

Paving Systems Using Clay Pavers in a Mortar Setting Bed

Abstract: This *Technical Note* describes the proper design and construction of pedestrian and light vehicular pavements made with clay pavers laid in a mortar setting bed.

Key Words: bonded systems, brick flooring, driveway, mortar, paving, plaza, rigid pavements, setting bed, sidewalk, unbonded systems.

SUMMARY OF RECOMMENDATIONS:

General

- Determine if application is for pedestrian applications or light or heavy vehicular traffic, and design with appropriate recommendations
- Implement regular maintenance program to maintain pavement in a safe and serviceable condition

Drainage

- Provide a minimum slope of ¼ in. per ft (20 mm/m or 2 percent grade)
- Provide weeps of at least a ⅜ in. (10 mm) diameter at the pavement edge at a maximum spacing of 24 in. (610 mm) o.c. or provide curb and gutter with appropriate slope
- Provide surface area drains as necessary
- For maximum surface runoff, orient continuous mortar joints parallel to direction of slope for drainage

Movement Joints

- Space expansion joints no more than 16 ft (4.9 m) o.c. for exterior pavements, and 24 ft (7.3 m) o.c. for interior applications
- For bonded systems:
 - Extend movement joint through entire pavement thickness from base up through pavers
- For unbonded systems:
 - Extend expansion joint through pavers and setting bed only
 - While alignment is not critical, place expansion joints as close as possible to control joints in concrete base

Clay Pavers

- For most residential, pedestrian and light vehicular applications, such as driveways, entranceways and passenger drop-offs, use clay pavers complying with ASTM C902
- For heavy vehicular applications, such as streets, commercial driveways and industrial applications, use clay pavers complying with ASTM C1272
- Minimum specified thickness of pavers in mortared paving system:
 - Pedestrian traffic: no minimum thickness
 - Light vehicular traffic: 1¼ in. (32 mm)
 - Heavy vehicular traffic: 2¼ in. (57 mm)

Mortar Setting Bed

- For exterior applications, use ASTM C270 Type M mortar
- For interior applications, use ASTM C270 Type M or Type S mortar
- Alternatively, mortar conforming to ANSI A118.1, A118.4 or A118.6 can be used
- For vehicular applications or extreme environments, use a latex-modified mortar
- Reinforce mortar setting bed in unbonded systems
- Thickness of mortar setting bed: minimum ⅜ in. (10 mm) and maximum 1½ in. (38 mm)
- During installation, lay setting bed no more than 2 ft (0.6 m) ahead of laying of pavers

Mortar/Grout Joints

- Mortar for the joints can be the same as used in the setting bed
- Completely fill joints with mortar or grout to minimize moisture penetration
- Tool with concave or grapevine jointer when mortar or grout becomes thumbprint hard
- Sand-filled joints over mortared brick paving are not recommended
- Dry sand and cement mixtures that are swept into joints between pavers are prone to early failure and are not recommended

Base

- Use a plain or reinforced concrete slab; minimum thickness of 4 in. (102 mm); minimum compressive strength of 4000 psi (27.6 MPa)
- For exterior applications, use concrete with a minimum air content of 6 percent for increased durability
- Finish with a rough texture to enhance bond to mortar setting bed
- Allow concrete to cure a minimum of seven days before installation of setting bed and pavers

Subbase and Subgrade

- Refer to *Technical Note 14*



Photo 1
Clay Pavers in a Mortar Setting Bed

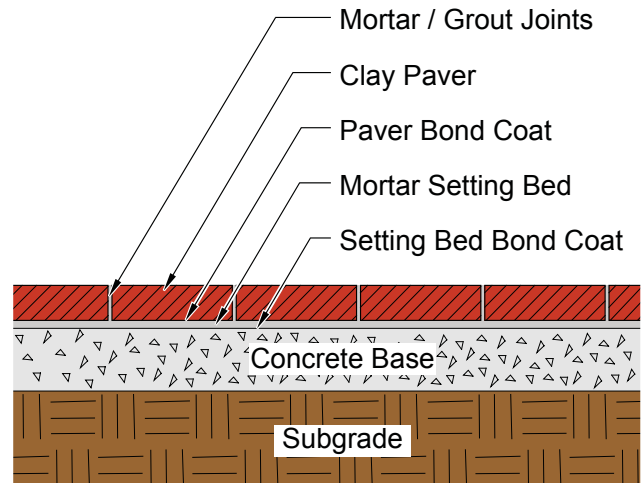


Figure 1
Typical Bonded Mortar Set Paver System

INTRODUCTION

This *Technical Note* covers the design, detailing and specification of clay pavers when set in a mortar bed (see [Photo 1](#)). This assembly uses mortar or grout to fill the joints between pavers. Mortar setting beds should be used only over a concrete base that provides adequate support. The ability of the system to support loads is based on the thickness of the concrete slab supporting the clay paving assembly with some minor contribution from the mortared clay pavers.

More periodic maintenance may be required of mortared paving assemblies than other brick paving assemblies because of the exposed mortar joints. However, when dealing with saturated soil conditions, steep slopes or an elevated/suspended concrete slab, this type of assembly may prove to be the most appropriate.

Applications

Clay pavers set in mortar are appropriate for virtually any paver application, ranging from pedestrian to heavy vehicular traffic. At a minimum, the system requires clay brick pavers bonded to a mortar setting bed. Below the setting bed, a concrete base should be placed and an aggregate subbase, if necessary. The thickness of the base and subbase materials is dependent on the traffic loads and on the subgrade conditions.

This *Technical Note* does not address specialized applications such as industrial and commercial areas requiring paving with chemical or thermal resistance.

Residential Patios, Walkways and Driveways. The combined thickness of base, setting bed and pavers should be enough to support traffic for residential applications, as in [Figure 1](#). The concrete base must be a minimum 4 in. (102 mm) thick to ensure sufficient rigidity to avoid cracking the mortar joints from pressures above or below the pavement. The mortar bed thickness should be $\frac{3}{8}$ to 1½ in. (10 to 38 mm) in thickness. There is no minimum thickness for the clay paver itself.

Commercial Walkways/Public Plazas. The pavement section shown in [Figure 1](#) may also provide adequate performance for commercial walkways and public plazas. Where vehicular traffic is expected, the thickness of the base may be increased. In addition to increasing the base, an increase in paver thickness may also contribute to the pavement's load-bearing capacity. In many cases the thickness of the pavement system and any required steel reinforcing will be determined by the load-bearing capacity of the soil beneath the pavement or whether the pavement is subjected to freeze-thaw cycles.

Light Vehicular Traffic. For parking areas and neighborhood streets serving light vehicles, such as cars, garbage trucks and delivery vans, a more substantial base will be necessary. A pavement with a thicker concrete base or more reinforcement may be required depending on the loading and underlying soil conditions. Paver thickness should not be less than 1¼ in. (32 mm).

Heavy Vehicular Traffic. Paving applications exposed to more than 251 daily equivalent single axle loads (ESAL) from trucks or combination vehicles having three or more loaded axles are considered heavy vehicular applications. Such paving systems are beyond the scope of this *Technical Note* series. Refer to references on concrete base design for more information [Ref. 2]. Paver thickness is generally 2¼ in. (57 mm) or greater for these heavier loading conditions.

Suspended Structural Decks/Slabs Used as Walkways and Plazas. When a clay pavement with a mortar setting bed is constructed over an enclosed space below, a suspended structural concrete slab should be used (see Figure 2). Such a slab acts as the base for the pavement above. The thickness of a suspended structural slab will be based on its span and loading conditions. For this application, it is preferred that the mortar setting bed not be bonded to the suspended structural slab in order to allow the pavement to move independently of the slab.

Structural design of suspended structural slabs is beyond the scope of this *Technical Note*, but more information can be found in References 2 and 4.

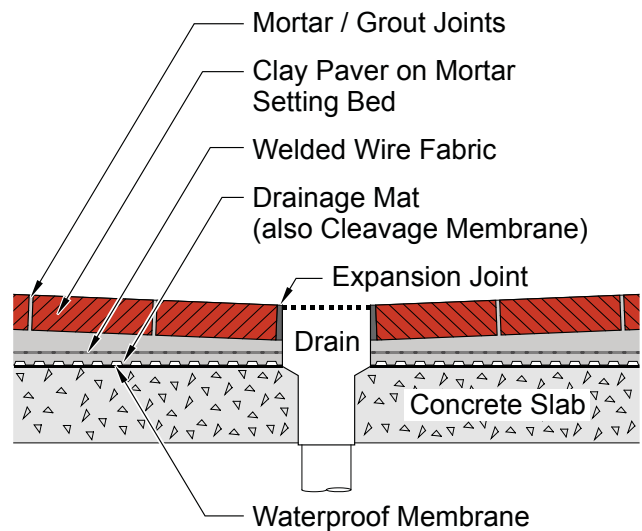


Figure 2
Suspended Structural Deck with Unbonded Mortar Set Paver System

DESIGN AND DETAILING CONSIDERATIONS

Climate

Mortar-set pavers can be used in all climatic conditions; however, slightly higher levels of maintenance should be anticipated in climates with freeze-thaw conditions, since the mortar is more susceptible to weathering than the brick pavers. Freeze-thaw climates may also dictate a thicker base to resist frost heave. Where the pavement experiences large temperature fluctuations, the positioning of movement joints often becomes critical to the success of the pavement. Temperature effects can be amplified by reflected heat from adjacent buildings and underlying insulation.

Pavement Section

Pavers set in a mortar setting bed should be installed only over a concrete base. Other types of bases are not rigid enough to resist cracking of the mortar joints. Concrete bases are typically lightly reinforced and contain control joints to control curing shrinkage and subsequent expansion and contraction. The base should be pitched to the same slope as the finished pavement so that the mortar setting bed can be a consistent thickness.

Subgrade

A description of different subgrade types is beyond the scope of this *Technical Note* and can be found in *Technical Note 14* and in *Flexible Vehicular Paving – A Heavy Duty Applications Guide* [Ref. 3] or other appropriate references. For this *Technical Note*, the subgrade is considered to consist of either sand or gravel, or clay or silt. The latter are more sensitive to moisture and frost. For all subgrade types it is important that the subgrade is properly prepared and compacted before base construction. Clays and silts will require adequate protection against shrinkage and swelling and against frost heave. This may require the use of subbase layers and appropriate drainage. The advice of a properly qualified and experienced pavement designer should be sought in regard to the preparation of the subgrade.

Base

The design of the base is beyond the scope of this *Technical Note*, and the advice of a properly qualified and experienced pavement designer should be sought. For preliminary design, it is reasonable to assume that no less

than 4 in. (102 mm) of concrete base will be needed for sand and gravel subgrades. For clay or silt subgrades, an additional 4 in. (102 mm) of aggregate subbase should be added. Additional thickness may be required to accommodate heavy axle loads such as fire trucks and tractor trailers. The minimum compressive strength of the concrete should be 4000 psi (27.6 MPa). For exterior applications, use concrete with a minimum air content of 6 percent for increased durability.

Bonded vs. Unbonded Systems

Pavements with mortar setting beds are considered either bonded systems (see Figure 1) or unbonded systems (see Figure 2 and Figure 3). In a bonded system, the mortar bed and pavers act compositely with the underlying concrete base. In an unbonded system, the mortar bed and pavers can act independently of the underlying concrete base.

Clay pavers in a mortar setting bed can be used in light vehicular traffic applications. For unbonded systems, a maximum speed of 35 mph (56 kph) is considered appropriate. A bonded system is preferred when vehicular access includes light commercial and emergency vehicles. Bonded mortar setting beds may be used where speeds above 35 mph (56 kph) are anticipated. Bonded systems are also preferred for concrete slabs on grade when freeze-thaw conditions exist. Unbonded systems are preferred when the pavers are laid over a suspended structural deck.

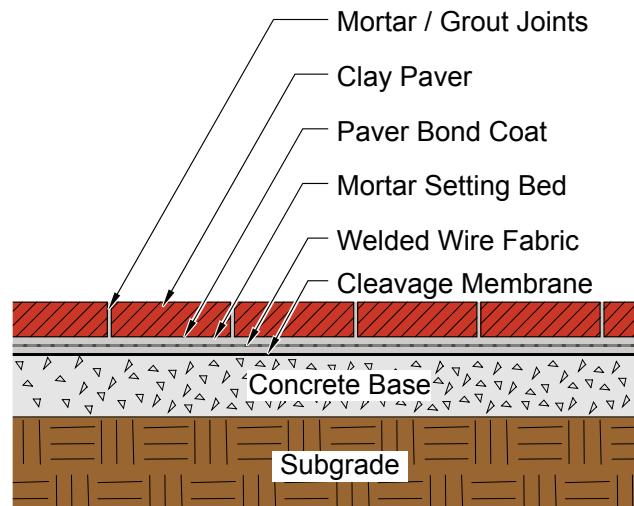


Figure 3
Typical Unbonded Mortar Set Paver System

Bonded Systems. In bonded systems, the clay pavers are adhered to the mortar setting bed, which is in turn adhered to the underlying concrete base. When the base moves, so will the pavers, and vice versa. As such, it is essential that all movement joints are carried through the concrete base, the mortar setting bed and the pavers. The location and design of movement joints should take into account the expansion and contraction properties of each of the pavement layers, as they will be subject to various temperature and moisture conditions. Movement joints in a concrete base should align with the paver expansion joint spacing. Mortar setting beds in bonded systems are usually between $\frac{3}{8}$ and $1\frac{1}{2}$ in. (10 and 38 mm) thick.

Unbonded Systems. In unbonded systems, the mortar bed is isolated from the underlying base by a cleavage membrane or crack isolation membrane. Reinforcement should be placed in the mortar setting bed of unbonded systems so that the setting bed and pavers can handle both compressive and tensile loads. The paver and mortar bed are free to move independently of the underlying concrete base; therefore, alignment of movement joints through the mortar bed and pavers with those through the concrete base is not required. Unbonded systems are preferred when the pavers are laid over a suspended structural deck.

For unbonded systems, control joints in the concrete base may be placed farther apart than the spacing of the movement joints in the mortar bed and pavers. The joints and mortar bed are unable to resist tensile forces; therefore, the mortar bed should be reinforced to prevent cracking between movement joint locations. Mortar setting beds are usually thicker in an unbonded system, since they must provide additional strength and adequate cover for the reinforcement, and may be between $\frac{3}{4}$ and 2 in. (19 and 51 mm) thick. Since a relatively smooth slab surface is required, the maximum tolerances of the concrete slab surface should be maintained.

Joints Between Pavers

Mortar joints between the pavers are typically $\frac{3}{8}$ in. (10 mm) to create a typical masonry module of 8 in. (203 mm). The mortar joints not only bond the components together, but they also accommodate tolerances in the pavers. The joint thickness can vary depending on the type of installation method is used. Slightly narrower joints can be used in the bricklayer's method (described more fully in the INSTALLATION section on page 10) with the minimum joint width as thin as $\frac{1}{4}$ in. (6 mm) depending on the dimensional tolerances of the paving units. Some shrinkage of mortar will occur due to curing, so joints wider than $\frac{5}{8}$ in. (16 mm) should be avoided. Wider joints may result

in the mortar separating from the paver or in mortar shrinkage that may allow moisture to enter the assembly and cause damage during freezing conditions. Use of sand in joints between pavers set in a mortar setting bed is not recommended because water has the potential to infiltrate the joints and settle at the top of the setting bed. Subsequent exposure to freezing and thawing cycles may lead to failure of the setting bed and debonding of the paver.

In the tile setter's method of construction, the joints are not filled until the setting bed has cured. In the bricklayer's method, the joint filling material may have the same constituents as the mortar, but is referred to as grout because of its method of installation. Slightly wider joints can be tolerated, with the normal range being $\frac{3}{8}$ in. (10 mm) to $\frac{5}{8}$ in. (16 mm)

Joints may be finished flush with or slightly recessed from the top of the pavers (see Figure 4). The former is preferred to allow faster drainage and to provide better frost resistance. Recessed joints or deeply tooled mortar joints are not recommended since they may be more prone to catching debris and may have a greater tendency for moss or algae growth in damp conditions. A concave surface is the most common profile and can add to the texture of the pavement by creating slight shadow lines.

Bond Patterns/Layout

As with other setting bed systems, the four basic bond patterns and their derivations are compatible with the mortar set system, except that the clay pavers will be $\frac{3}{8}$ in. (10 mm) less than the typical module. While a majority of clay pavers used in mortar setting beds are $3\frac{5}{8}$ by $7\frac{5}{8}$ in. (92 by 194 mm) in size to conform to the 8 in. (203 mm) module when laid with a typical $\frac{3}{8}$ in. (10 mm) joint, other sizes are available. See *Technical Note 14* for further details of these bond patterns.

Various groupings of whole and half pavers can be installed in a repeating pattern when laid out in a module. As joint widths in a mortar-set system can be variable, several interesting effects can be included in the patterns. These include curves and fans, or setting the pavers slightly skewed relative to one another (see Figure 5). However, mortar joints should not exceed $\frac{5}{8}$ in. (16 mm) in width, as mentioned previously. When laying pavers, exact grid line positions can be achieved by varying the joint widths to accommodate the size variations in the pavers. Typically, joint widths are between $\frac{1}{4}$ in. (6 mm) minimum and $\frac{5}{8}$ in. (16 mm) maximum. Thinner joint sizes are more difficult to construct, and thicker joint sizes are more susceptible to cracking and increased water penetration.

Drainage

Runoff from mortar-set pavers occurs primarily at the pavement surface and can be directed in sheet flow to channel drains or to area inlets. The recommended minimum slope is $\frac{1}{4}$ in. per foot (20 mm/m) or 2 percent. Area

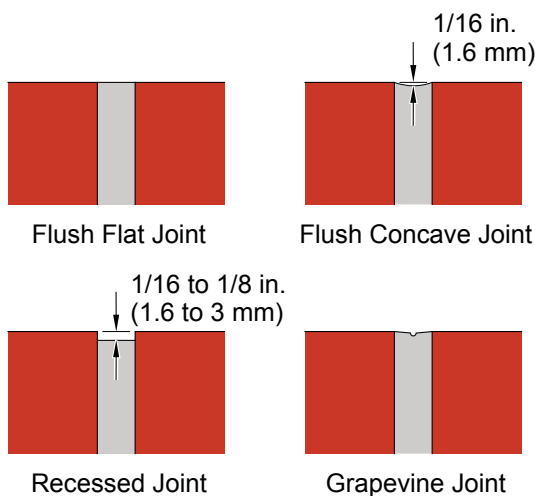


Figure 4
Mortar Joint Profiles

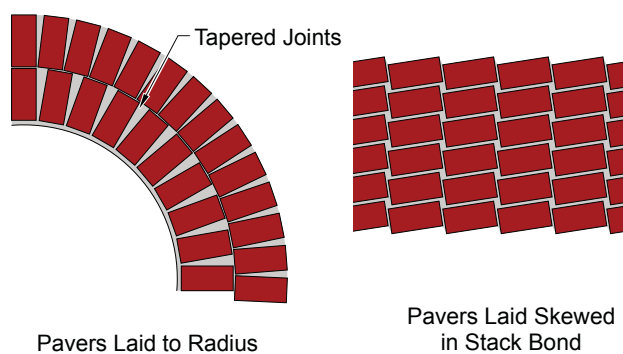


Figure 5
Laying Patterns with Variable Joint Thickness

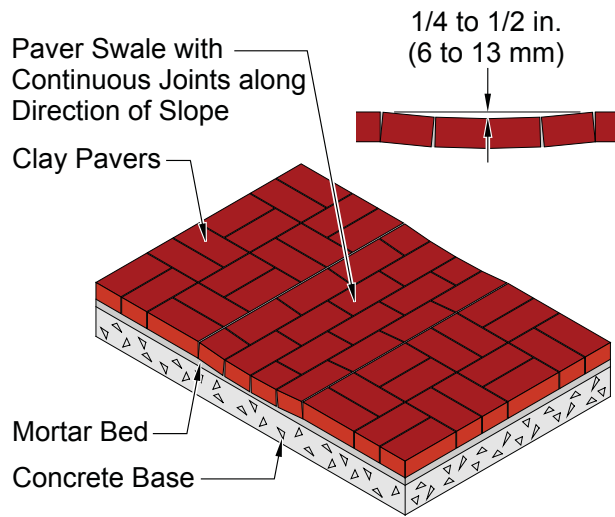


Figure 6
Drainage Swale

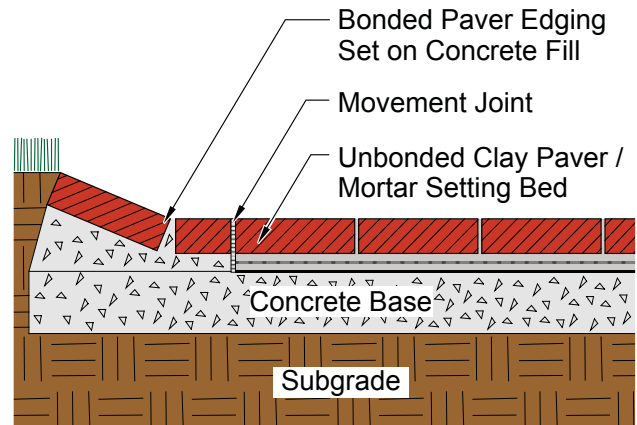


Figure 7
Unbonded System Edge Detail

drains can be incorporated in the middle of large paving systems and can be installed to drain water that has penetrated the mortar bed. Gutters and swales (see [Figure 6](#)) can be formed by slightly dishing or recessing the pavers in the mortar setting bed. Suspended structural slabs often incorporate a drainage mat under the mortar bed to allow the water to drain out at that level. To aid drainage, continuous joints should be aligned with the direction of water flow.

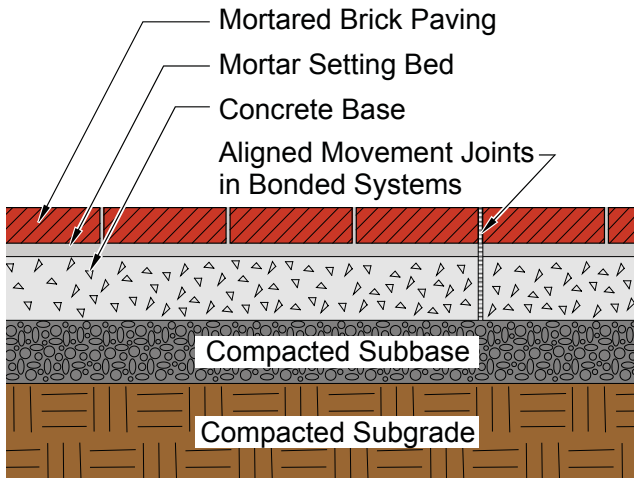
Edge Restraints

Bonded, mortar-set pavers do not require edge restraints. However, the exposed edge of the mortar bed should be sealed to prevent the ingress of moisture and potential subsequent frost damage. This is particularly important at planters and irrigated landscaping where water could seep under the system. Unbonded pavers placed on a cleavage membrane require minimal edge restraints for pedestrian loading (see [Figure 7](#)). The edging may include a bonded edging such as brick or stone pieces on a mortar bed, or pavers thin-set or glued directly to the base. If there is vehicular traffic, a more robust curb or suitably supported edging should be installed. Curbs can be constructed of brick, concrete or stone, and can be formed with or without a gutter. Steel angles used as edge restraints should be anchored to the base or to a suitable concrete foundation.

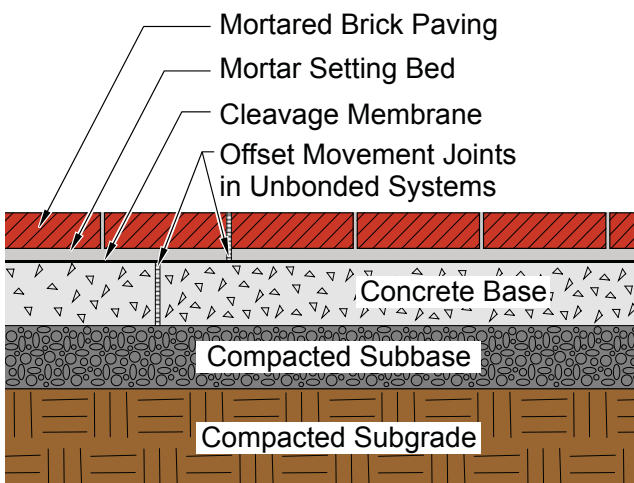
Movement Joints

Brick paving will expand and contract with a wider range of changing moisture and temperature conditions than that experienced by the base. As a result, pavements with a mortar setting bed should have movement joints that accommodate expansion and contraction. The brick paving assembly between the movement joints will form monolithic panels that act separately from adjacent panels. As the panel expands with rising temperatures, the movement joints will compress. In cold weather the panel will contract and the joint will open. The greatest amount of movement results from changes in temperature. A dark pavement surface can heat up to over 140 °F (60 °C), particularly on a structural deck where insulation is present below the surface, or a pavement surface may cool to below ambient air temperatures.

Calculation procedures that are used to determine movement of brick walls can be used for brick pavements as well; however, the temperature difference may be greater for paving assemblies. Movement joint spacing in the brick paving surface should not exceed 16 ft (4.9 m) in any direction, especially for exterior pavements. Mortared brick paving used indoors may not be exposed to the same temperature and moisture variations; therefore, the spacing can be increased but should be less than 24 ft (7.3 m) in any direction.



(a)



(b)

Figure 8

Movement Joints in Mortared Brick Paving

Movement joints should penetrate the setting bed and the pavers, as well as the drain mat when included. In a bonded system, they should be aligned directly over the underlying joints in the concrete base (see [Figure 8a](#)). In an unbonded system, they should be as close as possible to the underlying joints, but it is not necessary to align them (see [Figure 8b](#)). The spacing of movement joints in the brick paving is typically the same for both bonded and unbonded systems.

The movement joints should consist of compressible joint filler, debonding strip and joint sealant (see [Figure 9](#)). Backer rods may be used in place of debonding strips where the pavement is unlikely to be subjected to stiletto heels and similar point loads. Movement joint width should be based upon the movement potential of the joint and the type of sealant material used. Manufacturers' details should be consulted for sealant properties.

Penetrations

A number of features, such as utility covers, tree pits, light pole bases, sign posts and street furniture, will penetrate through the pavement layers. These may either penetrate the entire pavement section or be anchored to the concrete base. Most utility covers and light poles penetrate the entire pavement section and will be immovable compared with the pavement. In these cases an isolation joint should be installed around the penetration. Sign posts and street furniture typically rest on and are anchored to the underlying concrete base and will move along with it. A movement joint may not be necessary in these locations, and the mortar can be carried up to the penetration (see [Figure 10](#)).

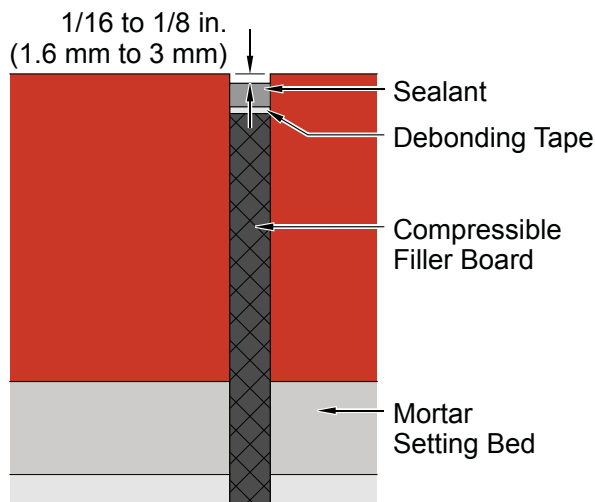


Figure 9
Movement Joint

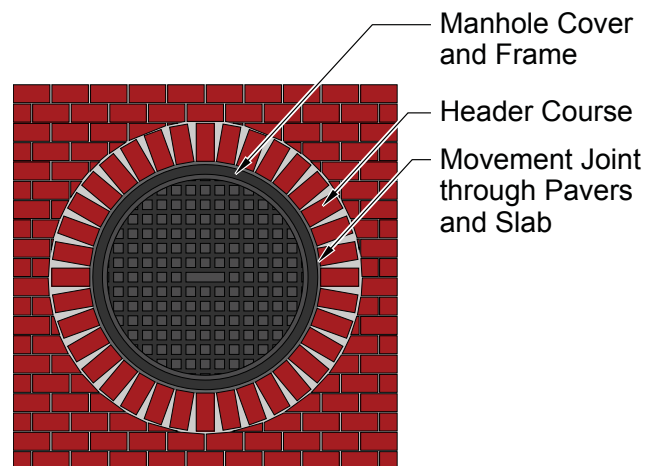


Figure 10
Typical Penetration

MATERIALS

Cleavage Membrane (Crack Isolation Membrane)

A cleavage membrane or crack isolation membrane is used only in an unbonded system. It is used to create a separation between the mortar bed and the underlying base so that the two layers can move independently of each other. This avoids stresses caused by horizontal movement between the two layers.

Plastic sheeting and roofing felt are among several materials that can be used as the cleavage membrane. The former includes:

- polyethylene sheeting complying with ASTM C171, *Specification for Sheet Materials for Curing Concrete* [Ref. 1];
- ASTM D4397, *Specification for Polyethylene Sheeting for Construction, Industrial and Agricultural Applications* [Ref. 1]; and
- polyethylene sheeting complying with ASTM D4068, *Specification for Chlorinated Polyethylene (CPE) Sheeting for Concealed Water-Containment Membrane* [Ref. 1].

The latter includes:

- asphalt saturated roofing felt complying with ASTM D226, *Specification for Asphalt Saturated Organic Felt Used in Roofing and Waterproofing* [Ref. 1]; and
- coal tar saturated roofing felt complying with ASTM D227, *Specification for Coal Tar Saturated Organic Felt used in Roofing and Waterproofing* [Ref. 1].

The minimum thickness for a single layer should be 6 mil (0.15 mm); however, the preferred option is to use two layers with a minimum thickness of 4 mil (0.10 mm) per layer.

Other appropriate materials to use as a crack isolation membrane include liquid-applied products or a layer of sand.

Drainage Mats

Drainage mats are used to allow horizontal drainage of water that might penetrate the paving surface. The drainage mat can be used in place of the cleavage membrane to form an unbonded system that is less susceptible to freeze-thaw damage, as well as on suspended deck applications. There are several types of proprietary drainage mats available that form a drainage path below the mortar bed, while still providing adequate support. The preferred type of drain mat has holes through the plastic core but does not include a filter cloth. Water is able to drain through channels formed in the underside of the sheet. These mats are typically 1/8 in. (3 mm) to 1/4 in. (6 mm) in thickness (see Figure 11) and must have provisions for drainage at their edges. Use of drainage mats should be carefully considered in heavy vehicular applications.

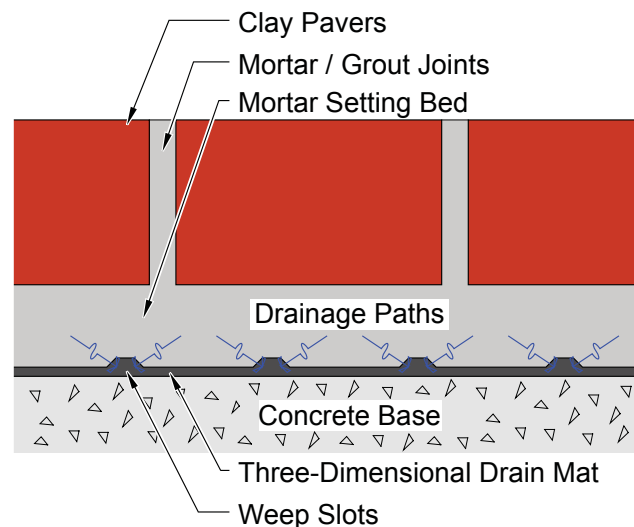


Figure 11
Mortared Brick Paving with Drainage Mat

Welded Wire Reinforcement

Welded wire reinforcement should be used to improve the tensile strength of the mortar bed between movement joints in all unbonded systems. This will help to prevent cracks from occurring as a result of expansion and contraction. Unchecked, such cracks can develop within the joints between pavers. Welded wire reinforcement should comply with the requirements of ASTM A82, *Specification for Steel Wire, Plain, for Concrete Reinforcement* [Ref. 1] and ASTM A185, *Specification for Steel Welded Wire Reinforcement, Plain, for Concrete* [Ref. 1]. Square opening sizes of 2 and 3 in. (50 and 75 mm) can be used with 16 gage or 13 gage wires, respectively, in both

directions. The present designations of these welded wire meshes are 2 × 2 - W0.3 × W0.3 (formerly 2 × 2 - 16/16) and 3 × 3 - W0.7 × W0.7 (formerly 3 × 3 - 13/13).

Movement Joint Filler

The compressible filler in a movement joint must be strong enough to prevent the sealant from being easily compressed into the joint. For this reason board type products are preferred over backer rods. There are several different types of compressible filler material that can be used. These include cork, sponge rubber and polyurethane bonded recycled rubber. These products should comply with the requirements of ASTM D1751, *Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Non-extruding and Resilient Bituminous Types)* [Ref. 1] and ASTM D1752, *Specification for Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction* [Ref. 1].

Setting Bed Bond Coat

A thin slurry bond coat is typically recommended with the bonded system to adhere the mortar setting bed to the underlying concrete base. This slurry consists of a mixture of cement, sand and water, although the water can be replaced with a liquid latex additive to improve the strength and durability of the mortar. Typical proportions of sand and cement are equal parts of each material with water or latex added so that a creamy consistency is achieved, suitable for brushing onto the concrete base.

Setting Bed Mortar

Mortar for the setting bed can be a mixture of cement and fine aggregate or a proprietary mortar or grout. The setting bed mortar will be exposed to the same severe environmental conditions as the pavers. As such, the mortar will need to have low permeability and high cement content. The use of latex additives in place of part or all of the mix water often improves the durability, bond strength and resiliency of the mortar while reducing its permeability. Additive manufacturers' instructions should be followed.

Type M mortar is recommended for exterior mortared brick paving on grade. The setting bed mortar should conform to ASTM C270, *Specification for Mortar for Unit Masonry* [Ref. 1]. This mortar Type is necessary in freezing climates to allow the mortar to resist freeze-thaw conditions. In addition, mortar with a higher air content (generally above 5 to 7 percent by volume) is also known to be more resistant to freeze-thaw deterioration. ASTM C270 Type S mortar can be used as an alternative, since it may be more workable than Type M mortar. Interior applications may use either Type M or Type S mortar. Masonry cements should only be used based on past experience in a similar climate.

Alternatively, mortar conforming to ANSI A118.1, A118.4 or A118.6 can be used as appropriate for the application. Thin set mortars typical of tile installation should not be used for exterior clay brick pavements unless experience has shown that they have satisfactory performance.

Type M mortars are mixed with 1 part portland or blended cement, up to ¼ part lime and 2½ to 3 parts sand. The aggregate for the setting bed mortar should comply with the requirements of ASTM C144, *Specification for Aggregate for Masonry Mortar* [Ref. 1]. Other mortars are mixed according to the manufacturer's recommendations.

Paver Bond Coat

A thin slurry bond coat is used in the tile setter's method to bond the pavers to the top of the mortar bed. The slurry consists of a mixture of cement and water, although the water can be replaced with a liquid latex additive to improve the strength and durability.

Pavers

Pavers covered by ASTM C902, *Specification for Pedestrian and Light Traffic Paving Brick* [Ref. 1] and ASTM C1272, *Specification for Heavy Vehicular Paving Brick* [Ref. 1], can be installed in a mortar setting bed, but the designer should select the appropriate Class and Type for the project. For external use this will generally be Class SX, Type I pavers. Pavers from all Applications, PX, PS and PA, are suitable, subject to variable joint widths. For more detailed information on specifying clay pavers, refer to *Technical Note 14*.

Clay pavers of any texture are compatible with the mortar setting system. However, pavers with a pronounced surface texture may accumulate mortar and grout materials that can stain their surfaces. Some paver manufacturers are able to supply special pavers that have their top surface coated with paraffin wax. The coating should have a melting point that will resist melting in direct sun but can be removed by steam cleaning. Typically this will range between 150 and 170 °F (66 and 77 °C).

A minimum paver thickness of 1¼ in. (32 mm) is recommended for exterior applications subjected to light vehicular traffic. For heavy vehicular applications the pavers should be at least 2¼ in. (57 mm) thick. The visible dimensions of the paver (referred to as length and width) may be limited by bond patterns that require pavers with a certain length-to-width ratio to preserve bond lines. Pavers for use with mortar setting beds are typically sized to accommodate a joint approximately ⅜ in. (10 mm) wide. Specifying pavers that are 7⅝ by 3⅝ in. (194 by 92 mm) is common, and can accommodate most bond patterns. However, several manufacturers also produce different sizes and shapes that are suitable for one-to-one, two-to-one and three-to-one modular layouts.

Most pavers set in mortar are square edged to create a clean edge to tool the mortar against. Chamfered edges and other edge treatments can be used, but since the joint will be finished at the bottom of the chamfer, it may create a larger joint than anticipated.

Mortar/Grout for Joints

Although joint filling material is referred to as mortar in the bricklayer's method and as grout in the tile setter's method, these materials are virtually the same. Mortar or grout for the joints is the same as material that is being used for the mortar setting bed. As an alternate, ANSI A 118.1, A118.4 or A118.6 can be used to specify the mortar or grout joint material.

Use of additives should be based upon the bedding and jointing material requirements. Latex additives may improve the durability of the joints. The mortar or grout should be mixed to a stiff plastic consistency and installed as work progresses. The mortar may be pigmented, but the pigment should be limited to less than 10 percent by weight of cement. Carbon black used as a pigment should be limited to 2 percent by weight of cement.

Grout may be mixed from pre-packaged products that are prepared for use with clay pavers. These may also be pigmented, and since they are not site batched, they will produce a more consistent color. The grout should be mixed with water or latex additive to a plastic consistency. If an additive is used, the manufacturer's directions should be followed. Aggregates meeting the requirements of ASTM C144 may be used.

Jointing mortar or grout should not consist of a dry mixture of cement and sand, especially if it is swept dry in between the pavers. Such a mixture inhibits the ability of the cement to absorb moisture and cure properly. The result is mortar that may not be resistant to freeze-thaw cycles.

Joint Sealants

There are several different joint sealant materials that may be used at the top of movement joints. These include silicone, urethane and polysulfide products. These products are available in a wide range of colors. Where the sealant may be impacted by stiletto heels or other point loads, it should have a Shore A hardness of at least 35.

Joint sealant materials should comply with ASTM C920, *Specification for Elastomeric Sealants* [Ref. 1]. There are many different classifications of sealants. They may be single component (Type S) or multi-component (Type M). They can be self-leveling on flat surfaces (Grade P) or gunnable for inclined surfaces (Grade NS). Class 25 sealants can withstand an increase of 25 percent of the joint width, but Class 12½ can withstand only half of this movement. Use T (traffic) is typically required for paving applications. The manufacturer's recommendations should be followed for preparation and installation requirements.

INSTALLATION

Two different construction methods used to install clay pavers are the bricklayer's method and the tile setter's method. The bricklayer's method uses a stiff plastic mortar for the setting bed and for filling the joints as the work progresses. The tile setter's method uses a semi-dry mortar as the setting bed and delays joint filling until the bed has cured. The latter method is more common, since it tends to have a lower initial cost, but either method can be used successfully.

Preparation

Prior to installation of the mortar setting bed or pavers, the installer should verify that the conditions are suitable for installation and undertake some preparatory work. The base must conform to the recommended or specified tolerances and the installer must verify its finish is acceptable for installation. This will include cleanliness so as to achieve a bond or to enable horizontal movement. The installer must also verify that all fittings built in, under or through the paving are properly located and installed. In addition to utility access covers, conduits, tree pits and similar features, this also includes baseplates and bolts that attach to penetrating features. Lines, levels and coursing should be established, as well as verifying the position of movement joints and other special joint treatments.

For pavements above occupied spaces, the installer should make sure that waterproof membranes, drainage mats and insulation have been inspected and approved, and record that these are undamaged when beginning work. The installer should be aware of open joints or uneven surfaces that could restrict movement between the mortar bed and the base. These materials must be protected from damage and soiling during the work.

For bonded systems, the concrete base should have a fine brush or wood float finish, and all curing compounds and other materials that could affect the bond should be cleaned off. For unbonded systems the concrete base should have a steel trowel finish. The surface should be cleaned of all loose material prior to installing the mortar bed each day.

Two different preparatory methods are required, dependent on whether a bonded or unbonded system will be used.

Bonded System Preparation. When a bonded system is being used, it is important to dampen the concrete base with clean water so that it does not absorb the moisture from the setting bed mix, causing improper curing. This is usually undertaken several hours before placing the setting bed, and any excess surface water should be removed before applying the bond coat. A thin layer of setting bed bond coat is spread over the base with brushes to form a continuous uniform coating immediately before placing the setting bed. The thickness should be $\frac{1}{16}$ in. (1.6 mm) or less. This work should be undertaken in small areas to avoid drying prior to covering with the mortar bed.

Unbonded System Preparation. Moisture content of the concrete base should be determined before applying the cleavage membrane so as not to trap moisture beneath the membrane. Prior to placement of the setting bed, the cleavage membrane should be placed over the base without forming folds or wrinkles. These may be detrimental to the creation of a true slip plane. Minimum end and side laps are typically 4 in. (102 mm) for membranes, and tears or cuts should be covered with a strip of membrane at least 12 in. (306 mm) in width. The welded wire mesh reinforcement should be placed over the cleavage membrane, lapped at joints by one full aperture. The mesh reinforcement should be supported so that it becomes embedded at mid-depth in the mortar setting bed. The edges of the wire mesh should be trimmed 1 in. (25 mm) from edges and movement joints.

Setting Bed and Paver Installation

Care should be taken with cementitious setting beds so that they are mixed, placed and cured without drying out. Initial set typically occurs in less than an hour, and only the amount that can be covered with pavers prior to initial set should be mixed at any time. The pavers should be cut to size with a wet saw to create clean edges. A paver splitter (guillotine cutter), or hammer and chisel can be used to cut pavers, but it may not result in straight cuts. If the installer works from the base side, care should be taken not to contaminate the base or to disturb the cleavage membrane or wire reinforcement. If the work is from the paver side, care should be taken to avoid disturbing the pavers that have just been set. Covering installed pavers with plywood sheets or other similar materials will reduce potential disturbance.

Bricklayer's Method. This method uses a stiff plastic mortar for the setting bed and joint filling. The setting bed should be spread out over the bond coat in a small area ahead of the laying face and should be slightly thicker than the required thickness to allow for compaction when the pavers are pressed into place. The clay pavers should be buttered with mortar on the bottom and edges that will abut pavers that are already in place. The pavers are then pressed into the mortar setting at the correct level. Excess mortar will be squeezed out of the joint and should be cleaned off with a trowel so that it does not stain the surface. If the joint is not completely full, then additional mortar should be worked into the joint with a trowel. Mortar that has reached initial set prior to placement of the pavers should be removed and discarded. Joints should be tooled to the required profile when the mortar

becomes thumbprint hard. The pavement should be cured under plastic sheeting or other methods to maintain moisture for at least seven days or as weather conditions dictate. It should not be opened to traffic until after this time.

Tile Setter's Method. The setting bed in this method is mixed dry and then spread and screeded to a uniform thickness with sufficient thickness for accurate setting of pavers to meet finished grade. When mixed with water, the mortar shall be of such a consistency and workability that will allow maximum compaction during tamping of the mortar bed. It is not adequate to leave the mortar bed partially compacted, as it will be prone to damage, particularly by frost. Mortar that has reached initial set prior to placement of the pavers should be removed and discarded.

A $\frac{1}{16}$ to $\frac{1}{8}$ inch (2 to 3 mm) thick paver bond coat is troweled onto the bottom surface of each paver as it is set in place. The pavers should be set accurately in the selected pattern with uniform joints and paver edges aligned within the required tolerances. A movable metal grid is often used to align the pavers. As in the bricklayer's method, if the installation pattern is modular, then it is important to determine the joint size based upon the actual paver dimensions. After a small area of pavers has been placed on the setting bed, it should be tamped with a wood leveling board and rubber mallets to achieve the correct elevations and profiles. The leveling board covers several pavers and helps to prevent lipping or an uneven surface. The setting bed should be thoroughly compacted, and if necessary any low pavers should be lifted and replaced with additional setting bed and fresh bond coat. The pavers should have full contact with the setting bed. The pavement should be cured under plastic sheeting or other methods to maintain moisture for at least seven days. Grouting of the joints can take place after an initial 24-hour curing period. Care should be taken to ensure that the joints do not become contaminated during this period.

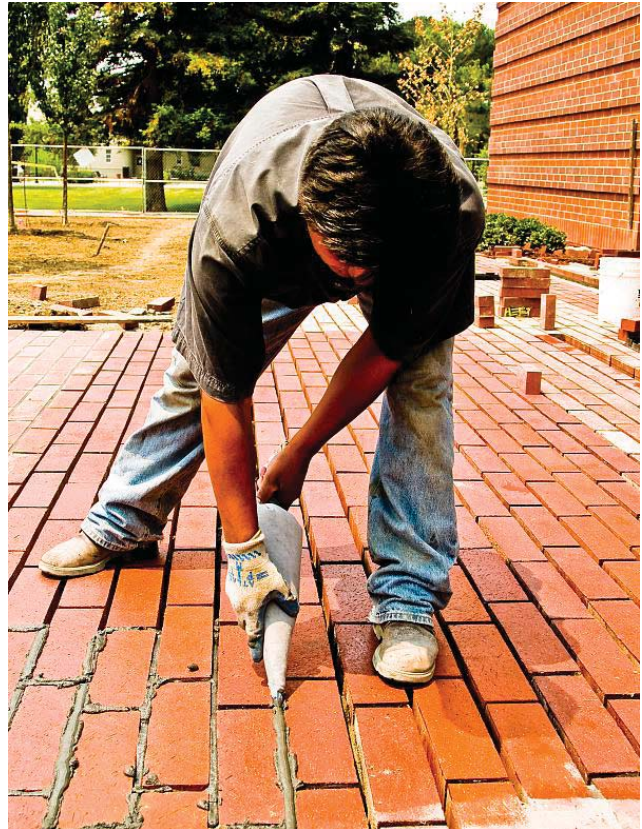


Photo 2
Installing Grout Between Pavers

When grouting the joints, the pavers should be damp to prevent premature drying of the grout. The work should be undertaken in small areas, cleaning as necessary to prevent grout stains on the paver surfaces. The grout should be worked in to the joints from the top (Photo 2), fully compressing the grout, so that the joints are completely filled and free of voids. Once the joints are completely full, the surface can be tooled to the required profile, taking care not to entrap air or to smear grout on the paver surfaces. Curing of the grout is undertaken by covering and maintaining in a damp condition for seven days. The pavement should not be opened to traffic until after this time.

Take care to ensure that the exposed faces of the pavers are not smeared with mortar or grout during installation. The plastic mortar or grout can get in the texture of the paver and be difficult to remove. Both the bricklayer's and tile setter's methods should keep the paver faces as clean as possible. As mentioned previously, some paver manufacturers can wax their pavers at the plant to allow easier cleaning after the system has cured properly.

Installing Movement Joints

For a bonded system, movement joints in the base should not have pavers laid directly over them. Rather, control joints in the concrete base should align with expansion joints in the brick surface. Care should be taken to ensure that the expansion joint material is continued through the full depth of the mortar bed and along the full length of all movement joints. To form the expansion joint, it is often easier to form one side of the joint against a temporary wood edge, placing the filler material immediately before the adjacent mortar bed is installed.

Installing the joint sealant should take place only after the mortar and grout have cured for at least 14 days and the grout is dry. The sides of the pavers along the joint should be cleaned so that an effective bond can be achieved. If necessary, a primer can be applied to the joint sides before installing the sealant. A debonding strip should be placed over the top of the filler so that the sealant bonds only to the sides of the joint. The work should be carried out in accordance with the sealant manufacturer's recommendations.

Installation Methods to Avoid

Some installation methods for mortar-set systems should be avoided. These include the use of dry cement and sand mixtures that are swept into the vertical mortar joints or the use of soupy grout that is squeegeed into the mortar joints. The first method does not allow adequate water to penetrate the mix and properly hydrate the cement, which may result in poor durability. The second method creates cleaning problems and may not fill the joints well. Either of these installation methods should be avoided, since they will not be durable and will require extensive maintenance.

MAINTENANCE

Cleaning

Cleaning of mortared paving during construction should be conducted according to the clay paver manufacturer's or mortar/grout manufacturer's instructions. More information on cleaning products and methods can be found in *Technical Note 20*.

Mortar-set pavers can be kept clean in most environments by regular sweeping. In environments that lead to a greater degree of buildup of grease, tire marks or other stains, the pavers may be cleaned by pressure washing. Request paver manufacturer's recommended cleaning directions and clean a small test area to evaluate the results. Pressure washing can be more effective when hot water is used and when mild detergents are applied. Special cleaners may be required to clean grout that has absorbed stains. The grout-filled joints are generally resistant to this treatment, but aggressive pressure washing can cause localized failure if the grout cracks or becomes soft. Sealed joints should be cleaned with caution. More stubborn stains, including paint and gum, can be cleaned by scraping off the hard residue and then scrubbing with a stiff bristle brush and scouring powder. In some cases, using dry ice or carbon dioxide can solidify the material so it can be removed more easily. Proprietary cleaning solutions are also available to clean in damp or shady areas where moss and lichens have grown on the surface of the paving system. As always, clean a test area and follow cleaning solution manufacturer's instructions.

Snow Removal

Snow prevention and removal can be carried out in a number of ways — by hand, by machine or by chemicals. Hand methods include shovels and brooms. Recessed joints can result in the edges of pavers becoming chipped by shovels. Mechanical methods include snow blowers, snow plows, and buckets or brushes fitted on tractors or skid steers. This equipment should be properly adjusted so that it does not damage the pavement surface. Blades can be fitted with plastic or urethane cutting edges, if necessary. When tractor and particularly skid-steer mounted equipment is used, the pavement must be able to support the wheel loads without damage.

There are a range of de-icing chemicals that are used on brick pavements. However, mortar joints are particularly vulnerable to de-icing chemicals, especially those containing chlorides. Residue from de-icing agents left on the surface can result in staining or efflorescence. Use non-chloride-containing de-icers to avoid these types of problems.

Repairs

Repairs to damaged pavers can be undertaken by saw-cutting around the perimeter of the affected paver so that it can be removed without damaging adjacent units. It may be necessary to break the paver with a hammer and chisel to remove all the pieces. If the mortar setting bed is in good condition, the top 1/8 in. (3 mm) can be roughened and the replacement paver thin-set onto it. Otherwise, the setting bed should be chipped out to sound material and the pavers reinstalled as per the original construction. Care should be taken in removing the old system to minimize damage to any wire mesh or cleavage membranes that might be present.

Repairs to grout joints should include chipping out loose material and sawing or grinding to a depth equal to at least twice the joint width. The joint should be cleaned and fresh grout installed as per the original construction.

Repairs to movement joints should include cutting back debonded sealant and assessing the condition of adjacent sealant. The paver edges should be thoroughly cleaned and primed before fresh sealant is installed. A new debonding strip should be used.

Coatings

It is generally not necessary or recommended to apply a coating to exterior mortar-set pavers. Some penetrating water repellents may help prevent joint staining, but the risks usually outweigh the advantages. Other types of coatings, such as acrylic, mineral gum waxes or stearates, are more commonly applied to interior brick floors to facilitate cleaning. Their use should be carefully considered, as they may trap water within the paving system and create failures.

SUMMARY

Clay pavers in a mortar setting bed may be either bonded or unbonded to the underlying concrete base. Bonded pavements are commonly used on concrete slabs on grade and for vehicular applications, while unbonded are preferred for suspended structural slabs. When properly constructed, mortar-set pavers can meet most design and performance requirements. This must be balanced against the higher levels of maintenance that may be required and the increased costs.

Technical Notes on Brick Construction are recommendations explicitly written for the design, installation and maintenance of masonry using fired clay brick. BIA does not advise the use of these recommendations with other products, including but not limited to those claiming to be similar to fired clay brick products. The information and suggestions contained in this Technical Note are based on the available data and the experience of the engineering staff and members of the Brick Industry Association. The information contained herein must be used in conjunction with good technical judgment and a basic understanding of the properties of brick masonry. Final decisions on the use of the information discussed in this Technical Note are not within the purview of the Brick Industry Association and must rest with the project architect, engineer and owner.

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