City of Alexandria, Virginia

MEMORANDUM

MEMORANDUM TO INDUSTRY NO. 10-11

DATE: OCTOBER 7, 2011

TO: CONTRACTORS, DEVELOPERS, AND DESIGN PROFESSIONALS

FROM: EMILY A. BAKER, P.E., CITY ENGINEER
TRANSPORTATION & ENVIRONMENTAL SERVICES

SUBJECT: PAVING FOR PARK AND PLAZA AREAS WHICH ARE TO BE CITY-OWNED AND MAINTAINED

Effective immediately, the City of Alexandria will allow an expanded range of paving materials to be installed in newly constructed or redeveloped park and plaza areas which are to be owned and maintained by the City.

The Department of Transportation and Environmental Services (T&ES) has the responsibility for maintaining paved areas within City-owned parks and plaza areas. In order to allow greater flexibility in terms of design, performance and appearance, the City shall allow an expanded range of paving and installation techniques for these areas. This Memo sets out:

- the areas of City-owned land where the expanded range of paving materials and installation is permitted
- the range of paving allowable, and
- the specifications for installation.

Background

The City maintains standards for paving installations on City-owned land in order to ensure a level of performance of paved surfaces, to facilitate its maintenance operations, to allow visual coherence and appropriateness (for example in historic districts) and to offer a clear direction to developers, contractors, design professionals and homeowners who are developing in the City.

The existing City standards for paving, and where they are permitted, can be found here:

- City's Memo to Industry 05-08 Standards for Brick Sidewalks:
http://alexandriava.gov/uploadedFiles/tes/info/StandardsforBrickSidewalks%20.pdf

- Paving materials for areas of Mt. Vernon Ave (see streetscape section): http://alexandriava.gov/uploadedFiles/planning/info/MtVernonAvenueurbanDesignGuidelinescomplete1993.pdf

Where is the expanded range of paving materials permitted?

The expanded range of paving material and installation techniques set out in this Memo applies only to areas of public parks or plazas which are maintained by the City's T&ES Department. It is intended that these areas are suitable for larger scale paving installation (either new areas of construction or areas previously developed) rather than localized or piecemeal installations, or repairs. The suitability of the site for installing the expanded range of paving shall be agreed by the City to the satisfaction of the Directors of T&ES and P&Z (Planning & Zoning), and in the case of Parks also to the satisfaction of the Director of RP&CA (Recreation, Parks & Cultural Activities).

City-owned Parks

The City parks covered by this Memo and applicable for the expanded range of paving are the publicly-owned parks identified on the City's website. The full list of Parks arranged in alphabetical order can be found here: http://alexandriava.gov/recreation/info/default.aspx?id=12342,.

The actual boundaries applicable to the expanded range of paving materials shall be determined in the development review process to the satisfaction of the Directors of RP&CA, T&ES and P&Z.

City-owned Plazas

The plazas covered by this Memo and applicable for the expanded range of paving are the publicly-owned open areas which are primarily paved in character and frequently found in urban locations. Plazas shall be considered to be outside the public right-of-way.

The actual boundaries applicable to the expanded range of paving materials shall be determined in the development review process to the satisfaction of the Directors of T&ES and P&Z.

Property that is privately-owned and maintained is not covered by this Memo, nor are City sidewalks and drive aprons, which are covered under separate paving standards. For the relevant paving standards for sidewalks and drive aprons, see the Memo to Industry 05-08 (listed above).

Paving materials

The two sizes and types of paving materials covered by this Memo shall be permitted in addition to the materials already allowed as City Standard paving materials.

Both types of paving units are extruded clay pavers, with specifications described below. For each type of paver, three alternatives (substantially similar in appearance but from different suppliers) are provided:

Paving Unit Type A
Dimensions:
4"x 12" x 2 1/4"
Color and manufacturer information:

i. 'Sienna Blend Paver A' by Belden
ii. 'Midnight Black L-4' by Interstate
iii. 'Sienna Manganese Ironspot' by Endicott

Paving Unit Type B
Dimensions:
8" x 8" x 2 1/4"
Color and manufacturer information:

i. 'Lighthouse Gray' by Belden
ii. 'Platinum L-4' by Interstate
iii. 'Grey Velour' by Endicott

Manufacturer contact information

Belden Brick Company PO box 20910 Canton, Ohio 44701-0910	Interstate Brick 9780 South 5200 West West Jordan, Utah 84088-5689	Endicott Clay Products PO Box 17 Fairbury, Ne 68352
(330) 456-0031 www.beldenbrick.com	(800) 233-8654 www.interstatebrick.com	(402) 729-3315 www.endicott.com

Paving Installation

Detailed paving installation specifications are provided as attachments to this Memo and shall be used in conjunction with the expanded range of paving materials.

The installation specifications are versions of the Brick Industry Association's (BIA) *Technical Notes* for a sand setting bed and a bituminous setting bed. Either type of setting bed (sand or bituminous) shall be considered by the paving installer and by the City, with site specific conditions and paving performance taken into account in determining the correct type of setting bed installation. The BIA specifications have been amended to meet the specific requirements of the City of Alexandria, with any specific conditions which do not apply to those requirements deleted.

The specifications are intended to provide standards for installation and offer variations to suit both the proposed performance of the paving and the site conditions. Given the range of site conditions within the City, and the varying performance expected for specific projects, these installation specifications will not adequately cover all types of installation. The installation for a specific project shall be directed by a professional paving contractor or designer, and shall be approved through the development review process to the satisfaction of the Directors of T&ES and P&Z, and in the case of Park installations by the Director of RP&CA.

Attachments
Attachment A: Installation on Sand Setting bed
Attachment B: Installation on Bituminous Setting bed

BIA Tech Note 14A modified by the City of Alexandria as an attachment to the City'sMemo to Industry xx/xx.

* Conditions amended / deleted by the City of Alexandria to be applicable with its Memo to Industry xx/xx are highlighted in text boxes identical to this text box *

Paving Systems Using Clay Pavers on a Sand Setting Bed

Abstract: This *Technical Note* describes the proper design and construction of pavements made with clay pavers on a sand setting bed in pedestrian and vehicular, ~~residential~~ and nonresidential projects.

Key Words: flexible, mortarless paving, paving, rigid, sand setting bed.

The uses covered by this Technical Note are specific to the City of Alexandria's Memo to Industry xx/xx and do not include residential applications.

SUMMARY OF RECOMMENDATIONS:

General
- Determine if application is pedestrian, light duty vehicular or heavy duty vehicular
- Implement regular maintenance program to maintain pavers in a safe and serviceable condition

Patterns
- Use herringbone pattern for pavements subject to vehicular traffic
- Design flexibility into layout to accommodate field conditions

Drainage
- Provide a minimum slope of 1/4 in. per foot (2 percent grade)
- For concrete and impermeable bases, provide weeps through base

Edge Restraints
- For pavements subject to vehicular traffic, use concrete or stone curbs or steel angles anchored to a concrete base or foundation or a proprietary system rated for traffic
- For all other pavements, use any of the above or clay pavers in a concrete foundation, proprietary plastic or metal edge restraint systems spiked into aggregate
- Use edge restraint with vertical face at paver interface

Clay Pavers

Refer to the City of Alexandria's Memo to Industry xx/xx for the type of paver unit to be used.

Joint and Setting Bed Sand
- Use concrete sand complying with ASTM C 33

This section of the BIA Tech Note does not apply to the City of Alexandria's clay paver installation specification per the City's Memo to Industry xx/xx.

Concrete Base
- For concrete base on ground, provide control joints spaced a maximum of 12 ft (3.66 m) o.c.
- For elevated concrete slab, provide control joints through concrete slab and expansion joints through pavement above aligned with control joints
- Provide weeps through base for drainage

Base, Subbase and Subgrade
- Refer to *Technical Note* 14

INTRODUCTION

This *Technical Note* covers the design, detailing and specification of clay pavers when laid on a sand setting bed (see Figure 1). Refer to *Technical Note* 14 for clay paver design considerations, including traffic, site conditions, drainage and appearance. Sand-set pavers are the most cost-effective method of constructing a pavement made with clay pavers. The system relies upon developing interlock in the paving course, which is generated by friction between the pavers and the jointing sand. This enables the pavers to function as part of the structural pavement system.

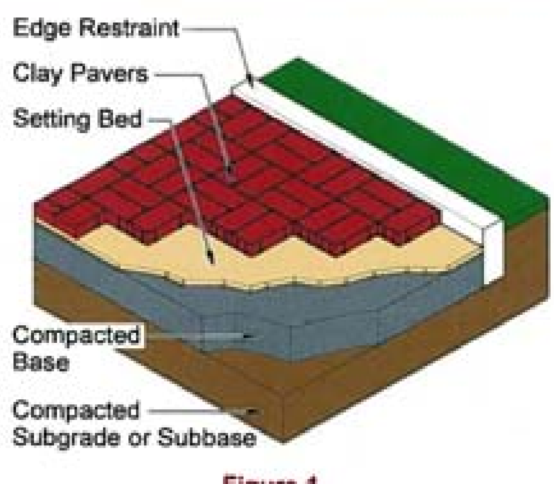

Figure 1
Typical Brick Pavement

This section of the BIA Tech Note does not apply to the City of Alexandria's clay paver installation specification per the City's Memo to Industry xx/xx.

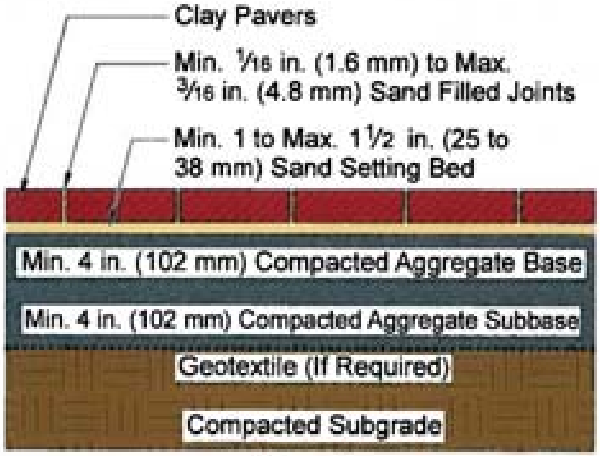

Figure 4
Typical Commercial/Pedestrian Public Plaza/Sidewalk

Applications

Clay pavers set on a sand setting bed are appropriate for virtually any paver application, ranging from pedestrian to heavy duty vehicular traffic. At a minimum, the system requires clay brick pavers and a sand setting bed, compacted after paver placement. Depending on subgrade conditions, additional layers, base and subbase may be required.

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Commercial/Public Plazas and Walkways. With increased pedestrian traffic and increased risk of injury from any localized differential displacements, these types of applications require a firm pavement, similar to that of residential driveways. For plazas, however, a minimum 4 in. (102 mm) compacted aggregate base and subbase typically are used (see Figure 4). Note that for these applications on sites consisting of silty or clayey soils, geotextile should be placed on the compacted subgrade, below the subbase.

The sand setting bed thickness should be 1 to 1½ in. (25 to 38 mm). The base typically consists of coarse aggregate (gravel) of varying gradation, compacted to a minimum thickness of 4 in. (102 mm) using mechanical tamping or vibration.

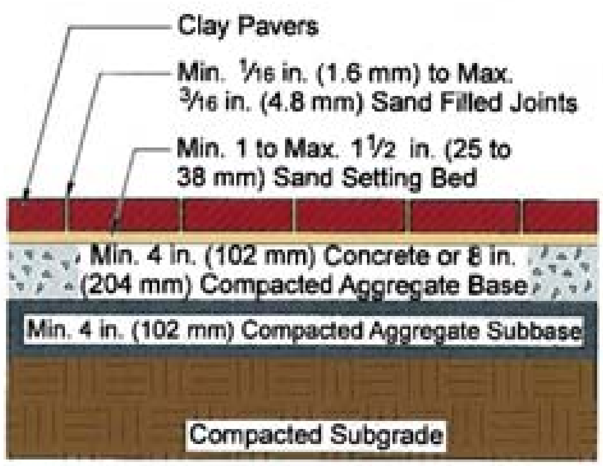


Figure 5
Typical Light Duty Vehicular

Light Duty Vehicular. For parking areas and neighborhood streets serving light duty vehicles, the brick pavement section should be similar to that of a residential driveway, but with a more substantial base. A pavement with a concrete base as depicted in Figure 5 or a thicker aggregate or asphalt base is required.

Heavy Duty Vehicular. Paving systems 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 duty vehicular applications. Such paving systems are beyond the scope of this *Technical Note* series. For further information about heavy vehicular applications, refer to *Flexible Vehicular Brick Paving – A Heavy Duty Applications Guide* [Ref. 6].

GENERAL DESIGN AND DETAILING CONSIDERATIONS

Interlock

Sand-set pavers interlock with one another by generating friction across the joints. This is the result of tightly packing sand into the joints during the vibration process. The interlock improves as the pavement is subjected to traffic. There are three types of interlock present in a sand-set paver pavement when properly constructed: vertical, horizontal and rotational interlock. Interlocked pavers cannot be readily extracted from the pavement.

Vertical interlock allows load transfer across joints between pavers. When a load is applied to one paver, a portion is transferred through sand in the joints to adjacent pavers, as shown in Figure 6, distributing the load to a greater area and reducing the stress on the sand bed and the underlying layers. Vertical interlock allows a paving layer to act as a structural layer. Without vertical interlock, the pavers do not act as a structural layer, and localized stress on the setting bed directly under a loaded paver is increased. Pavers installed on a sand setting bed should not be laid with 1/4 in. (6.4 mm) joints, because this is too wide to achieve interlock, making the pavers unable to transfer load to adjacent pavers. The proper joint width is 1/16 to 3/16 in. (1.6 to 4.8 mm).

Rotational interlock is the result of lateral resistance from adjacent pavers and adequate edge restraints, as shown in Figure 7. It is improved with full joints that support the top of the paver. Without adequate restraint, the pavers can roll in the direction of lateral loading, which may result in an irregular surface profile.

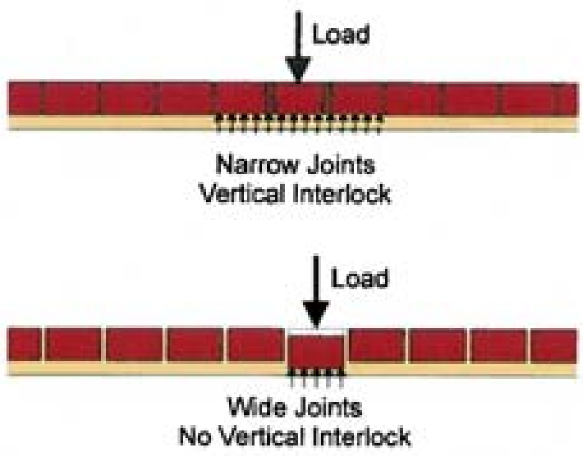


Figure 6
Vertical Interlock of Pavers

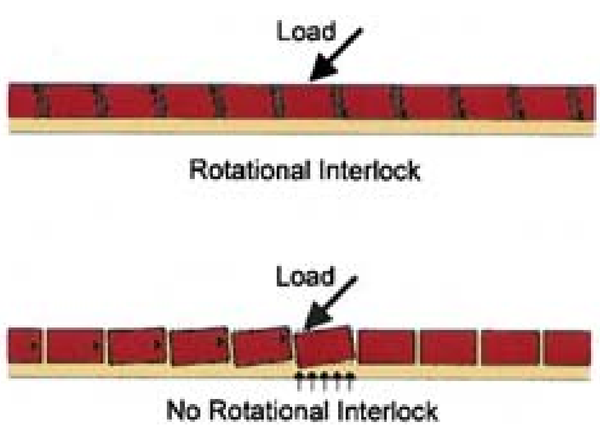


Figure 7
Rotational Interlock of Pavers

The extent of horizontal interlock depends upon the laying (bond) pattern of the pavers and the edge restraint. Patterns that have staggered joint lines allow the load to be distributed to a larger number of pavers, as shown in Figure 8. This reduces joint compressive stress and potential for horizontal creep of pavers. Continuous joints result in minimal load distribution and increased joint compressive stress, which may produce horizontal movement.

Pavement Section

Clay pavers over a sand setting bed can be installed over a flexible or rigid base, including aggregate, asphalt, cement-treated aggregate or concrete bases. For further information on bases, refer to *Technical Note* 14.

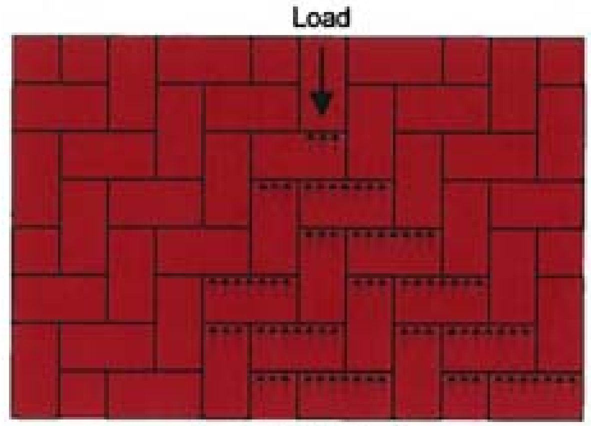
The design of the base is beyond the scope of this *Technical Note*, and the advice of a qualified and experienced pavement designer should be sought. For preliminary design, it is reasonable to assume that a minimum of 4 in. (102 mm) of concrete, cement-treated aggregate, asphalt or aggregate base will be needed for sand and gravel subgrades. For ~~residential driveway,~~ commercial/pedestrian and light duty vehicular applications with clay or silt subgrades, an additional 4 in. (102 mm) of aggregate subbase or base should be added to each option. Additional thickness may be required when the subgrade is susceptible to frost heave or when the pavement must support heavy axle loads from trucks.

The uses covered by this Technical Note are specific to the City of Alexandria's Memo to Industry xx/xx and do not include residential applications.

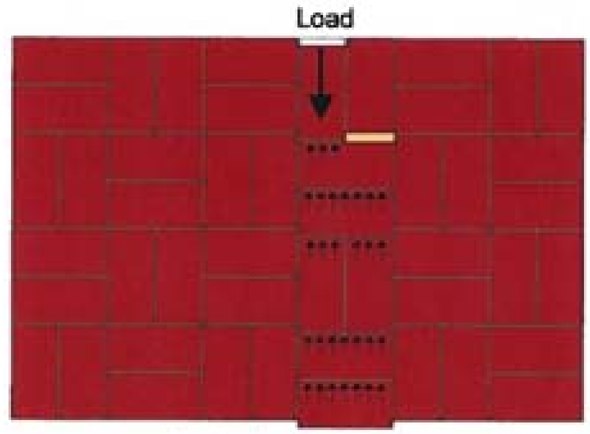
Concrete bases should be reinforced with welded wire fabric or reinforcement bars and should have control joints spaced at 12 ft (3.66 m) intervals to control expansion and contraction. To minimize movement of slabs, detail movement joints as shown in Figure 9. Control joints in suspended structural slabs should extend through the entire slab and align with an expansion joint through the pavement above. Control joints should have dowels or a keyway to limit vertical separation across the joint.

Vehicular Traffic

For light duty vehicular paving systems, a maximum traffic speed of 30 mph (50 kph) is considered appropriate for pavers in a sand setting bed. When frequent vehicular traffic is anticipated, additional attention is required to ensure that joints between pavers remain filled with sand. Higher speed applications require more vigilance, as the interlock between pavers is reduced with sand loss. Paving systems for vehicular traffic applications usually will include a compacted subbase to distribute loads (see Figure 5).



Horizontal Interlock



No Horizontal Interlock

Figure 8
Horizontal Interlock of Pavers

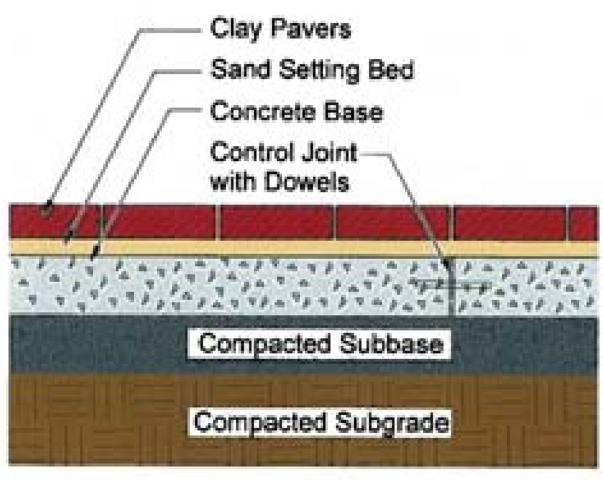


Figure 9
Control Joints

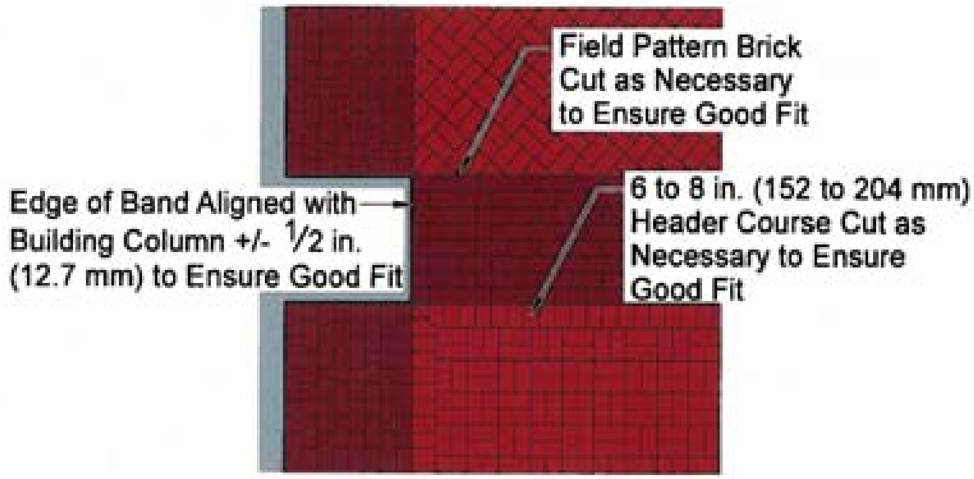


Figure 10
Pattern Options to Maintain Specified Joint Widths

The designer should consider the bond pattern for vehicular traffic applications. Any pattern may be used under foot traffic. When vehicles operate on a pavement, patterns that distribute horizontal loads (i.e., loads from turning, accelerating or braking vehicles) across multiple pavers, such as herringbone, are recommended. Patterns with continuous joints, such as stack bond or running bond, are more susceptible to creep from horizontal loading. Where such patterns are used in vehicular pavements, continuous joint lines should be oriented perpendicular to the direction of vehicle travel.

Bond Patterns/Layout

The size of pavers may influence the selection of a suitable bond pattern. Pavers for use on a sand setting bed typically are manufactured in sizes that accommodate a joint width of approximately 1/8 in. (3.2 mm) to encourage optimal interlock.

Bond patterns such as herringbone, basket weave and others make use of the 1:2 or 1:3 ratios between the pavers' length and width to maintain the pattern and joint alignment. Pavers sized to accommodate joint widths of approximately 3/8 in. (9.5 mm) do not achieve these ratios. Such pavers typically are used in pavements with mortar joints. When they are laid on a sand setting bed, only a running bond, stack bond or chevron pattern should be used, since these patterns do not depend on these ratios.

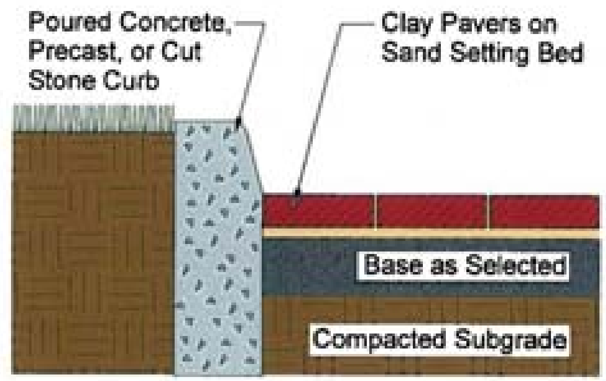
An individual clay paver's dimensions may be slightly different from the dimensions of another clay paver from the same run. The inherent variability of their dimensions is a result of their manufacturing process. Pavers may be larger or smaller within allowable tolerances of their specified size. This variability may not be consistent, because actual dimensions may be greater or smaller than the specified dimensions. As such, the pavers may not be able to be placed in a standard modular pattern. Blending of pavers from multiple cubes during installation can overcome this issue. The installer should constantly monitor paver size during installation to ensure that the bond pattern and joint size are maintained.

When designing an installation pattern with changes in bond and color, incorporating some tolerance in the placement of certain paver features is recommended. This can be achieved by using saw cut pavers at junctions of colored areas or by allowing approximate dimensions and realistic tolerances when placing certain paver features. Two examples are depicted in Figure 10.

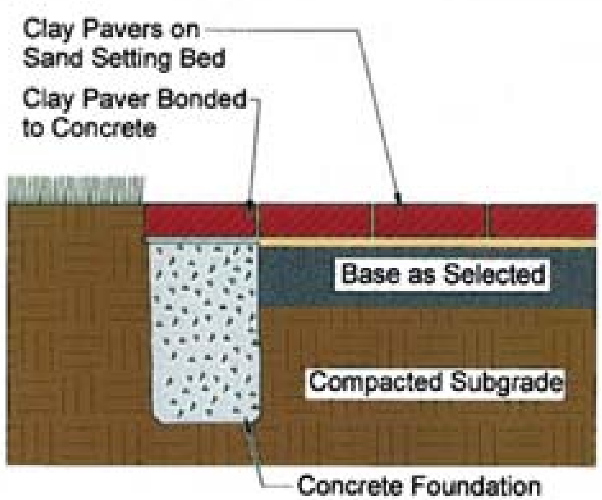
This section of the BIA Tech Note does not apply to the City of Alexandria's clay paver installation specification per the City's Memo to Industry xx/xx.

Edge Restraints

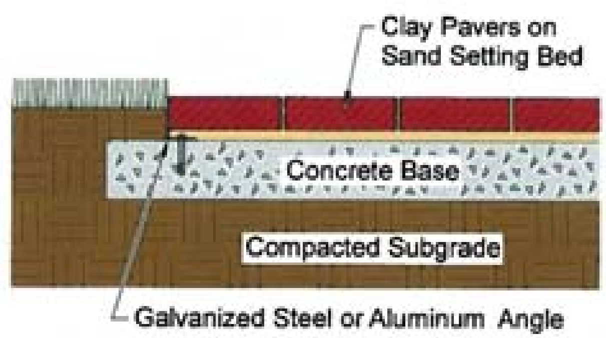
Edge restraints are critical in a pavement with a sand setting bed to enable consistent interlock and resist horizontal loads transferred from pavers. Selection of edge restraint will depend on pavement section and use. Figure 11 (pages 6 and 7) presents various options, in increasing order of load capacity. Concrete curbs or steel angles attached to a concrete foundation or concrete base layer are the most robust edge restraints. They are recommended for all pavements subject to regular vehicular traffic. Edge restraints for other applications may include pavers bonded to a concrete foundation, and a range of proprietary plastic and metal edge restraint systems that are typically spiked into aggregate bases. Timber edging and concrete backing poured to restrain edge pavers may not be effective over the long term. It is important that all edge restraints have a vertical rather than inclined face for the pavers to butt against.



(d) Curb Edge

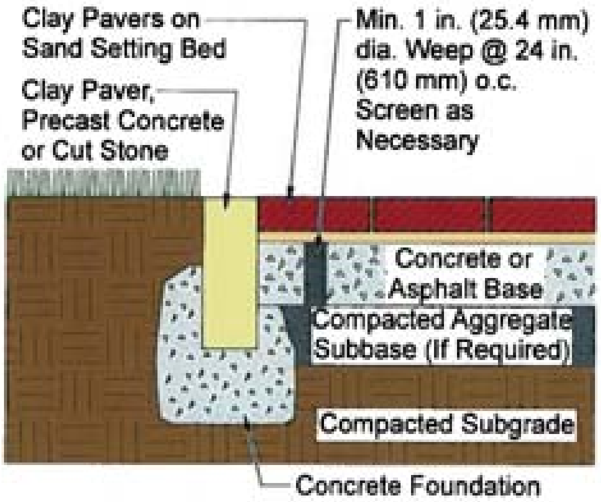


(c) Bonded Clay Paver Edge Restraint

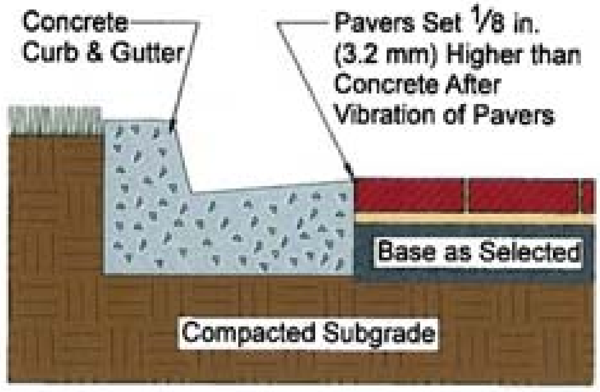


(e) Steel Angle Edge Restraint

Figure 11
Edge Restraints



(f) Clay Paver, Precast Concrete or Stone Edge Restraint



(g) Poured Concrete Curb and Gutter Edge Restraint

Figure 11 (continued)
Edge Restraints

Drainage

Adequate drainage is important to the performance and durability of any clay paving system. Water should be drained from the paving system as quickly as possible. A minimum slope of 1/4 in. per foot (2 percent grade) is recommended. Adequate drainage should be provided to ensure the integrity of all layers in a paving system.

A sand setting bed will continue to consolidate slightly after construction is complete. Pavers should be finished slightly higher than drainage inlets and other low edges of a pavement. This will minimize water puddling at these locations. Typically 1/8 in. (3.2 mm) will be adequate and will not present a short-term tripping hazard.

Over time, small amounts of water will migrate through sand joints. Consequently, a sand-set paving system with an impermeable base will require weep openings at low points in the pavement. Weep openings permit moisture to seep out of the pavement rather than saturating the setting bed. Even a well-compacted aggregate base may benefit from installing weep openings. Sand is less durable in a saturated state than when dry or slightly damp.

Several weep opening options are available. A small-diameter (1½ to 2 in. [38 to 51 mm]) pipe with ends wrapped in geotextile may be placed through the side wall of drain inlets or through edge restraints. Such weeps should be installed at spacings of 2 to 6 ft (0.60 to 1.83 m) depending on pavement geometry and profiles, environmental conditions and pavement use. As an alternative, a drainage mat may be placed vertically through the base. This may be used in conjunction with small pipes at drain inlets. For a concrete base, holes may be drilled or formed through the slab to weep water to the subbase. Locating holes away from the impact of wheel loads is necessary since subbase materials may be moisture-sensitive.

Penetrations

Large and small features that penetrate through the paver layer should be properly detailed. These features include utility covers, tree pits, light pole bases, signposts and street furniture. Features may either penetrate the entire pavement section to an independent structure or foundation, or be anchored to a concrete subslab. Such features can present some issues in cutting the pavers to form a uniform joint around them.

Some utility covers and other frames are relatively shallow, or have buttresses, inclined faces, anchor bolts or other features that may interfere with the bottom of a paver. Where possible, features should be specified,

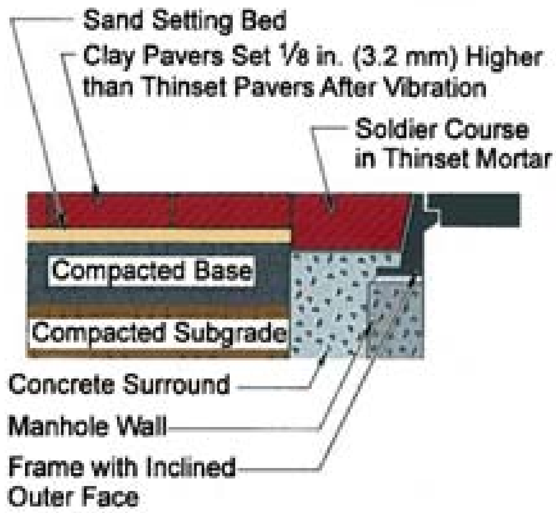


Figure 12
Large Penetration

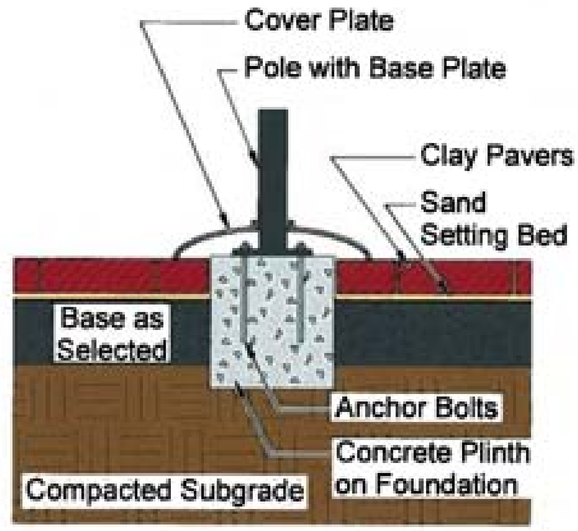


Figure 13
Small Penetration

designed and installed deeper than the setting bed. Where this is not possible, casting a concrete collar around the frame and thin-setting a header course of pavers on the concrete may clear obstructions to the sand setting bed interface, as shown in Figure 12.

Accurately cutting and placing pavers against small features may prove difficult. An alternative is to construct a concrete plinth up to the pavement surface and to install a cover plate to conceal the anchorage of the feature, as shown in Figure 13. This also allows easy access for repairs, without removing pavers.

MATERIALS

Subgrade

For design purposes, the subgrade is considered to be either sand/gravel or clay/silt. The latter are more sensitive to moisture and frost and may require the use of subbase layers and proper drainage to protect against shrinkage, swelling and frost heave. The advice of a properly qualified and experienced pavement designer should be sought in regard to the preparation of the subgrade.

Base and Subbase

Base materials for pavers laid in a sand setting bed may be of aggregate, cement-treated aggregate, asphalt or concrete. When a subbase is required, aggregate generally is used. Aggregate materials should comply with ASTM D 2940 and be compacted in accordance with ASTM D 698 to 95 percent maximum density. Asphalt should meet ASTM D 3515. Concrete should have a minimum compressive strength of 4,000 psi (27.6 MPa) and should have control joints spaced a maximum of every 12 feet (3.66 m). For a more detailed discussion of base and subbase materials, refer to *Technical Note* 14.

Geotextiles

Geotextiles are used on top of silt or clay soils to help stabilize subgrades and under sand setting beds to prevent loss of sand through weep openings and other gaps in the pavement base or at edge restraints or penetrations. The preferred type of geotextile is a woven, polypropylene fabric complying with ASTM D 4751, *Test Method for Determining Apparent Opening Size of a Geotextile* [Ref. 5], with an approximate opening size from a No. 70 to No. 100 sieve size opening. Nonwoven geotextiles can be used for light-traffic applications. Geotextiles should be lapped at the sides and ends of rolls a minimum of 12 in. (305 mm). Care should be taken to not locate laps directly under anticipated wheel paths. Geotextiles should extend 6 in. (152 mm) beyond potential areas of sand loss. These may be adhered in place, but generally will stay in position once covered by the sand setting bed. Geotextiles should not be allowed to span over unfilled holes or pits in the surface of the base that are greater than 1 in. (25.4 mm).

Setting Bed Sand

A sand setting bed provides a strong support layer under pavers and accommodates variations in paver thickness to produce a smooth surface profile. A portion of setting bed sand penetrates the joints during vibration and initializes the development of interlock between the pavers. Sand for the setting bed should be clean, naturally occurring material with angular and subangular shaped particles, with a maximum size of about 3/16 in. (4.8 mm). Concrete sand conforming to the requirements of ASTM C 33, *Specification for Concrete Aggregate* [Ref. 1], or local department of transportation standards is recommended for use as setting bed material. This provides a more stable and durable setting bed than mason sand or screenings, which have a more rounded shape and should not be used. Sand rich in silica-based minerals is desirable, because carbonate-based minerals are softer and can break down when saturated. Manufactured limestone sand usually causes efflorescence and should be avoided unless it has a proven track record on similar projects.

Clay Pavers

Refer to the City of Alexandria's Memo to Industry xx/xx for the type of paver unit to be used.

Jointing Sand

Sand within pavement joints creates interlock between pavers by generating friction across the joint. Larger particles present in joints reduce the potential for lateral movement. Finer particles act to reduce contact stresses around the larger particles, reducing the potential of the particles breaking down. The sand also accommodates the variations in paver size and reduces the potential for contact between pavers that can lead to chipping. ASTM C 33 concrete sand should be placed in joints before vibration to maximize interlock at the bottom portion of joints. However, coarse particles that do not fall into joints should be brushed off the pavement surface rather than worked in. After vibration, finer jointing sand may be placed so that it penetrates to the bottom of the joints and achieves better filling. ~~When the typical joint dimension exceeds 3/16 in. (4.8 mm), stabilized sand or joint sand stabilizer should be used.~~

This section of the BIA Tech Note does not apply to the City of Alexandria's clay paver installation specification per the City's Memo to Industry xx/xx.

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INSTALLATION AND WORKMANSHIP

Subgrade

The subgrade should be brought to the proper level and cleared of organic material. Compaction should comply with ASTM D 698 to 95 percent maximum dry density for clay and 100 percent maximum dry density for sand/gravel. For a more detailed discussion of subgrade preparation, refer to *Technical Note* 14.

Base and Subbase

Base and subbase materials should be placed per the design. Aggregate should be compacted in accordance with ASTM D 698 to 95 percent maximum density. The maximum variation under the setting bed should be +/- 3/16 in. (4.8 mm) when a 10 ft (3.05 m) straightedge is laid on the surface. The minimum slope of the concrete base surface should be 1 in. (25.4 mm) in 4 ft (1.22 m) to allow for drainage. For a more detailed discussion on the installation of base and subbase materials, refer to *Technical Note* 14.

Setting Bed

Whenever possible, the direction of installation should be planned to protect the paving against premature use or damage by rain or other construction activities. The surface of the underlying base material should be thoroughly clean and dry before installation of the bedding sand. Elevations should be verified to ensure that the sand setting bed will be a consistent thickness after compaction. The setting bed should not be used to bring the pavement to the correct grade. Isolated high and low spots should be corrected before sand placement to avoid an uneven pavement surface resulting from variable sand setting bed thicknesses. Lines should be established for setting out the pattern. The contractor should become aware of size variations in the pavers to maintain the pattern without localized opening or closing of joints to meet a fixed edge. All areas of potential sand loss should be covered with geotextile.

Screed rails should be set on the surface of the base to proper line and level. They are typically placed 8 to 12 ft (2.44 to 3.66 m) apart, or closer when working on a grade. An allowance should be made in the thickness of the setting bed for compaction of bedding sand as pavers are installed, as well as additional consolidation in service. An experienced contractor will be aware of the proper thickness for different conditions to achieve the correct long-term surface profiles. The bed thickness should be established so that when the pavers are compacted, their top surface will be 1/8 in. (3.2 mm) above the required grades to allow for limited settling in service.

To prevent disturbance, setting bed sand should not be spread too far ahead of the paver laying face. Voids left after removing the screed rails should be filled. The screeded bedding sand may be affected by wind or rain as well as by wayward construction operations. If sand is disturbed, it should be loosened and rescreeded. Extensive areas of screeded sand should not be left overnight unless they are properly protected from disturbance and moisture. Moisture content of setting bed sand should be kept as uniform as possible to minimize undulations in the pavement surface. The sand should be kept in a damp condition conducive to packing. Water should not be applied except by very light misting. Stockpiled sand should be covered to protect it from wind and rain.

Paver Installation

The pavers are laid on the setting bed working away from an edge restraint or the existing laying face while following the pattern lines that have been established. Full pavers should be laid to the required pattern with 1/16 to 3/16 in. (1.6 to 4.8 mm) wide joints. The optimum joint width for vehicular traffic is between 1/16 and 1/8 in. (1.6 and 3.2 mm), but some wider joints may be required with Application PS pavers, and particularly with

Application PA pavers. Lugs enable the correct joint width to be achieved when the pavers are placed in contact with one another. Pavers should not be forced together, resulting in excessive contact, because this may cause the pavers to chip during installation or compaction. At least two cubes of each color of pavers should be drawn from at one time, and the manufacturer's recommendations on color blending should be followed. The pavers should be adjusted to form straight pattern lines while maintaining the correct joint widths.

Several feet of pavers should be installed before beginning to add cut pavers as infill against edge conditions. Bench-mounted masonry saws are the best means of cutting the pavers to achieve a neat edge and a vertical cut face. Use of a wet saw or dust collection system is recommended to control dust. Guillotine cutters also may be used, but their cuts typically are not as straight and neat. Convex curves can be formed using multiple cuts, but this requires a skilled craftsman to meet allowable joint tolerances. Concave curves are very difficult to form and should be avoided when possible.

Pavers should be compacted at the end of each day to prevent any damage while left unattended. The pavement surface should be compacted using a plate compactor. These typically have a plate area of 2½ to 3 sq ft (0.23 to 0.28 sq m) and operate at a frequency of 80 to 100 Hz. To prevent pavers from chipping during vibration, a little bedding sand material can be swept into the joints, or the underside of the plate compactor can be fitted with a rubber mat. Pavers also can be covered with a sheet of geotextile or sheets of plywood during vibration For molded pavers, vibration is especially important since irregularities and dimensional variations on the underside could lead to air gaps or improper support if not properly compacted into the sand setting bed. Compaction should not be carried out within 4 ft (1.2 m) of unfinished edges.

The vibrated surface should be slightly above adjacent pavement surfaces, drainage inlets and channels to allow for secondary compaction of the bedding layer under traffic. The maximum variation in surface profile should be less than 3/16 in. (4.8 mm) in 10 ft (3.05 m). Water should drain freely from the surface and not form puddles. Lipping between adjacent pavers should not be greater than 1/8 in. (3.2 mm) if the pavers have chamfers, or 1/16 in. (1.59 mm) if they have square edges.

After vibration of the pavers to finished elevations, dry fine-grained jointing sand is brushed over the surface of the pavement and additional vibration is undertaken until all of the joints are completely filled with sand. Surplus jointing sand should be maintained on the surface to enhance the process of joint filling. Typically the sand should be level with the bottom of the chamfer or approximately 1/8 in. (3.2 mm) below the top of square edge pavers.

Joint Sand Stabilizers

This section of the BIA Tech Note does not apply to the City of Alexandria's clay paver installation specification per the City's Memo to Industry xx/xx.

MAINTENANCE

This section of the BIA Tech Note does not apply to the City of Alexandria's clay paver installation specification per the City's Memo to Industry xx/xx.

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The information and suggestions contained in this Technical Note *are based on the available data and the combined experience of 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 contained 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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THE BRICK INDUSTRY ASSOCIATION | TECHNICAL NOTES on Brick Construction | 14B

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BIA Tech Note 14B modified by the City of Alexandria as an attachment to the City's Memo to Industry xx/xx

* Conditions amended / deleted by the City of Alexandria to be applicable with its Memo to Industry xx/xx are highlighted in text boxes identical to this text box *

Paving Systems Using Clay Pavers on a Bituminous Setting Bed

Abstract: This *Technical Note* describes the proper design and construction of pavements made with clay pavers laid on a bituminous setting bed in pedestrian and vehicular, ~~residential and~~ nonresidential projects.

The uses covered by this Technical Note are specific to the City of Alexandria's Memo to Industry xx/xx and do not include residential applications.

Key Words: asphalt, bituminous setting bed, flexible, mortarless paving, paving, rigid.

SUMMARY OF RECOMMENDATIONS:

General
- Determine if application is pedestrian, light or heavy vehicular
- Maintain proper installation temperatures of bituminous materials
- Place tack coat and bituminous setting bed adhesives within proper time
- Implement regular maintenance program to maintain pavers in a safe and serviceable condition

Patterns
- Use herringbone pattern for pavements subject to vehicular traffic
- Design flexibility into layout to accommodate field conditions

Drainage
- Provide a minimum slope of ¼ in. per ft (2 percent grade)
- For impermeable bases, provide weeps through base or edge restraint

Edge Restraints
- For pavements subject to vehicular traffic, use concrete or stone curbs, steel angles anchored to a concrete base or footing, or a proprietary system rated for vehicular traffic
- For all other pavements, use any of the above or clay pavers in a concrete footing, aluminum or steel edging
- Use edge restraint with vertical face at paver interface

Joint Sand
- For maximum interlock between pavers and for vehicular applications, use concrete sand complying with ASTM C33 or a proprietary joint sand
- For adequate interlock, use masonry sand complying with ASTM C144 and a joint sand stabilizer
- Do not add cement to joint sand

This section of the BIA Tech Note does not apply to the City of Alexandria's clay paver installation specification per the City's Memo to Industry xx/xx.

Clay Pavers

Refer to the City of Alexandria's Memo to Industry xx/xx for the type of paver unit to be used.

Modified Asphalt Adhesive
- Use neoprene modified asphalt adhesive with 2 percent neoprene, 10 percent asbestos-free fibers and 88 percent asphalt

Bituminous Setting Bed
- Use asphalt cement/binder complying with ASTM D3381 or ASTM D6373
- Use fine aggregate complying with ASTM D1073 or ASTM D3515

Tack Coat
- Use for vehicular traffic applications
- Use either emulsified asphalt complying with ASTM D977, Type SS-1 or SS-1h or cutback asphalt complying with ASTM D2028

Base, Subbase and Subgrade
- Refer to *Technical Note* 14

INTRODUCTION

This *Technical Note* covers the design, detailing and specification of paving systems using clay pavers when set on a bituminous setting bed (see Figure 1). Pavements with bituminous setting beds can be used in most applications and are especially suited for pavements subjected to vehicular traffic or large amounts of water runoff. The pavers are held in place by the bonding action of the setting bed materials and by some contribution from interlock between the pavers. Refer to *Technical Note* 14 for guidance in selection of bases, subbases and subgrades and other general design information.

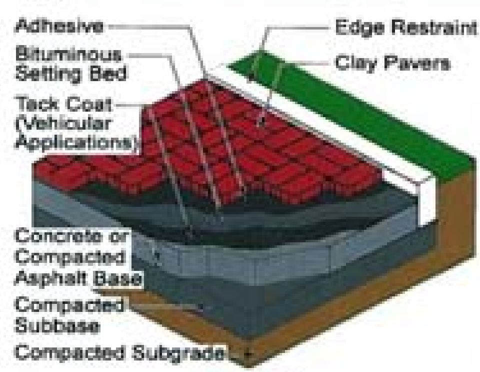

Figure 1
Typical Brick Pavement on Bituminous Setting Bed

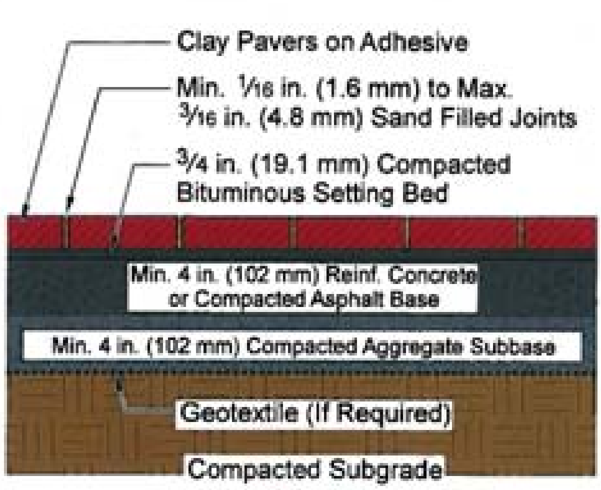

Figure 2
Typical Commercial/Public Plazas and Walkways

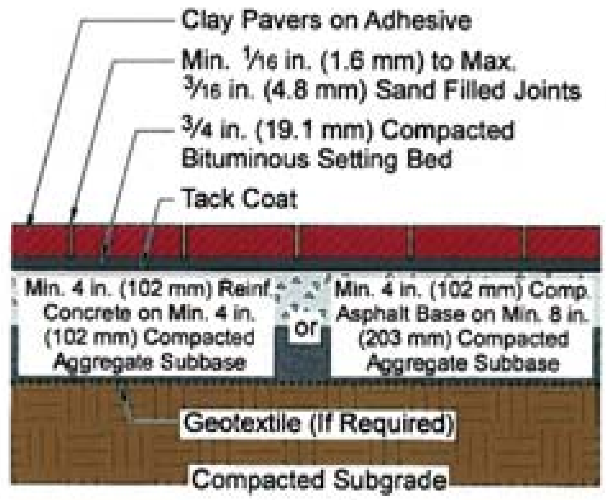

Figure 3
Typical Light Vehicular Traffic

Applications

Clay pavers set on a bituminous setting bed are appropriate for pedestrian and both light and heavy vehicular traffic. At a minimum, the system requires clay brick pavers adhered to a compacted bituminous setting bed with a tack coat of neoprene modified asphalt adhesive. Below the setting bed, a concrete or asphalt base should be placed on an aggregate subbase. The thickness of base and subbase and materials should be based on the application and subgrade conditions.

This section of the BIA Tech Note does not apply to the City of Alexandria's clay paver installation specification per the City's Memo to Industry xx/xx.

Commercial/Public Plazas and Walkways. With large amounts of pedestrian traffic and occasional light vehicular traffic, these types of applications require a firm pavement (see Figure 2). Clay pavers should be set in an adhesive on a compacted bituminous setting bed ¾ in. (19.1 mm) in thickness. A minimum 4 in. (102 mm) reinforced concrete or asphalt base should be used. A subbase of coarse aggregate (gravel) should be used and compacted to a minimum thickness of 4 in. (102 mm) using mechanical compaction or vibration. Alternatively, a minimum full depth 8 in. (203 mm) of concrete or asphalt can be used as the base course and subbase. For applications on sites consisting of silty or clayey soils, a geotextile should be placed on the compacted subgrade, below the subbase.

Light Vehicular Traffic. For parking areas and neighborhood streets serving light vehicular traffic (cars and delivery trucks), the brick pavement section should be more substantial (see Figure 3). Clay pavers should be set in an adhesive on a compacted bituminous setting bed ¾ in. (19.1 mm) in thickness. A tack coat to adhere the bituminous setting bed to the base should be used, since this is a vehicular application. For a concrete base, use a minimum 4 in. (102 mm) of reinforced concrete with a 4 in. (102 mm) compacted subbase or 8 in. (203 mm) of reinforced concrete as the base and subbase. For an asphalt base, use a minimum 4 in. (102 mm) of asphalt with an 8 in. (203 mm) subbase or 12 in. (305 mm) of asphalt as the base and subbase. The subbase should be coarse aggregate (gravel) of varying gradation and compacted using mechanical tamping or vibration. For applications on sites consisting of silty or clayey soils, a geotextile should be placed on the compacted subgrade, below the subbase.

Heavy Vehicular Traffic. Paving systems 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. For further information about heavy vehicular applications, refer to *Flexible Vehicular Brick Paving – A Heavy Duty Applications Guide* [Ref. 2].

GENERAL DESIGN AND DETAILING CONSIDERATIONS

Adhesion and Interlock

The bituminous setting bed bonds the pavers to the base to resist horizontal movement and uplift. The pavers are adhered to the setting bed with an adhesive of neoprene modified asphalt. A tack coat of emulsified or cutback asphalt is typically used between the base and setting bed in vehicular applications. The bituminous setting bed, adhesive and tack coat, if used, are viscous at construction temperatures, but stiffen as they cool. During hot weather, these materials will become slightly viscous, potentially increasing paver creep due to horizontal traffic loads compared to a pavement with a sand setting bed.

Vertical, horizontal and rotational interlock between pavers occur in a bituminous setting bed pavement, but not as effectively as in a sand setting bed. Interlock is described more thoroughly in *Technical Note* 14A. The interlock between the pavers is reduced because the sand may not penetrate the full depth of the joints, and is not consolidated by mechanical vibration during construction. Interlock usually improves over time as traffic and environmental factors increase the densification of the joint sand.

Movement Joints

Concrete bases should have control joints spaced at 12 ft (3.66 m) intervals to control expansion and contraction. Dowels or keyways should be incorporated to limit vertical separation across the joint. Control joints should extend through the entire slab and continue as an expansion joint through the pavement above to reduce the likelihood of shifting and damage to the pavers.

Climate

Bituminous-set pavers can be used in all climatic conditions. However, the bituminous setting bed material should not be placed when the temperature is below 40 °F (4 °C). Slightly higher levels of maintenance may be required for climates with very high temperatures and more frequent vehicular traffic. Bituminous materials soften as their temperature increases. This can result in a reduction of bond between the pavers and the base, and an increased potential for creep under horizontal forces.

Vehicular Traffic

For paving systems designed for light vehicular traffic, a maximum speed of 35 mph (56 kph) is considered appropriate for pavers on a bituminous setting bed. When vehicular traffic is anticipated, a tack coat between the base and the bituminous setting bed should be used. For pavement experiencing higher traffic volume, additional attention is required to ensure that joints between pavers remain filled with sand. Higher-speed applications require more vigilance, as the interlock between pavers is reduced with sand loss. Paving systems with a bituminous setting bed usually will include a compacted subbase to distribute loads. The designer should consider the appropriateness of the bond pattern for vehicular traffic applications, as discussed below.

Bond Patterns/Layout

When selecting a bond pattern, the designer should consider the traffic that will use the pavement. Any pattern may be used for pedestrian traffic. When vehicles operate on a pavement, patterns that distribute horizontal loads (i.e., loads from turning, accelerating or braking vehicles) across multiple pavers, such as herringbone, are recommended. Patterns with continuous joints, such as stack bond or running bond, are more susceptible to creep from horizontal loading and are not recommended for vehicular applications. Continuous joint lines should be oriented perpendicular to the direction of vehicle travel.

The integrity of the paving relies primarily upon adhesion to the base and, to a lesser extent, on interlock between pavers. The pavers may be placed with joints that can range from 1/16 to 3/16 in. wide (1.6 to 4.8 mm) after the pavers have been aligned. For vehicular pavements, narrow joints are preferred to minimize the potential for creep occurring in response to horizontal loading. For a pedestrian pavement with limited vehicular access, less stringent dimensional tolerances can be accepted, and the joints between pavers may be wider. When Application PS pavers are installed in vehicular applications, they should be laid in running bond or other bonds not requiring extremely close dimensional tolerances. Joint widths wider than ¼ in. (6.4 mm) should be used with caution, as the joints may not align in a herringbone pattern and will be too wide in a basket weave pattern. Wider joints are more likely to experience sand loss, which may result in loss of interlock and adhesion, followed by paver creep.

Bond patterns such as herringbone, basket weave and others make use of the 1:2 or 1:3 ratios between the pavers' length and width to maintain the pattern and joint alignment. Pavers sized to accommodate joint widths of approximately ⅜ in. (9.5 mm) do not achieve these ratios. Such pavers typically are used in pavements with mortar joints (see *Technical Note* 14C). When they are laid on a bituminous setting bed, only a running bond, stack bond or chevron pattern should be used, since these patterns do not depend on these ratios.

An individual clay paver's dimensions may be slightly different from the dimensions of another clay paver from the same run. The inherent variability of their dimensions is a result of their manufacturing process. Pavers may be larger or smaller within allowable tolerances of their specified size. This variability may not be consistent, because actual dimensions may be greater or smaller than the specified dimensions. As such, the pavers may not be able to be placed in a standard modular pattern. The dimensional tolerances of Application PS pavers are adequate for running bond and other pattens not requiring extremely close dimensional tolerances. Application PX pavers have tighter dimensional tolerances that allow consistently narrow joints and placement in all patterns. Blending of pavers from multiple cubes during installation distributes dimensional variations and can help overcome this issue. The installer should constantly monitor paver size during installation to ensure that the bond pattern and joint size are maintained.

When designing an installation pattern with changes in bond or color, incorporating some tolerance in the location of certain features is recommended. This can be achieved by using saw cut pavers at junctions of colored areas or by allowing approximate dimensions and realistic tolerances when placing such features.

Edge Restraints

Bituminous-set pavers require edge restraints to prevent spreading of pavers at the pavement boundaries. Figure 4 presents various options, in order of increasing load resistance. For pedestrian loading, an edging of pavers bonded to a concrete footing; clay pavers, precast concrete or cut stone on a concrete footing; or aluminum angles anchored to a concrete base may be used. For a pavement subjected to vehicular traffic within 3 ft (0.9 m) of an edge, a more robust edge restraint should be used. Steel angles anchored to a concrete base, a precast or cut stone curb on a concrete footing or a poured concrete curb and gutter may be used. The side of the edge restraint in contact with the paver should be perpendicular to the pavement surface.

Drainage

A pavement with a bituminous setting bed can provide a high level of moisture protection to the underlying materials. Initially, the bituminous setting bed will allow some water to seep through until it is fully compacted by traffic. The neoprene modified asphalt adhesive under the pavers prevents most of the surface water from penetrating into the bedding material; however, some will enter and must be able to drain out of the system. This can be achieved by installing weeps through the base, at inlets and other low points in the pavement (see Figures 4b and 4d). The asphalt mixture is semi-permeable and should allow migration of water to weeps. Weeps may continue through the setting bed if desired, however this is likely to require a significant increase in effort during installation of the setting bed. A thicker subbase layer should be installed over subgrade soil that does not readily drain or is subject to freezing and thawing. If the bituminous setting bed is not allowed to drain it can deteriorate, affecting the stability of the overlying pavers.

Drainage openings can be formed by drilling 1 in. (25.4 mm) or larger diameter holes through the concrete base or side walls of drain inlets. Drainage openings should be filled with an open-graded aggregate to prevent their filling with setting bed material. Heat resistant tubing and drain mat materials may also be used but should not be located under wheel traffic. Geotextiles that could be affected by the heat of the setting bed should be avoided. The setting bed material will not leach away through the drainage openings once it has been compacted and cooled.

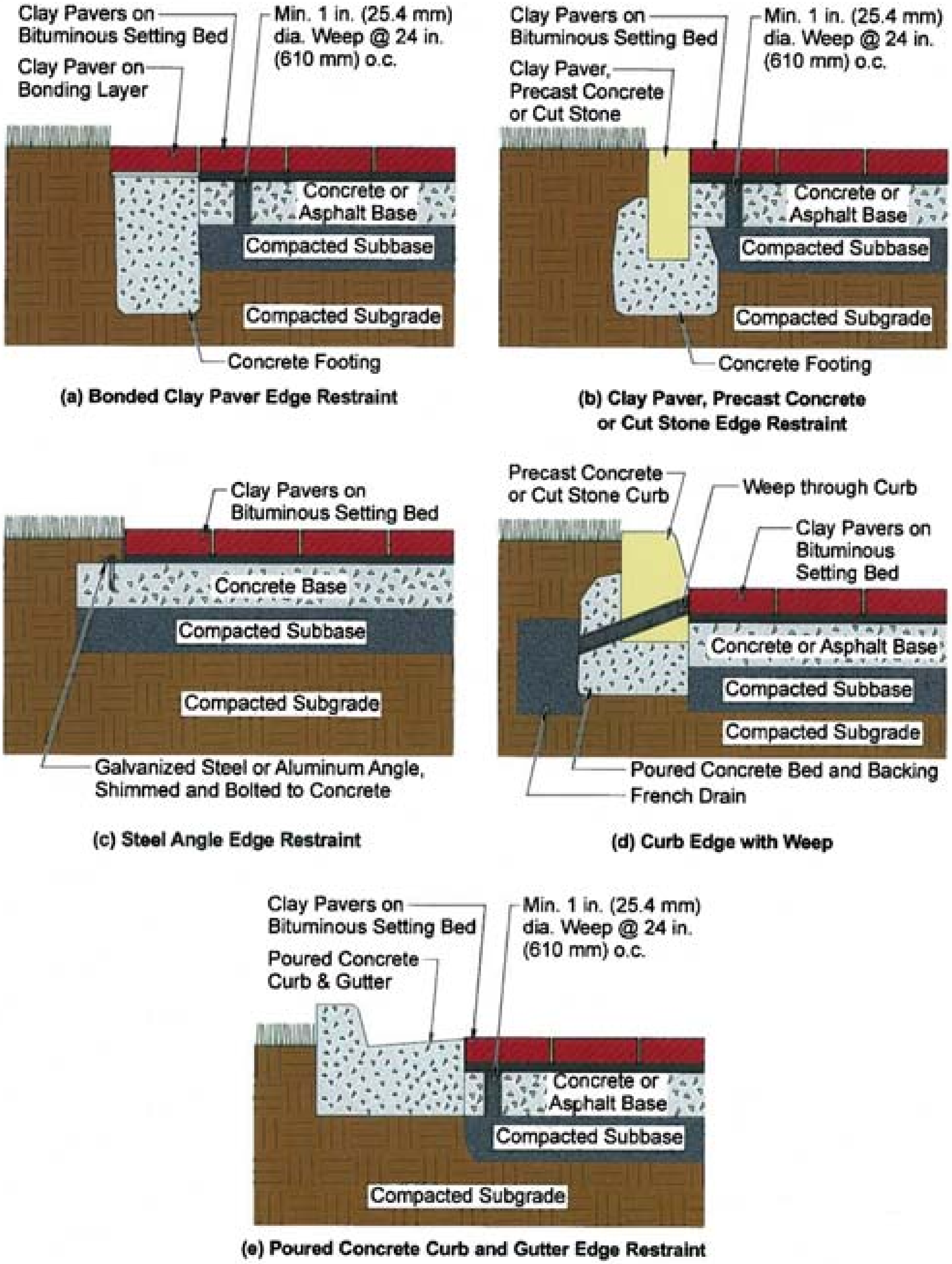

Figure 4
Edge Details for Brick Pavements

Penetrations

Large and small features that penetrate through the paver layer should be properly detailed. These features include utility covers, tree pits, light pole bases, signposts and street furniture. Features may either penetrate the entire pavement section to an independent structure or foundation or be anchored to a concrete footing. Such features can present some issues in cutting the pavers to form a uniform joint around them.

Some utility covers and other frames are relatively shallow, or have buttresses, inclined faces, anchor bolts or other features that may interfere with the bottom of a paver. Where possible, features should be specified, designed and installed deeper than the setting bed. Where this is not possible, casting a concrete collar around the frame and thin-setting a header course of pavers on the concrete may clear obstructions to the bituminous setting bed interface, as shown in Figure 5.

Accurately cutting and placing pavers against small features may prove difficult. An alternative is to construct a concrete footing up to the pavement surface and to install a cover plate to conceal the anchorage of the feature, as shown in Figure 6. This also allows easy access for repairs, without removing pavers.

MATERIALS

Subgrade

For design purposes, the subgrade is considered to be either sand/gravel or clay/silt. The latter are more sensitive to moisture and frost and may require the use of subbase layers and proper drainage to protect against shrinkage, swelling and frost heave. Geotextiles may be used on top of silt or clay soils to help stabilize subgrades. Further information on geotextiles can be found in *Technical Note* 14. The advice of a properly qualified and experienced pavement designer should be sought in regard to the preparation of the subgrade.

Base and Subbase

Base materials for pavers laid on a bituminous setting bed may be of concrete or asphalt. A subbase layer of aggregate is usually placed below the base. Aggregate subbase materials should comply with ASTM D2940, *Standard Specification for Graded Aggregate Material For Bases or Subbases for Highways or Airports*, and be compacted in accordance with ASTM D698, *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft³ (600 kN-m/m³))*, to 95 percent maximum density. Concrete base materials should have a minimum compressive strength of 4000 psi (27.6 MPa) and should have control joints spaced a maximum of every 12 ft (3.66 m). Asphalt base materials should meet ASTM D3515-01, *Standard Specification for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures*. For a more detailed discussion of base and subbase materials, refer to *Technical Note* 14.

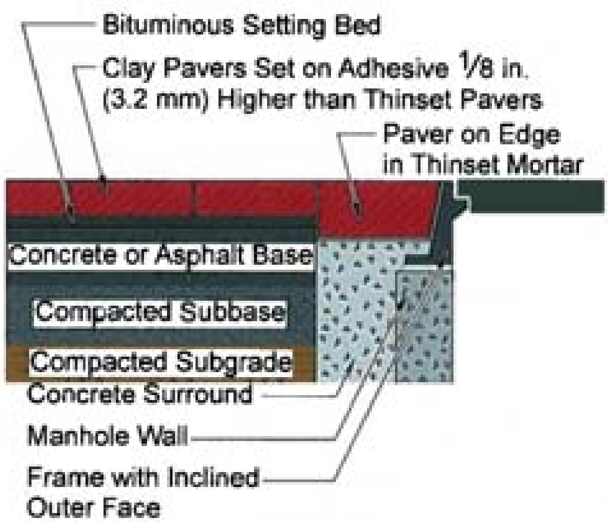

Figure 6
Large Penetration Through Pavement

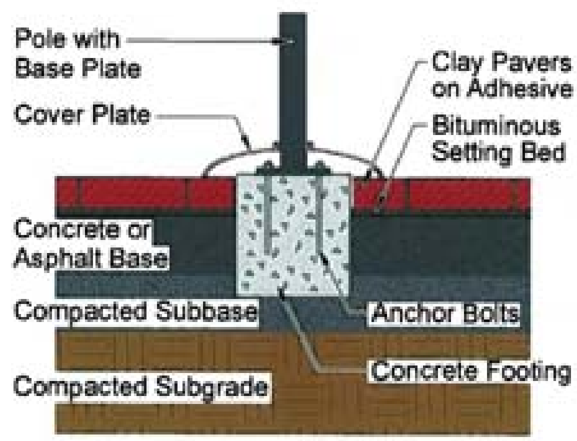

Figure 7
Small Penetration Through Pavement

Tack Coat

The tack coat, if used, enhances the bond of the setting bed to the underlying base. For residential and pedestrian applications with no vehicular traffic and limited pedestrian traffic, the tack coat may be omitted. Typical highway tack coat materials can be used, including emulsified asphalts and cutback asphalts. The type of tack coat will be based upon the prevailing environmental conditions and the procedure used by the installer. Emulsified asphalt is a mixture of asphalt and water. The water will evaporate once the emulsion is exposed to the atmosphere, leaving the asphalt cement solids behind. This process is known as breaking. Emulsified asphalt should comply with ASTM D977, *Specification for Emulsified Asphalt*, Type SS-1 or SS-1h [Ref. 1]. Rapid curing cutback asphalt is a mixture of asphalt and solvent and should comply with ASTM D2028, *Specification for Cutback Asphalt (Rapid-Curing Type)* [Ref. 1]. The solvent will evaporate in a process known as curing.

In most cases, the tack coat material will be supplied in pails or drums. They should be stored in accordance with the manufacturer's directions and be thoroughly mixed before application.

Bituminous Setting Bed

The bituminous setting bed is a mixture of asphalt cement and fine aggregate. The following sections discuss the components and the mix properties available. All types may not be available at all hot mix plants.

Asphalt Cement. Hot-mix plants will only use one or two different grades to suit local highway construction requirements. When available, AC 20 or AR-8000 viscosity graded asphalt cements complying with ASTM D3381, *Specification for Viscosity-Graded Asphalt Cement for Use in Pavement Construction* [Ref. 1] can be used. These materials have a long record of success, but are gradually being replaced with performance grade, PG 64-22, binders complying with ASTM D6373, *Specification for Performance Graded Asphalt Binder* [Ref. 1]. Similar characteristics can be obtained with a PG 64-22 asphalt cement. The digits relate to pavement design temperature extremes expressed in degrees Celsius where the first digits indicate the maximum temperature and the last digits indicate minimum temperature.

Although this grade is used throughout the United States, other grades are available to meet local design temperatures and traffic characteristics. Areas with colder climates may use grade PG 58-28 binders, and those with hotter climates may use grade PG 70-16 binders.

TABLE 1
Typical Gradation for Bituminous Setting Bed Aggregate

ASTM Sieve Size	Percentage Passing	
	Densely Graded Aggregate	Open Graded Aggregate
⅜ in. (9.5 mm)	100	100
No. 4 (4.75 mm)	80 - 100	100
No. 8 (2.36 mm)	65 - 100	75 - 100
No. 16 (1.18 mm)	40 - 80	50 - 74
No. 30 (600 µm)	25 - 65	28 - 52
No. 50 (300 µm)	7 - 40	8 - 30
No. 100 (150 µm)	3 - 20	0 - 12
No. 200 (75 µm)	2 - 10	0 - 5

Aggregate. Fine aggregate materials available at hot mix plants are typically natural or manufactured sands. Fine aggregates should comply with ASTM D1073, *Specification for Fine Aggregate for Bituminous Paving Mixtures*, or ASTM D3515, *Specification for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures* [Ref. 1]. Alternatively, they may comply with local department of transportation requirements that use local aggregates. Table 1 lists typical gradations that have been successfully used, but their availability should be verified before including in a specification. The left column is dense graded mixture that will typically be achieved by blending two aggregate sizes. When fully compact, it will have small, discrete air voids that will not permit moisture to drain. The right column is more open graded being achieved from only one aggregate size. It will have larger air voids and may be slightly more permeable. The asphalt content may need to be higher for this latter gradation. Either material is suitable for pedestrian or light vehicular pavement applications.

The sand should consist of clean, hard, durable particles and be free from adherent coatings of clay, organic matter and salts. The aggregate should have a verifiable history of being resistant to stripping. Manufactured sands typically have a higher stability than natural sands.

Mix. The bituminous setting bed material should be mixed at a hot-mix asphalt plant. The dried aggregates and asphalt cement are heated to the appropriate temperatures and are combined and mixed at approximately 300 °F (149 °C). This will produce a uniform mixture with all of the aggregate particles evenly coated with asphalt cement. The supplier should determine the exact proportions to achieve the best mix to suit the materials, the site and the installation conditions. Typical mix proportions are approximately 6 to 8 percent asphalt cement by weight with 92 to 94 percent aggregate. Geotextiles should not be used directly under bituminous setting beds, where they may be affected by the temperature of the bituminous setting bed materials when laid.

Adhesive

The pavers are bonded to the bituminous setting bed using an adhesive of neoprene modified asphalt. Typical proprietary materials contain 75 percent solids in a mineral spirit solvent. The solids consist of 2 percent neoprene, 10 percent asbestos free fibers and 88 percent asphalt. The adhesive should have a density of 8.0 to 8.5 lb per gal (0.94 to 1.0 kg per liter). The adhesive is typically supplied in pails or drums. The material should be stored in accordance with the manufacturer's recommendations and be thoroughly mixed before application.

Clay Pavers

Refer to the City of Alexandria's Memo to Industry xx/xx for the type of paver unit to be used.

When square-edged pavers or pavers without lugs are selected, care should be taken to ensure that they do not make direct contact with or lip under adjacent pavers. A minimum 1/16 in. (1.6 mm) wide sand-filled joint should separate each clay paver to minimize potential chipping. However, the maximum joint width should be no more than 3/16 in. (4.8 mm) to minimize the potential for horizontal movement under vehicular traffic.

If pavers with spacers and/or a rounded or chamfered edge are installed, there is less potential for direct paver contact at or near the wearing surface. When lugs are used, the potential for creep is also reduced.

Joint Sand

The joint sand should be selected on the basis of the anticipated joint widths and the extent of interlock required. Coarse aggregate conforming to ASTM C33, *Specification for Concrete Aggregates* [Ref. 1] may be used if the joint width is likely to be greater than 1/8 in. (3.1 mm) and if the maximum interlock between pavers is required. If the joints are consistently less than 1/8 in. (3.1 mm) wide, the joint sand may need to be finer and could comply with the fine aggregate requirements of ASTM C33 or alternatively with ASTM C144, *Specification for Aggregate for Masonry Mortar* [Ref. 1] or could be a proprietary joint sand mix. The ASTM gradations are presented in Table 2.

Mixtures of sand and cement have been used to fill joints; however this often results in staining of the paver. Pavers bedded in sand/cement mixtures behave more like pavers bedded in mortar and need expansion joints. For these reasons, mixing cement with joint sand is not recommended.

TABLE 2
ASTM Gradations for Joint Sand

ASTM Sieve Size	Percentage Passing			
	ASTM C33		ASTM C144	
	Fine Aggregate	Course Aggregate	Natural Sand	Manufactured Sand
⅜ in. (9.5 mm)	100	90 - 100		
No. 4 (4.75 mm)	95 - 100	20 - 55	100	100
No. 8 (2.36 mm)	80 - 100	5 - 30	95 - 100	95 - 100
No. 16 (1.18 mm)	50 - 85	0 - 10	70 - 100	70 - 100
No. 30 (600 μm)	25 - 60	0 - 5	40 - 75	40 - 75
No. 50 (300 μm)	5 - 30	0 - 5	10 - 35	20 - 40
No. 100 (150 μm)	0 - 10	N/A	2 - 15	10 - 25
No. 200 (75 μm)	N/A	N/A	0 - 5	0 - 10

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INSTALLATION AND WORKMANSHIP

Subgrade

The subgrade should be brought to the proper level and cleared of organic material. Compaction should comply with ASTM D698 to 95 percent maximum dry density for clay and 100 percent maximum dry density for sand/gravel. For a more detailed discussion of subgrade preparation, refer to *Technical Note* 14.

Base and Subbase

Base and subbase materials should be placed per the design. Aggregate subbase should be compacted in accordance with ASTM D698 to 95 percent maximum density. Concrete base materials should be allowed to cure for a minimum of three days prior to paver installation and seven days prior to vehicular loads. Asphalt base materials should be installed before they cool to temperatures below 200 °F (93 °C). The maximum variation of the base under the setting bed should be ±3⁄16 in. (4.8 mm) when a 10 ft (3.05 m) straightedge is laid on the surface. The minimum slope of the base surface should be 1 in. (25.4 mm) in 4 ft (1.22 m), a 2 percent grade, to allow for drainage. For a more detailed discussion on the installation of base and subbase materials, refer to *Technical Note* 14.

Tack Coat

The tack coat, if used, should be installed when the ambient temperature is above 50 °F (10 °C). The surface of the base material should be thoroughly clean and dry before application. The tack coat should not be applied if rain is likely before placing the setting bed. The tack coat should be thoroughly mixed and heated to the appropriate application temperature, taking all necessary safety precautions. The tack coat should not be diluted. It should be uniformly applied by spraying, brushing or squeegeeing to the top of the base and to all surfaces that will be in contact with bituminous setting bed. The application rate should be established before the work starts. As work progresses, the rate can be verified by marking out the area that one pail or drum will cover. The installer should not apply more tack coat at any time than can be covered with the bituminous setting bed during the same day.

Emulsified asphalt tack coats are typically applied at a rate of 0.9 to 1.3 gal per 100 ft² (3.6 to 5.3 liters per 10.0 m²) to concrete bases and 0.6 to 1.0 gal per 100 ft² (2.5 to 4.1 liters per 10.0 m²) to asphalt bases. Cutback asphalt tack coats are typically applied at a rate of 1.2 to 1.5 gal per 100 ft² (4.8 to 6.1 liters per 10.0 m²) to concrete bases and 1.0 to 1.3 gal per 100 ft² (4.1 to 5.3 liters per 10.0 m²) to asphalt bases. Once applied the tack coat should not be disturbed and should be allowed to cure or break before covering with the setting bed material. This may take a few hours dependent on weather conditions.

The tack coat should be applied to the base in a thin, continuous, uniform layer. If it is applied too thin or so that some areas of the base remain uncoated, the setting bed will not bond properly, creating a weakness or layer separation in the pavement. This can be detrimental if water accumulates and freezes in the separated area. If too much tack coat is applied, the thicker areas can create a slip plane, or the tack coat can penetrate the bituminous setting bed material and reduce its stability. These issues become more critical as the amount of vehicular traffic increases.

Setting Bed

The temperature should be above 40 °F (4 °C) before placing setting bed material. Depth-control rails should be set on the existing surface to proper line and level using shims to account for surface irregularity. Allowance should be made for compaction of the bituminous mix, not only during construction but also in service. An experienced contractor will increase the thickness for different conditions so as to achieve the correct long-term surface profiles. Without additional recommendations, the setting bed thickness should be established so that when the pavers are fully set on the adhesive layer, their top surface will be about ⅛ in. (3.1 mm) above the required grades to allow for future settlement.

Setting bed material should be delivered to the job site in trucks with steel linings that are clean and have not been treated with materials (e.g., gasoline, kerosene, etc.) detrimental to the asphalt mix. To retain heat, the bituminous mixture should be covered prior to use. The temperature of the setting bed material at the time of delivery should not be less than 260 °F (127 °C) or more than 320 °F (160 °C). The installer should work quickly to spread and roll the material before it cools below 180 °F (82 °C). When installing by hand, small orders of 1 or 2 tons (900 to 1800 kg) are generally all that can be handled before the mixture cools. Aggregate particles within the mixture ⅜ in. (9.5 mm) or larger should be removed during installation.

Steel depth control rails, typically 12 ft. (3.6 m) long, are set up at 8 to 12 ft (2.4 to 3.6 m) centers on shims to achieve a uniform profile. The compacted setting bed should be within ±⅛ in. (3.2 mm) of ¾ in. (19.1 mm) in thickness. Care should be taken to ensure that release agents applied to the screed rails and tools do not cause damage to the bituminous setting bed. The hot bituminous material should be spread over the tack-coated base and screeded to the appropriate profile between the depth control rails. The screeded panels should be advanced across the pavement as each screed rail length is completed. To minimize foot traffic on the screeded material, alternate panels should be constructed so that the screed rails and shims can be removed without disturbing the screeded material. The infill panel is screeded using the edges of the two outside panels to set the thickness.

Fill low spots and depressions with additional hot material as the work progresses to produce a firm even surface. Prior to filling, a depth of at least ¼ in. (6.3 mm) should be formed around the edges of low spots to avoid creating feather edges that could deteriorate prematurely. Low spots must not be filled with other materials. During installation of the setting bed the levels and surface profiles should be verified by fully compacting a small area of the setting bed.

Care should be taken to compact the bituminous material to a uniform density and surface texture while still hot. This can be achieved with a light power roller in static mode. If the setting bed is not adequately compacted, the adhesive will be over applied and will be squeezed through the joints to the surface as the setting bed is further compacted in service. This more frequently happens when the bituminous material has cooled below the appropriate working temperature.

The extent of the bituminous bed installed can be equal to two to three days of subsequent paver installation. Setting bed that is not covered by pavers should be protected from rain, dust and traffic. If any contamination or damage occurs, the affected areas of setting bed should be removed and replaced to their full depth.

Adhesive

Neoprene modified asphalt adhesives are proprietary materials that should be prepared in accordance with the manufacturer's instructions. The adhesive should be applied by trowel, brush or squeegee to achieve a uniform coat of adhesive no more than 1/16 in. (1.6 mm) thick over the top of the bituminous setting bed. Typical application rates are between 2 and 3 gal per 100 ft² (8.2 to 12.3 liters per 10.0 m²). To ensure that sufficient adhesive is being applied, occasionally lift random pavers during installation to verify complete coating of the underside with adhesive. If too much adhesive is used it may ooze up to the surface through the joints. The adhesive should be permitted to become tacky before placing the pavers. This may take two to three hours after spreading, dependent on climatic conditions. While the adhesive is becoming tacky the installer may establish string lines to maintain the pattern.

Pavers

The pavers are laid on the adhesive working away from an edge restraint or the existing laying face while following the pattern lines that have been established. Pavers should be laid to the required pattern with 1/16 to 3/16 in. (1.6 to 4.8 mm) wide joints. The optimum joint width for vehicular traffic is between 1/16 and 1/8 in. (1.6 and 3.2 mm), but some wider joints may be required with Application PS pavers, and particularly with Application PA pavers. Application PX pavers more easily accommodate the narrower joints and herringbone pattern recommended for vehicular traffic. Lugs enable the correct joint width to be achieved when the pavers are placed in contact with one another. Pavers without lugs should not be forced together, resulting in excessive contact, because this may cause the pavers to chip during installation or use. At least two cubes of each color of pavers should be drawn from at one time, and the manufacturer's recommendations on color blending should be followed.

String or chalk grid lines should be used to establish straight pattern lines. The contractor should expect the size of pavers to vary slightly from the specified size and adjust the laying module accordingly. A laying module can be established by installing a small section of pavers, adjusting the pavers for proper joint width and pattern alignment and then measuring the pavement over several feet to determine the variation from the nominal paver size. Parallel and perpendicular grid lines should be established and adjusted for the difference, set every 3 to 10 ft (0.9 to 3 meters) as needed to ensure proper pattern alignment. Closer grid line spacings should be considered when complex bond patterns are used, installers are unfamiliar with laying clay pavers, or pavers with greater dimensional variation are selected. The pavers should be aligned before they are bonded to the tack coat or pressed into the tack coat as the installer walks on them.

Cut pavers should be placed only after several square feet of surrounding whole pavers have been installed. Bench-mounted masonry saws are the best means of cutting the pavers to achieve a neat edge and a vertical cut face. Use of a wet saw or dust collection system is recommended, as the dust generated by dry sawing brick may contain silica and may be a potential health hazard. Guillotine cutters also may be used, but their cuts typically are not as straight and neat. Convex curves can be formed using multiple cuts, but this requires a skilled craftsman to meet allowable joint tolerances. Concave curves are very difficult to form and should be avoided when possible.

Joint Filling

The spaces between pavers should be filled with sand as soon as possible after the pavers have been placed. To ensure full penetration of the jointing sand, the joints should be cleaned of all debris by using power air blowers or vacuums. To fill the joints, sweep dry joint filling sand over surface of paving until all joints are completely filled. Once the initial filling of the joints is completed, the surface of the pavers may be rolled to fully compact the pavers into place. This should be undertaken with a light rubber-tired roller with sufficient pressure to achieve a full bond to the setting bed. The roller should not be used in a vibrating mode, as this may cause cracking of the pavers. If there is significant lipping of the pavers, the surface may be protected with plywood or other suitable materials to prevent damage to the edges of the pavers. Rolling should be undertaken at the warmest part of the day, but prior to final set of the adhesive. Care should be taken to ensure that the alignment is not altered.

After rolling, dry sand should be added to the joints as necessary to ensure that the sand has penetrated to the bottom of the joints. Do not vibrate the pavers after they or the sand have been placed on the setting bed. When the sand shows no sign of further settlement roll the surface prior to applying sand stabilizer if required. Add additional sand as necessary.

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The information and suggestions contained in this Technical Note *are based on the available data and the combined experience of 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 contained in this* Technical Note *are not within the purview of the Brick Industry Association and must rest with the project architect, engineer and owner.*

REFERENCES

1. Annual Book of Standards, ASTM International, West Conshohocken, PA, 2009:

Volume 04.02

ASTM C33	"Specification for Concrete Aggregates"

Volume 04.03

ASTM D977	"Specification for Emulsified Asphalt"
ASTM D1073	"Specification for Fine Aggregate for Bituminous Paving Mixtures"
ASTM D2028	"Specification for Cutback Asphalt (Rapid-Curing Type)"
ASTM D2940	"Standard Specification for Graded Aggregate Material For Bases or Subbases for Highways or Airports"
ASTM D3381	"Specification for Viscosity-Graded Asphalt Cement for Use in Pavement Construction"
ASTM D3515	"Specification for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures"
ASTM D6373	"Specification for Performance Graded Asphalt Binder"

Volume 04.05

ASTM C144	"Specification for Aggregate for Masonry Mortar"
ASTM C902	"Specification for Pedestrian and Light Traffic Paving Brick"
ASTM C1272	"Specification for Heavy Vehicular Paving Brick"

Volume 4.08

ASTM D698	"Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3 (600 kN-m/m^3))"

Volume 4.13

ASTM D4751	"Test Method for Determining Apparent Opening Size of a Geotextile"

2. *Flexible Vehicular Brick Paving — A Heavy Duty Applications Guide*, Brick Industry Association, Reston, VA, 2004.