Tech Spec Guide

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Tech Spec 25

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Construction Guidelines for Segmental Concrete Paving Slabs and Planks in Pedestrian 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 725 (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.

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 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 developed by ICPI notes a maximum lifetime exposure of 30,000 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 be 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 is recommended to be placed on the compacted soil subgrade and sides of the excavation. A 12 in. (300 mm) strip of geotextile can be used under the bedding sand and turned up at the edge restraint to prevent bedding sand loss. 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

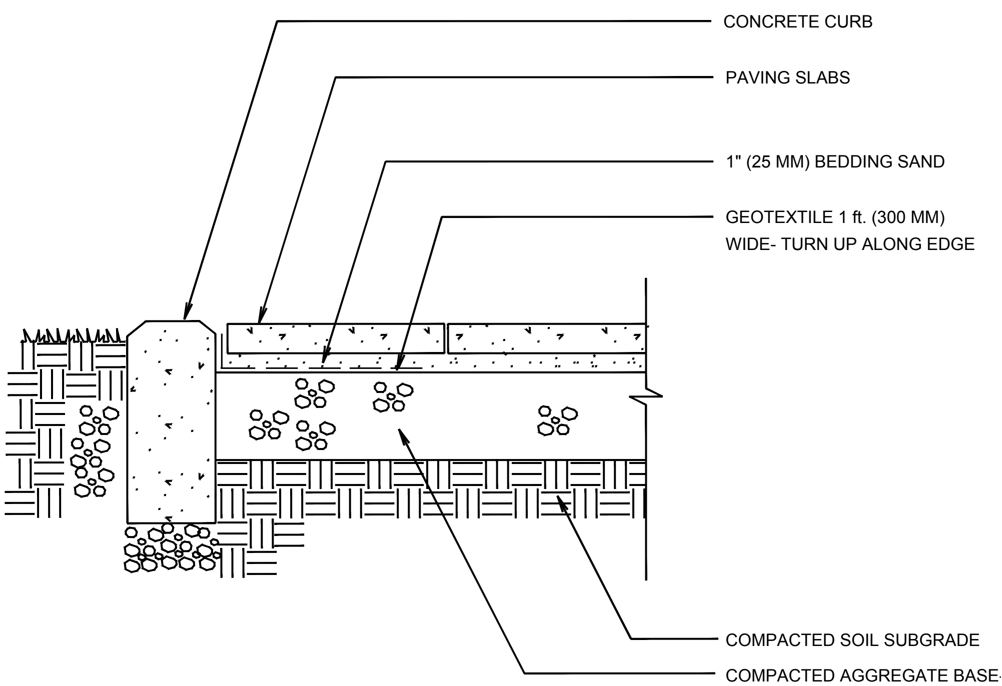

Figure 1. Typical paving slab assembly using an aggregate base

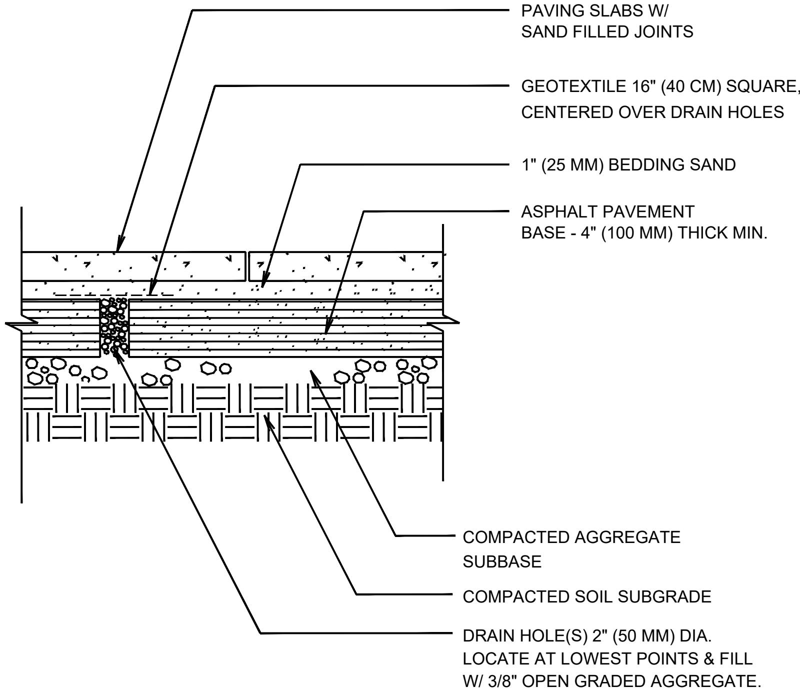

Figure 2. A typical cross section with an asphalt base and sand-set paving slabs

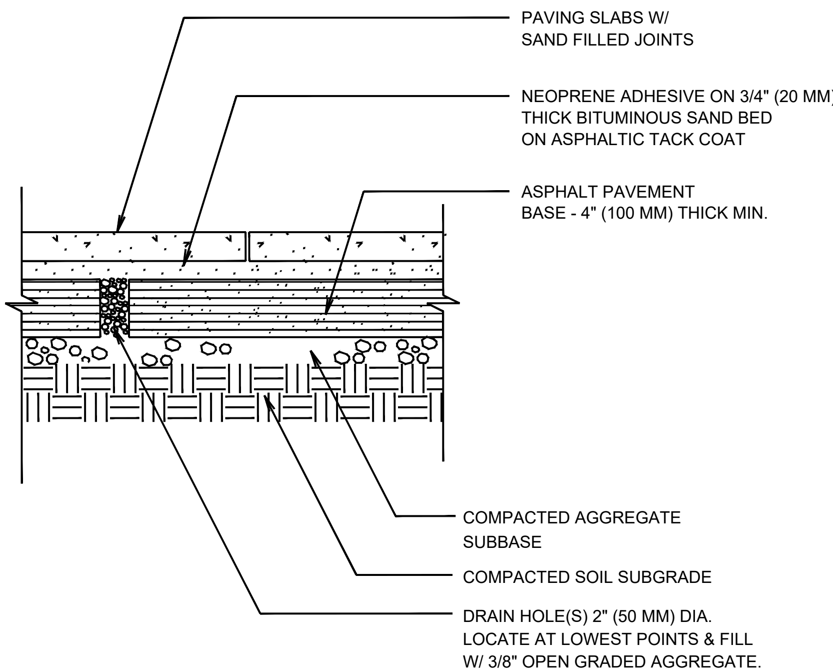

Figure 3. A typical cross section with an asphalt base and bitumen-set paving slabs

accommodate sand and bitumen-sand bedding materials. As noted for aggregate bases, the installed surface tolerance should be ± 1/4 in. (6 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. Typically 2 in. (50 mm) diameter holes through the asphalt base, filled with washed angular 3/8 in. (9 mm) gravel, and covered

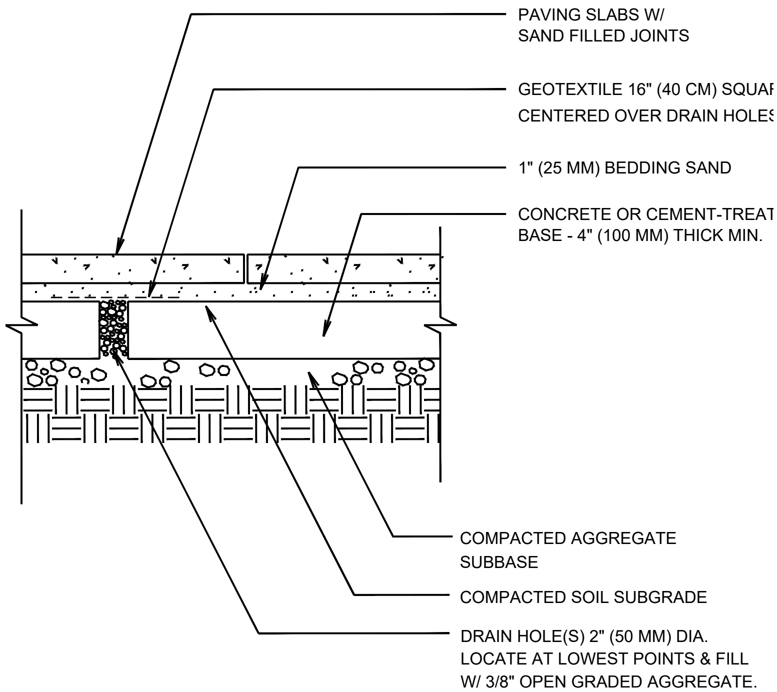

Figure 4. Typical cross section of sand-set paving slabs on a concrete base

with geotextile, to prevent loss of bedding sand, provide drainage of the bedding layer. Alternate bedding drainage systems should be considered in locations where infiltration into the subgrade is not encouraged.

Concrete bases—These should be made with minimum 3,000 psi (20 MPa) concrete per ASTM C39 *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*. The minimum concrete base thickness should be 4 in. (100 mm). Using at least #3 rebar placed at 24 in. centers will help prevent the concrete base from displacing when it cracks. Weep holes are recommended at the lowest elevations. These should be 2 in. (50 mm) in diameter, filled with washed angular 3/8 in. (9 mm) gravel, and covered with geotextile to prevent loss of bedding sand. Alternate bedding drainage systems should be considered in locations where infiltration into the subgrade is not encouraged. 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 because they do not drain water. Cement-stabilized sand should not be used due to lack of

Figure 5. Precompacting the bedding sand

FIgure 6. Installing planks on uncompacted bedding sand.

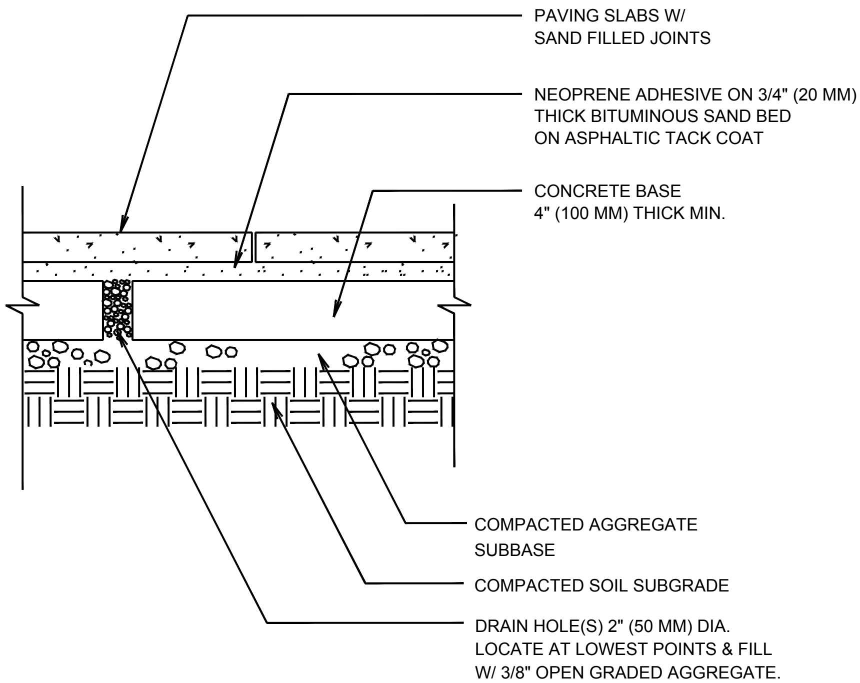

Figure 7. Typical cross section of bitumen-set paving slabs on a concrete base

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 plate compactor as shown in Figure 5. 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. For planks 18 in. (450mm) and longer or 4 in. (100 mm) and narrower pre-compaction of the bedding sand is recommended to minimize breakage. Shorter or wider planks can be installed on uncompacted bedding sand. See Figure 6.

Bitumen-set applications—These require a concrete base or asphalt base with a surface tolerance of ± ¼ in. (6 mm) over a 10 ft (3 m) straightedge. ICPI's *Tech Spec 20–Construction of Bituminous-Sand Set Interlocking Concrete Pavement* provides a detailed description of the materials and construction procedures for both. Pedestrian applications can have bases constructed from either concrete or asphalt, whereas vehicular applications should only use concrete bases.

Slabs and planks may be installed with this method, and the paving units must conform to a height tolerance of +/- $^{1}/_{16}$ in. (1.5 mm) which will require additional processing by the manufacturer. Concrete curbs, grade beams, cut stone or metal angle edge restraints are required. Pedestrian applications do not require a tack coat of emulsified asphalt on base materials, but it is required for vehicular applications. A ¾ in. (15mm) layer of

Figure 8. Sidewalk application illustrating the neoprene adhesive on an asphalt bedding layer under paving slabs

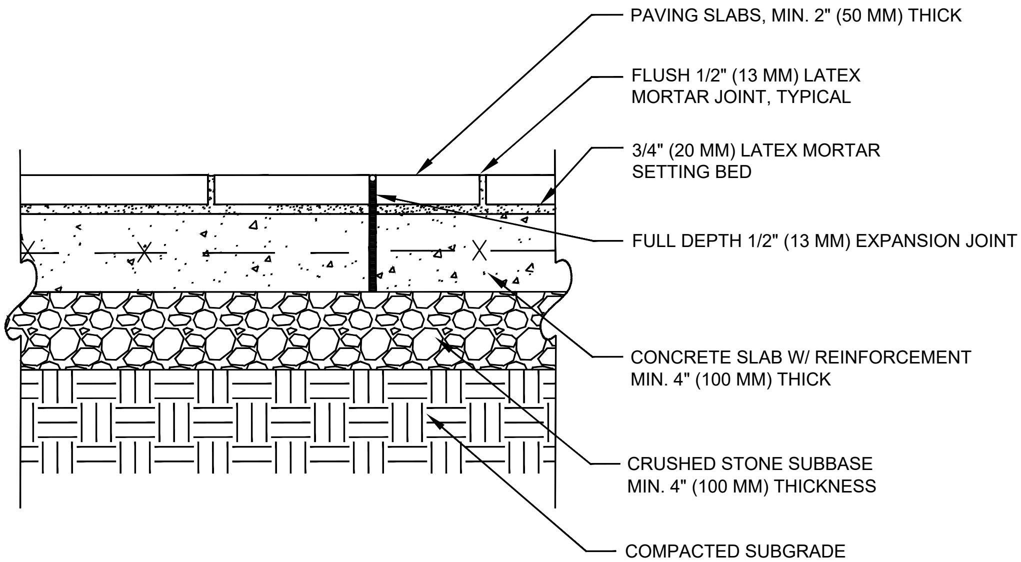

Figure 9. Typical mortar set slab application

heated sand-asphalt mix is then applied and compacted while cooling. This setting bed material may be specified from provincial, state or local road agencies as the sand-asphalt surface mix (topping layer) is typical to most asphalt roads. Figure 6 illustrates a typical cross section. While the setting bed asphalt layer is cooling, a roller or plate compactor is used to consolidate and flatten the surface. The paving units may then be placed in the specified pattern. For additional strength, a neoprene-asphalt mastic can be troweled or squeegeed onto the consolidated asphalt setting bed surface per manufacturer's instructions. This material generally takes an hour or two to "break". Then the paving slabs or planks can be placed. See Figure 7. This adhered process will not allow for paving units to be removed without damaging the setting bed and requiring additional repair.

Washed concrete sand is swept into joints and a roller compactor is applied to pavement surface to consolidate the jointing sand in place. The edge restraints will prevent horizontal creep or movement effectively locking the paving units in place. A liquid joint sealant may be applied to help with joint sand loss or a stabilized joint sand also may be used.

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

Figure 10. Single hand scissor clamp for lifting small and thin paving slabs

Figure 11. Double hand clamp for lifting larger paving slabs

Figure 12. Self-contained vacuum lifter with boom

Figure 13. Large vacuum head lifts an oversize paving slab

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 9 shows a typical cross section.

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

Figure 14. Two-person vacuum lift for paving slabs

Figure 15. Two-person vacuum lift for larger paving slabs.

Figure 16. Using vacuum equipment to install paving slabs in a residential application

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, 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 10 and 11. Single hand clamps are suitiable for units up to 24 in. (600 mm) long and maximum 130 lbs (58 kg). Double hand clamps require 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 clamp. 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

Source: Interpave UK

Figures 17 and 18. 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]

are especially suited for paving large areas. See Figure 12.

For very large units, lifting devices exist that can lift and place slabs weighing as much 11,000 lbs (5,000 kg). Figure 13 illustrates such a device which uses more than one vacuum head attached to the paving slab.

Smaller devices use battery or electric powered slab lifters, or they can be attached to an existing machine that provides power for creating the vacuum. Figures 14 through 16 illustrate these devices. The device shown in Figure 14 has a lifting capacity of 330 lbs (150 kg) and Figure 15 has a capacity of 440 lbs (200 kg). Figure 16 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 thicknesses of foam sealant and 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 17 and 18.

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. Manufacturers may need to grind or "gauge" slabs or planks to achieve the dimensional tolerances shown in Table 1. These result in efficient installation and tight, aligned joints specified in most applications.

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 19. 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 be 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

Figure 19. Compacting paving slabs with a roller attachment on a plate compactor

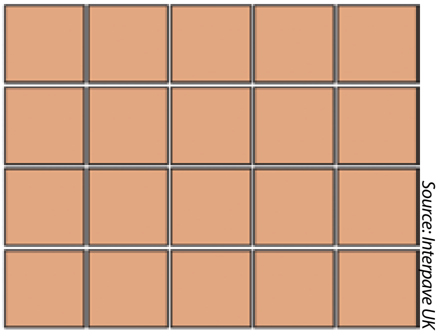

Figure 20. Stack bond

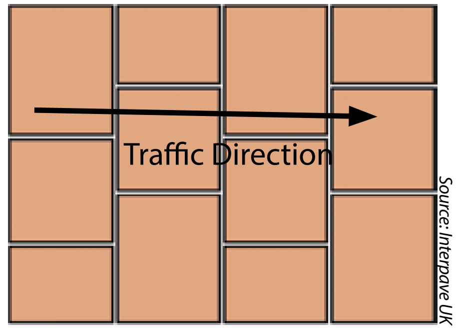

Figure 21. Transverse Running Bond

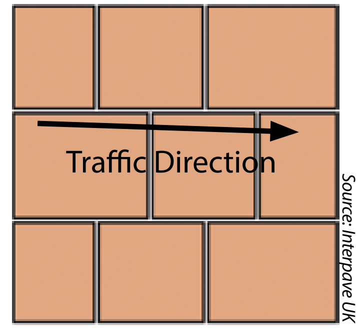

Figure 22. Longitudinal Running Bond

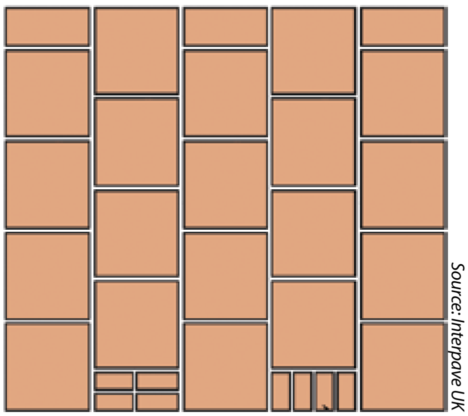

Figure 23. Running bond edges filled with concrete paver sailor or soldier courses

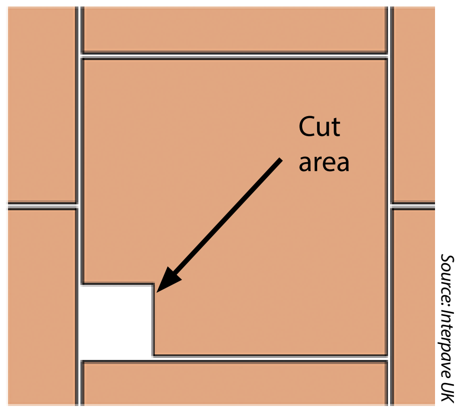

Figure 24. Cut areas less than 25% of the slab area generally do not require additional cuts on the paving slab to reduce the risk of cracking.

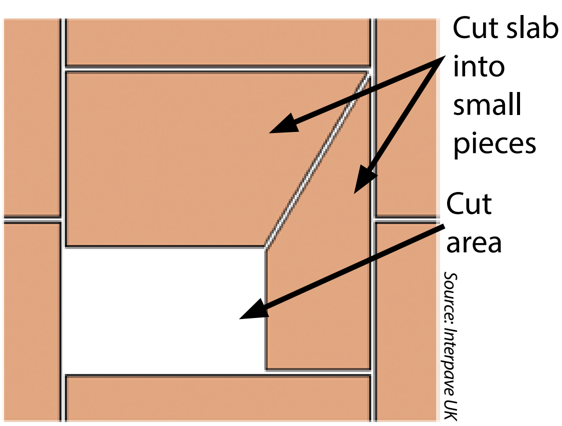

Figure 25. Cut areas 25% or greater of the slab area often require additional cuts to reduce the risk of cracking.

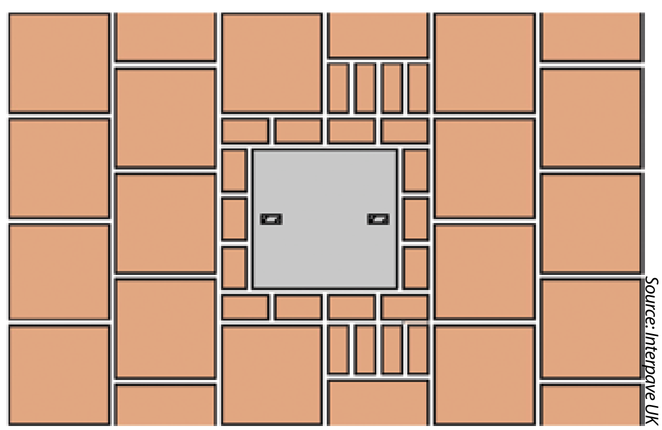

Figure 26. Using concrete pavers to fill around a utility cover

formulated for concrete paving units can be 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 efflorescence to work its way out of the concrete. Tech Spec 5 provides additional information on managing efflorescence.

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 20. Running bond can be placed longitudinal, i.e., the longer dimension in the traffic direction, or transverse, i.e., the shorter dimen-

Figure 27. Example of a utility cover that does not fit neatly into the paving pattern.

Figure 28. Another example of cutting pavers to accommodate a utililty cover set at an acute angle to the paving slab pattern

Figure 29. Filling the outside of a utility cover with mortar-set stone paving units

sion in the direction of traffic. These are shown in Figures 21 and 20. If subject to vehicular traffic, a running bond pattern is recommended using square units as they will be less prone to damage.

Figure 23 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 24 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 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 26.

In most cases, the utility cover and the paving pattern will not align with the paving slab module or with the paving pattern. Figures 27 and 28 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 filling in the outside radius of the cover with smaller stone units as shown on Figure 29. The stones are mortared 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 30 and 31. Figure 30 shows a sidewalk that does not dip into the driveway apron and Figure 31 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.

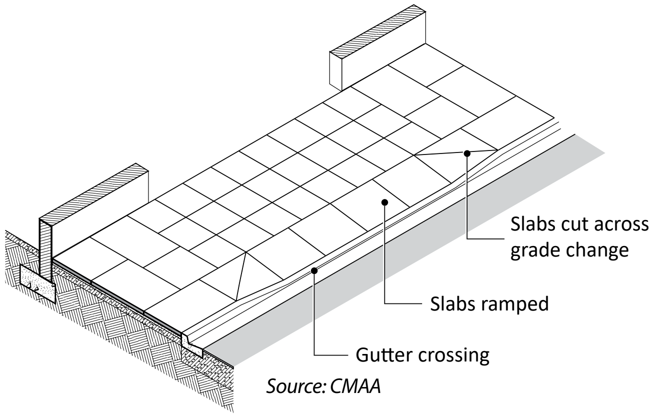

Figure 30. Driveway entrance with a ramped apron

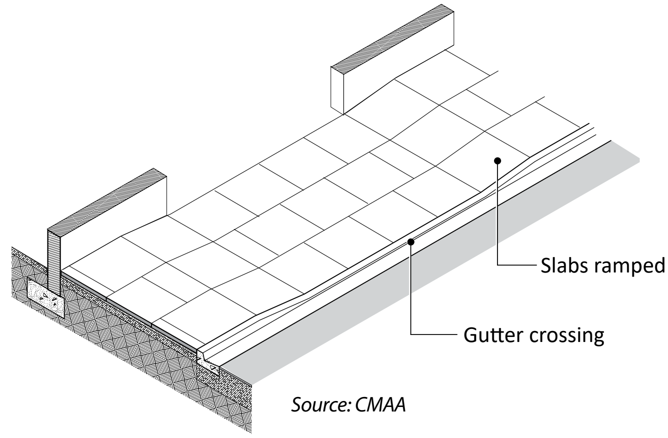

Figure 31. Driveway entrance with a depressed sidewalk surface.

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 contractors 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 permeable applications—Paving slabs can be used in permeable applications. Slabs 16 x 16 in. (400 x 400 mm) and larger should be limited to pedestrian uses only and 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. Slabs smaller than 16 x 16 in. when used in 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 (80 mm).

Detailed construction guidelines for permeable subbases, base, bedding/jointing aggregates and edge restraints can be found in *ICPI Tech 18–Construction of Permeable Interlocking Concrete Pavement Systems.* These construction guidelines apply to slabs and planks designed for permeable applications. These units have 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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BOD Approved: August 2020