaw durability requirements.

Planks—While there are no product standards for planks, they are generally defined as follows:

- Face area less than or equal to 288 in.2 (0.185 m^2)
- Length divided by thickness equal to or greater than 4
- Length divided by width equal to or greater than 4
- Minimum thickness = 2.375 in. (60 mm)
- Minimum length = 11.75 in. (298 mm)
- Maximum length = 48 in. (1220 mm)
- Minimum width = 3 in. (75 mm)
- Maximum width = 6 in. (153 mm)

Dimensional tolerances are provided in Table 1 under the Construction Guidelines section.

Flexural strength for planks can be determined using bending test apparatus like that in ASTM C1782 or CSA A231.1. At the time of delivery to the job site, the recommended minimum average flexural strength is 725 psi (5 MPa) with no individual unit below 650 psi (4.5 MPa). Freeze-thaw durability can be tested using methods referenced in ASTM C1782 or CSA A231.1.

Loading Limits Of Interlocking Concrete Pavements Compared To Paving Slabs and Planks

Paving slabs and planks are designed to be subject to much lower vehicular traffic than interlocking concrete pavers (or simply concrete pavers). Structural design guidance being develpoped by ICPI notes a maximum lifetime exposure 75,000 18,000 lb (80 kN) equivalent single axle loads (ESALs). In contrast, *ICPI Tech Spec 4–Structural Design of Interlocking Concrete Pavements* and ASCE 58-16 *Structural Design of Interlocking Concrete Pavement for Municipal Streets and Roadways* provides base and subbase thickness design tables for lifetime ESALs up to *10 million*. The ICPI and ASCE structural design methods are not applicable to paving slabs and planks.

Paving slabs and planks can be produced using dry cast, wet cast, hydraulically pressed manufacturing processes. For applications on aggregate bases, the units generally will installed according to subgrade, base, bedding sand materials and construction methods described in *ICPI Tech Spec 2–Construction of Interlocking Concrete Pavements*. Applications on compacted aggregate bases and bedding sand are for pedestrian or light automobile traffic with limited trucks. For additional vehicular traffic loads, slabs and planks should generally be installed on bedding sand over a concrete or asphalt base. For additional durability under vehicular traffic, paving slabs can be construed on a concrete base using the methods in *ICPI Tech Spec 20–Construction of Bituminous-Sand Set Interlocking Concrete Pavement*.

Construction Guidelines for Paving Slabs and Planks

Subgrade compaction and geotextiles—Per recommendations in Tech Spec 2, the soil subgrade should be compacted to at least 98% of standard Proctor density as specified in ASTM D698 *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort* (12 400 ft-lbf/ft^3 (600 kN-m/m^3)). Separation geotextile placed on the compacted soil subgrade and sides of the excavation. The separation fabric should be selected per AASHTO M-288 Geotextile Specification for Highway Applications.

Aggregate bases—These should conform to provincial, state, or local road agency specifications for bases used under asphalt. If there are no agency specifications, use ASTM D2940 *Standard Specification for Graded Aggregate Material For Bases or Subbases for Highways or Airports* for aggregate materials. Installed base surface tolerances should be ± 1/4 in. (6 mm) over a 10 ft (3 m) straightedge. This tolerance is tighter than the ± 3/8 in. (10 mm) over a 10 ft (3 m) straightedge for interlocking concrete pavements. The reason for the tighter base surface tolerance for slabs is to provide a more uniform support and help prevent vertical movement due to lack of interlock among the paving units. Bases should slope a minimum of 1.5% for drainage. The installed density should be at least 98% of standard Proctor density per ASTM D698. Figure 1 illustrates a typical cross section using an aggregate base.

Asphalt bases—These should conform to provincial, state or local road agency specfications. Asphalt bases can accommodate sand and bitumen-sand bedding materials. As noted for aggregate bases, the installed surface toler-

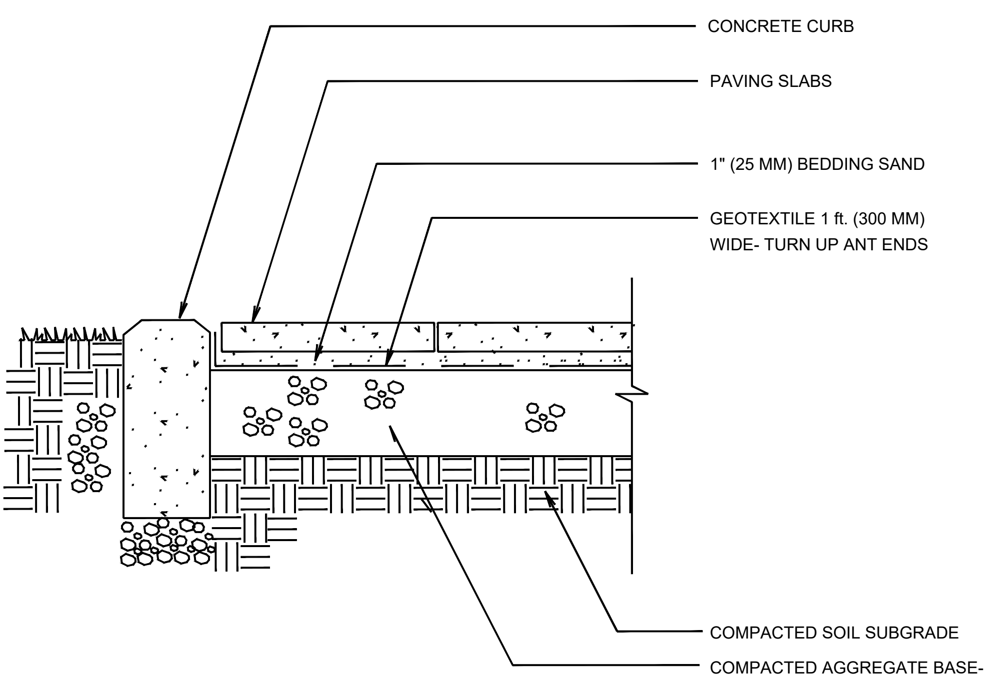

Figure 1. Typical paving slab assembly using an aggregate base

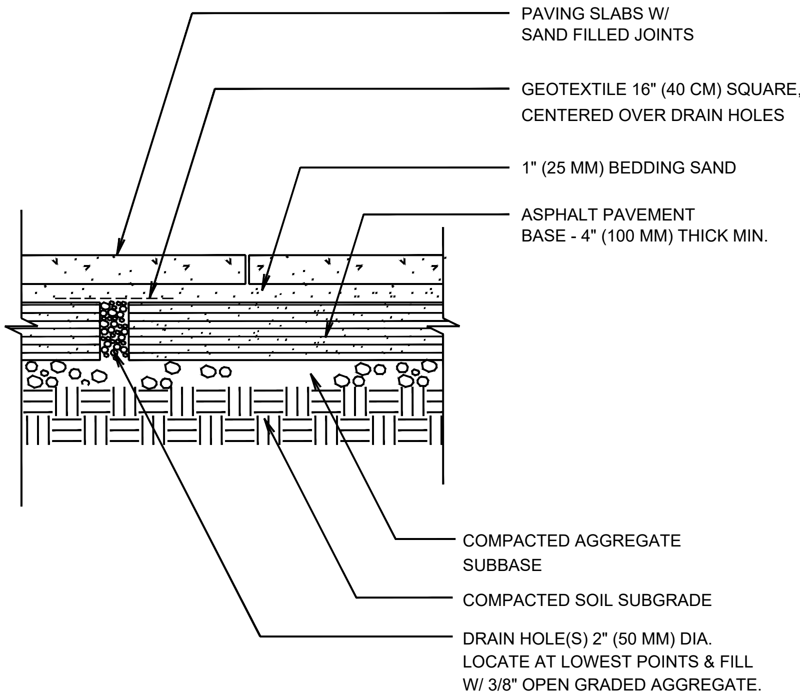

Figure 2. A typical cross section with an asphalt base and sand-set paving slabs

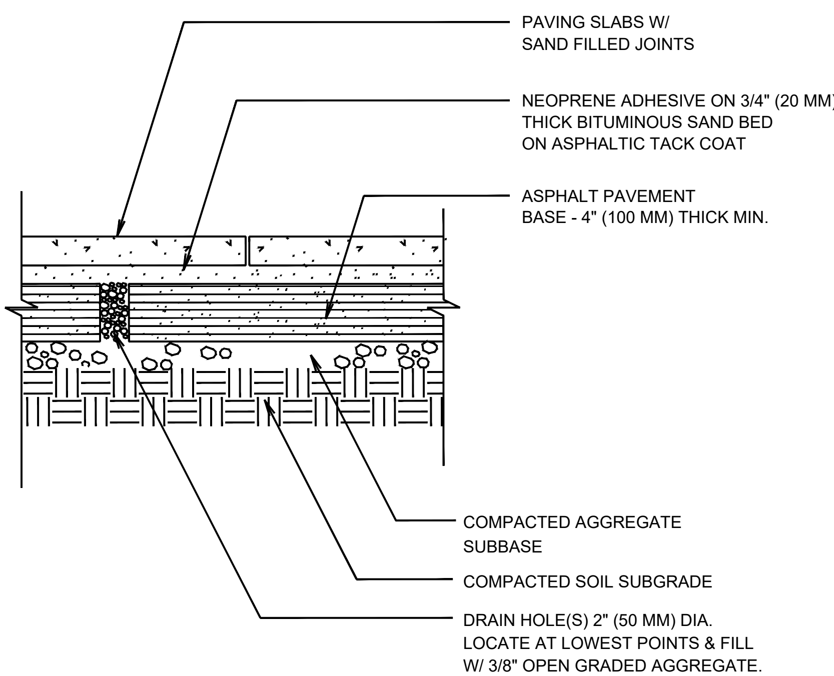

Figure 3. A typical cross section with an asphalt base and bitumen-set paving slabs

ance should be ± $^{3}/_{8}$ in. (10 mm) over a 10 ft (3 m) straightedge. Bases should slope a minimum of 1.5% for drainage.

Figures 2 and 3 illustrate sand-set and bitumen-set paving slab applications on an asphalt base.

Concrete bases—These should be made with minimum 3,500 psi (25 MPa) concrete per ASTM C39 *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*. The minimum concrete base thickness should

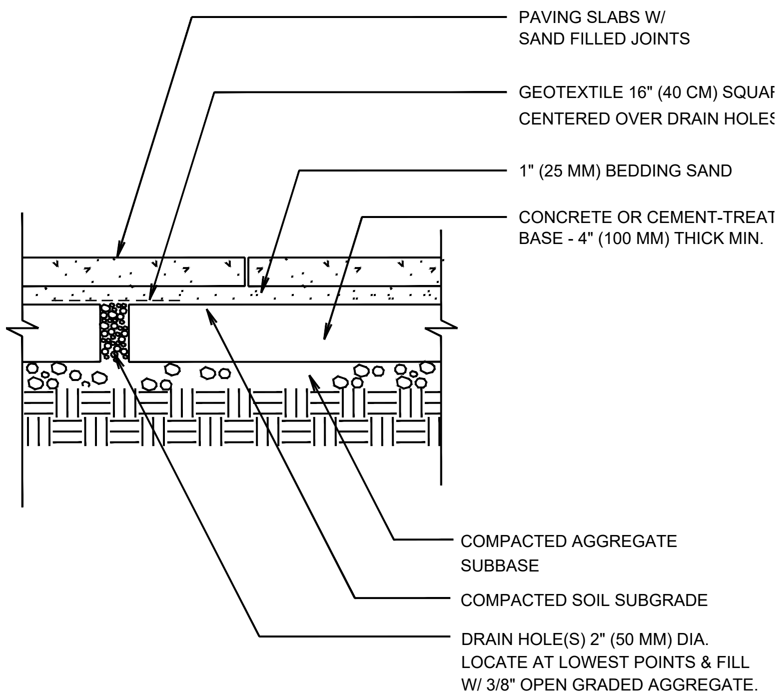

Figure 4. Typical cross section of sand-set paving slabs on a concrete base

be 4 in. (100 mm). Weep holes are recommended at the lowest elevations. These should be 2 in. (50 mm) in diameter, filled with washed pea gravel, and covered with geotextile to prevent loss of bedding sand. The surface tolerances of the concrete base should be ±¼ in. (6 mm) over a 10 ft (3 m) straightedge. Figure 4 shows a typical cross section.

Bedding sand materials and pre-compaction – Bedding sand should be 1 in. (25 mm) compacted thickness. This material should be washed concrete sand conforming to the gradations in ASTM C33 or CSA A23.2A. The percent passing the 0.075 or 0.080 mm sieves in these specifications should be no greater than 1%. Screenings or stone dust should not be used. Cement-stabilized sand should not be used due to lack of drainage and potential variability of cement content and resulting stiffness in the mix.

A very smooth, even bedding sand surface is required to seat paving slabs. For paving slab applicatons, some contractors prefer to pre-compact screeded bedding sand with a small plate compactor. If pre-compaction is done, care must be taken to leave no indentations in the bedding sand surface from the plate compactor. See Figure 5. These can be removed by screeding the surface to create a thin layer (6 – 10 mm) of uncompacted sand (also known as fluffing).

The entire bedding layer should not be used to compensate for variations in the base surface beyond the specified tolerances. Paving slabs do not interlock and therefore do not spread loads to their neighbors via joint sand. Given this condition, there is no requirement to force bedding sand into the bottom of the joints when compacting the units on uncompacted bedding sand, as is done with interlocking concrete pavers. Planks do not require pre-compaction of the bedding sand when installed over aggregate or concrete bases.

Figure 5. Precompacting the bedding sand

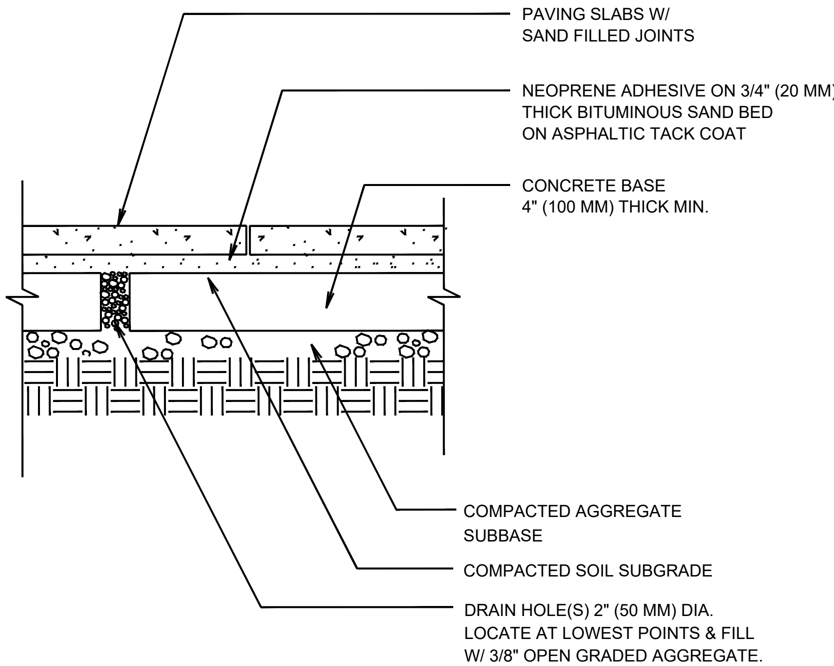

Figure 6. Typical cross section of bitumen-set paving slabs on a concrete base

Bitumen-set applications—These require a concrete base with a surface tolerance of ± ¼ in. (6 mm) over a 10 ft (3 m) straightedge. *ICPI Tech Spec 20 Construction of Bituminous-Sand Set Interlocking Concrete Pavement* provides a detailed description of the materials and construction procedures. For vehicular applications, a tack coat of emulsified asphalt is applied to the concrete base. This tack coat is not needed for pedestrian applications. A thin layer of sand-asphalt is then applied and compacted while hot. This layer is generally 3/4 in. (15 mm) thick. The material can be specified from provincial, state or local road agencies as the sand-asphalt surface layer typical to most asphalt roads. Figure 6 illustrates a typical cross section. Planks may be bitumen-set as well as paving slabs.

After the thin compacted asphalt layer is allowed to cool, a neoprene-asphalt mastic is troweled or squeegeed onto it surface per manufacturers instructions. This materials generally takes an hour or two to cure. When cured, it is ready to receive paving slabs or planks. See Figure 7. Once placed on the mastic, the units cannot be moved, so a correct, initial installation for each unit is critical to job efficiency. Removing and reinstating improperly installed paving units, as well as re-heating and re-applying the damaged sand-asphalt layer can be very time consuming.

Mortar bedding materials—Mortar is not commonly used with paving slabs and planks due to its increased expense compared to other assemblies, potential marring units with it during placement, and overall lack of construction speed. If specified, Type M mortar should conform to ASTM C270 S*tandard Specification for Mortar for Unit Masonry*. The appendix to this specification cautions on the use of mortar in pavement applications. Also, mortar conforming to ANSI A118.4–Latex Portland Cement Mortar, A118.7–Polymer Modified Cement Grouts or A118.8–Modified Epoxy Emulsion Mortar/Grout. Mortar bedding can be used in pedestrian applications in non-freezing climates and in freezing climates if fortified with a latex or epoxy additive as mortar can be susceptible to damage and deterioration from deicers. Figure 8 shows a typical cross section.

Figure 7. Sidewalk application illustrating the neoprene adhesive on an asphalt bedding layer under paving slabs

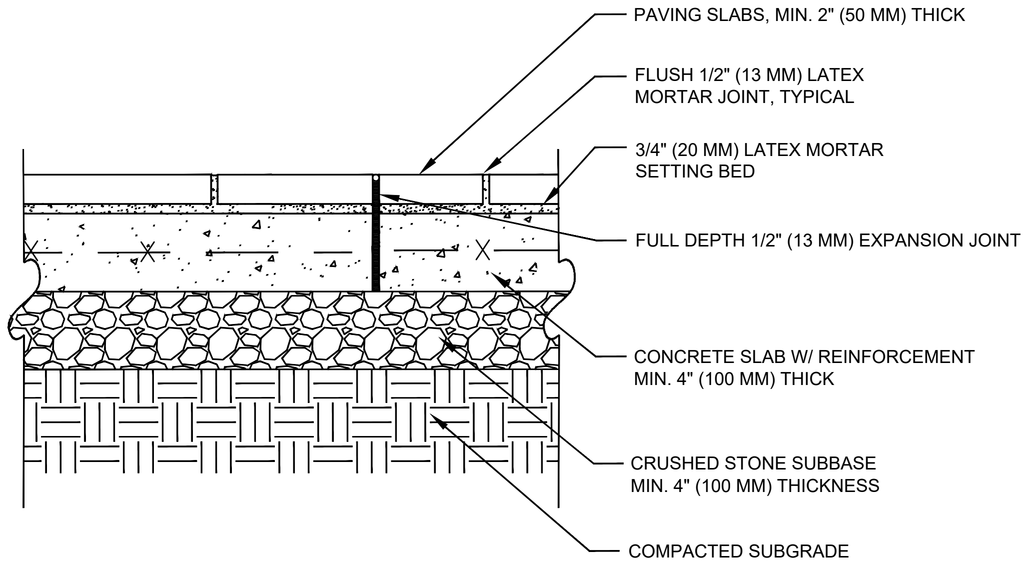

Figure 8. Typical mortar set slab application

Mortar-set paving slabs or planks are not recommended in vehicular applications in any climate. The exception to using mortar in vehicular applications is for positoning very thick (> 5 in. or >125 mm) and large (<4 ft or 1.2 m) paving slabs onto a concrete base. These size units provide significant spreading of loads, thereby reducing stress on the weaker mortar layer.

Mortar beds can be thin-set with a trowel to approximately $^1/_2$ in. (13 mm) if the concrete base beneath is correctly constructed with close surface tolerances and proper elevations. If not, then thick-set (~$1^1/_2$ in. or 40 mm) mortar is placed, the bottom of the paving units dampened with water prior to setting on these setting bed thicknesses, and then the units placed on the mortar. A rubber mallet is used to align each unit with adjacent ones. The joints are filled with mortar squeezed from in a caulk-type tube or from a mortar bag. The mortared joints are tooled flat so they do not hold water. Mortar accidently dabbed on a slab or plank surface should be removed immediately.

Installation equipment to lift and place paving units—Paving slabs are heavy and the larger units require at least two persons to install them. Serious injury from repetitive movements from manual installation of paving slabs can be avoided by using specialized lifting and placing equipment. Every effort should be made to use such equipment to avoid fatigue and injury. Most projects will have a pavement area with cut units and these may require manual installation. Therefore, worker energy should be reserved for accomplishing these manual tasks,

Figure 9. Single hand scissor clamp for lifting small and thin paving slabs

Figure 10. Double hand clamp for lifting larger paving slabs

Figure 11. Self-contained vacuum lifter with boom

Figure 12. Large vacuum head lifts an oversize paving slab

and by using slab installation equipment across as much pavement area as possible.

Installation equipment for paving slabs ranges from manual scissor clamps, that allow one or two workers to lift and place paving slabs, to vacuum lifters.

Scissor clamps—These vary in size depending on the length and width of the unit to be moved. Single hand and double hand clamps are illustrated in Figures 9 and 10. Single hand clamps are suitiable for units up to 24 in. (600 mm) long and maximum 130 lbs (58 kg). Double hand clamps requires two people to operate. These are suitable for paving slabs up to 24 x 24 in. (600 x 600 mm) weighing up to 150 lbs (68 kg). These have brackets on each end that grab the paving unit and use its weight to tighten the grip on it. Gripping may be assisted by rubber pads fixed to the brackets. The unit must be grabbed from the center to avoid twisting injury when lifted by the clampt. Fingers must be kept away from pivot points.

Vacuum equipment includes a self-contained vacuum lifter with a boom arm that rotates or swings in most any direction. These machines increase installation efficiency and are especially suited for paving large areas. See Figure 11.

For very large units, lifting devices exist that can lift and place slabs weighing as much 11,000 lbs (5,000 kg). Figure 12 illustrates such a device which uses more than one vacuum head attached to the paving slab.

Smaller devices include battery or electric powered slab lifters, or attached to an existing machine that provides power for creating the vacuum. Figures 13 through 15 illustrate these devices. The device shown in Figure 13 has a lifting capacity of 330 lbs (150 kg) and Figure 14 has a capacity of 440 lbs (200 kg). Figure 15 illustrates using a slab lifter for smaller slabs.

The piece of equipment that directly attaches via vacuum force to the paving slab is called a lifting head. These come with various thickness of foam sealant and

Figure 13. Two-person vacuum lift for paving slabs

Figure 14. Two-person vacuum lift for larger paving slabs.

Figure 15. Using vacuum equipment to install paving slabs in a residential application

configurations that enable lifting of textured slab or those with detectable warnings. Equipment manufacturers can recommend lifting heads for various paving slab surfaces. The sealants wear out, compromise suction, and must be replaced. In addition, most vacuum machines have air filters that must be replaced regularly to maintain a high vacuum force.

Mechanical turning of vertically stacked paving slabs - When shipped to a job site, most paving slabs are stacked vertically on their edges. There are attachments that can grab vertically stacked slabs on a pallet and rotate them to a horizontal position, ready for installation. See Figures 16 and 17.

Placing and compacting paving slabs—As with any segmental pavement, string lines should be pulled for mortared applications or chalk lines snapped onto bedding material set perpendicular to a baseline. These provide lines to guide placement. Joints are typically $^{1}/_{8}$ to $^{3}/_{16}$ in. (3 to 5 mm) wide unless specifically recommended by the manufacturer or designer. For many applications, paving slabs or planks may require grinding or 'gauging' to achieve consistent length, width and thicknesses. This process, if needed, should achieve the dimensional tolerances shown in Table 1. These result in efficient installation and tight, aligned joints required in most sand-set and all bitumen-set slab applications.

Source: Interpave UK

Figures 16 and 17. Vertically stacked paving slabs on a shipping pallet can be lifted, turned to a horizontal position and placed with a vacuum device.

Table 1. Recommended dimensional tolerances paving slabs and planks in sand-set and bitumen-set applications

Length and Width, in. [mm]	Thickness, in. [mm]	Concave or Convex Warpage in One Dimension, in.[mm]
Units up to and including 24 in. [610 mm]:		Up to and including 17.75 in. [450 mm]:
–0.04 [1.0] and +0.08 [2.0]	±0.12 [3.0]	±0.08 [2.0]
Units over 24 in. [610 mm]		Over 17.75 in. [450 mm]
–0.06 [1.5] and +0.12 [3.0]	±0.12 [3.0]	±0.12 [3.0]

Once in place, the slabs or plank surface is cleaned if needed. The units are compacted with minimum 5,000 lbf (22 kN) plate compactor with a roller attachment. See Figure 18. At least two passes should be made, with the second pass perpendicular from the first. Any cracked units should be removed and replaced, and then compacted in place.

Jointing sand—Jointing sand should conform to the gradations in C144 *Standard Specification for Aggregate for Masonry Mortar* or CSA A179 *Mortar and Grout for Unit Masonry*. This sand is placed into the joints and the pavement surface cleaned prior to compacting again to prevent surface scratches. At least two passes should be made with a roller attachment on the plate compactor. The second pass is perpendicular from the first. Compaction can follow directly behind spreading sand into the joints.

Joint sand stabilizers can be used to achieve early stabilization and reduce water ingress. Manufacturers instructions should strictly followed. *ICPI Tech Spec 5 Cleaning, Sealing and Joint Sand Stabilization of Interlocking Concrete Pavement* provides additional guidance.

Sealers—Sealers can be applied to paving slabs and planks to protect them from stains and enhance their color. Tech Spec 5 provides general guidance on sealer types with advantages and disadvantages of each. If efflorescence appears on the surface, cleaners specifically formulated for concrete paving units can applied to remove it prior to applying sealers. However, it is best to wait through a wet or winter season prior to applying a sealer. This allows time for the effloresence to work its way out of the concrete. Tech Spec 5 provides additional information on managing efflorésence.

Constructions Details

Stack Bond and Running Bond—For square slabs and rectangular slabs, units are placed in stack or running bond. Stack bond is shown in Figure 19. Running bond can longitudinal, i.e., the longer dimension in the traffic direction, or transverse, i.e., the shorter dimension in the direction of traffic. These are shown in Figures 20 and 21. If subject to vehicular traffic, a running bond pattern is recommended using square units as they will be less prone to damage.

Figure 22 illustrates filling cut areas with saw cut paving slabs or smaller concrete pavers. The area that receives the concrete pavers as a sailor course or soldier course should be of such dimensions to accept either without cutting.

Cutting Details—When a section of a paving slab must be cut and the cut area is less than 25% of the total slab area, there is no need to include additional cuts to reduce the risk of a cracked unit. Figure 23 illustrates this.

If more than 25% of a paving slab must be cut and removed, consideration must be given to installing additional cuts to reduce the risk of cracking under loads. Figuure 24 illustrates this treatment.

Detailing Around Utilities—Provided that they are squared with the paving pattern, placing paving slabs

Figure 18. Compacting paving slabs with a roller attachment on a plate compactor

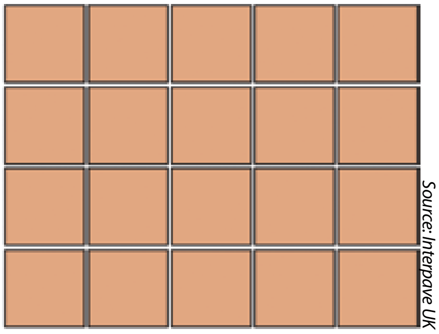

Figure 19. Stack bond

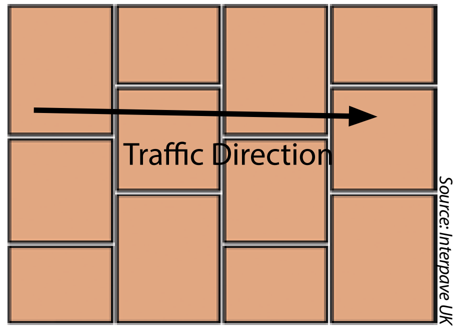

Figure 20. Transverse Running Bond

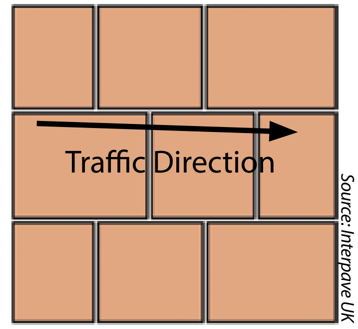

Figure 21. Longitudinal Running Bond

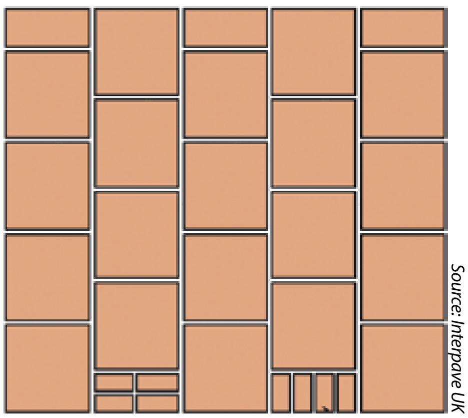

Figure 22. Running bond edges filled with concrete paver sailor or soldier courses

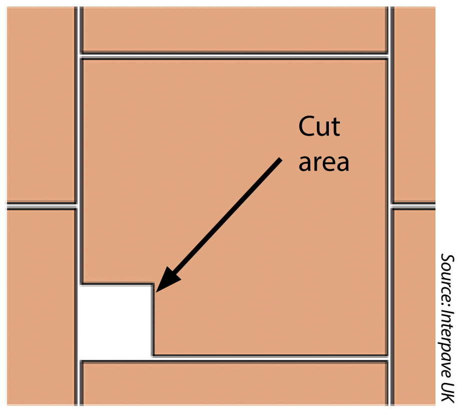

Figure 23. Cut areas less than 25% of the slab area generally do not require additional cuts on the paving slab to reduce the risk of cracking.

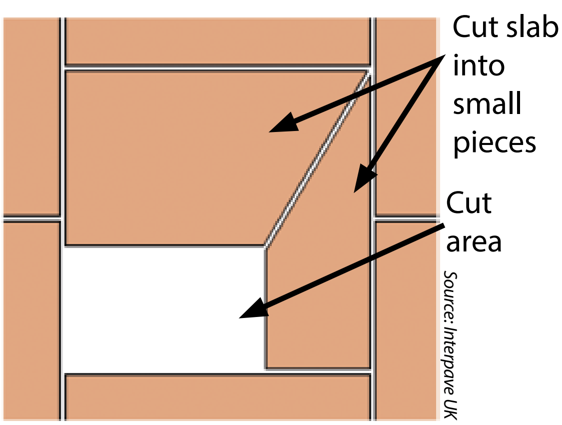

Figure 24. Cut areas 25% or greater of the slab area often require additional cuts to reduce the risk of cracking.

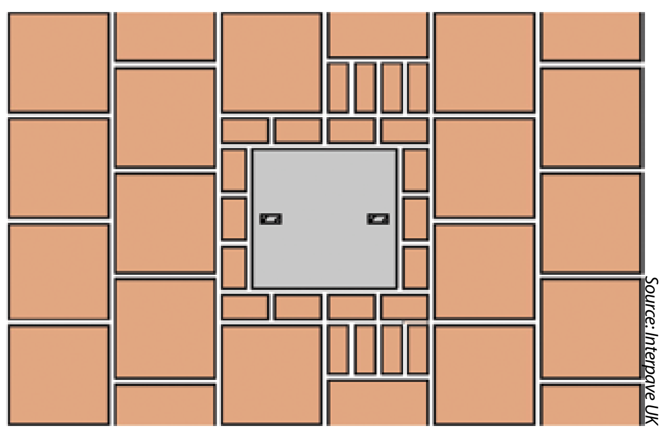

Figure 25. Using concrete pavers to fill around a utility cover

around square or rectangular access covers is fairly straightforward. When slabs are cut to fit a running bond pattern, the cut areas can be filled with a cut slab or with smaller concrete pavers as shown in Figure 25.

In most cases, the utility cover and the paving pattern will not align with the paving slab module or with the paving pattern. Figures 26 and 27 illustrate how covers are detailed in these situations. Round utility covers should be encased in a square concrete collar sized to fit the paving slab module if possible. Another, more elegant option is are filling in the outside radius of the cover with smaller stone units as shown on Figure 28. The stones are mor-

Figure 26. Example of a utility cover that does not fit neatly into the paving pattern.

Figure 27. Another example of cutting pavers to accommodate a utilitly cover set at an acute angle to the paving slab pattern

Figure 28. Filling the outside of a utility cover with mortar-set stone paving units

tared into the concrete collar around the cover.

Curb Ramp Details—Curb ramps and driveway entrances can be detailed one of two ways shown in Figures 29 and 30. Figure 29 shows a sidewalks that does not dip into the driveway apron and Figure 30 shows one that does.

Edge Restraints—These should follow guidance provided in Table 2 of *Tech Spec 3–Edge Restraints for Interlocking Concrete Pavements*. This Tech Spec provides a summary of the types and recommended applications.

Maintenance—Extra paving slabs or planks should be ordered for future maintenance should a paving unit become unduly stained or crack and require replacement. An advantage of segmental paving is that it can be removed and reinstated after base or underground utility repairs. *Tech Spec 6–Reinstatement of Interlocking Concrete Pavements* provides specific steps on removing and reinstating paving units.

Use of ICPI Certified Installers—ICPI offers training and experience certification of segmental concrete pavement installers. This training includes taking a two-day course, passing the exam and providing evidence of at least 10,000 sf (1,000 m^2) of installation experience. Continuing education requirements must be met as well, eight hours over two years.

A step further for contractor is receiving the Commercial Specialist Designation. This includes taking a course, passing the exam and providing evidence of a minimum of 50,000 sf (5,000 m^2) of paving units installed in commercial applications. This area may include paving slabs and planks. Specifiers are encouraged to include this ICPI designation in commercial project specifications and also specify that the contractor submit proof of slab or plank installation experience as appropriate to the project.

Slab and plank requirements for pedestrian applications—Paving slabs can be used in permeable applications. However, slabs 16 x 16 in. (400 x 400 mm) and larger should be limited to pedestrian uses only. Their minimum thickness should be 3.125 in. (80 mm). Using 16 x 16 in. or larger units in vehicular applications risks tipping and cracking, hence their relegation to pedestrian only uses. Slabs smaller than 16 x 16 in. for vehicular applications should be at least 3.125 in. (80 mm) thick.

Planks for permeable applications longer than 12 in. (300mm) are recommended for pedestrian only uses and their minimum thickness should be 3.125 in.

Detailed construction guidelines for permeable subbases, base, bedding/jointing aggregates and edge

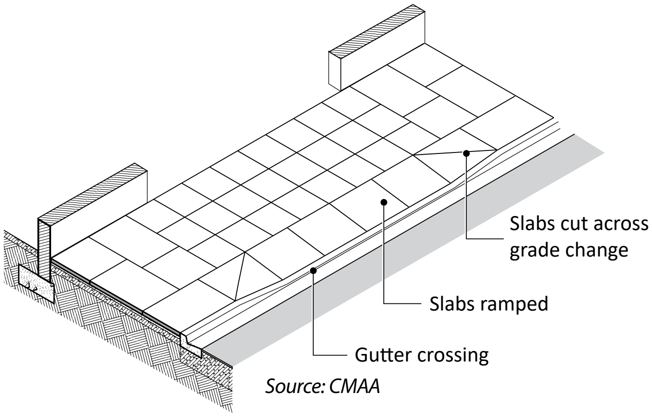

Figure 29. Driveway entrance with a ramped apron

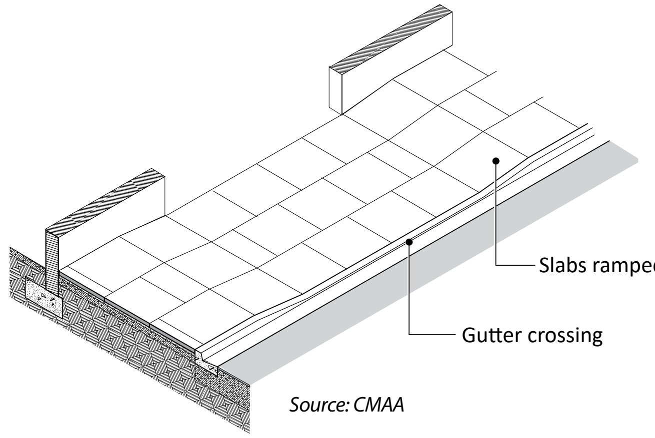

Figure 30. Driveway entrance with a depressed sidewalk surface.

restraints can be found in *ICPI Tech 20–Construction of Permeable Interlocking Concrete Pavement Systems*. These construction guidelines apply to slabs and planks designed for permeable applications. These units have wider wider joints (typically filled with No. 8 or 89 stone) than non-permeable applications in order to receive stormwater runoff. *Note*: Compaction of slabs and planks for permeable applications should be done with roller attachment on the plate compactor as previously described.

References

Concrete Masonry Association of Australia (CMAA), *PA05 Concrete Flag Pavements – Design and Construction Guide*, Australia, 2014 (www.cmaa.com.au)

Interpave UK, *Concrete Flag Paving: Guide to the Properties, Design, Handling, Construction, Reinstatement and Maintenance of Concrete Flag Pavements*, Edition 4, United Kingdom, 2010 (www.paving.org.uk)

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