

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.

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

Stabilized Joint Sand

- Use where potential sand loss is anticipated
- Follow paver manufacturer's recommendation regarding the use of stabilized joint sand or joint sand stabilizer
- Use performance history as a basis for selection

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
- Refer to *Technical Note 14* for additional recommendations

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.

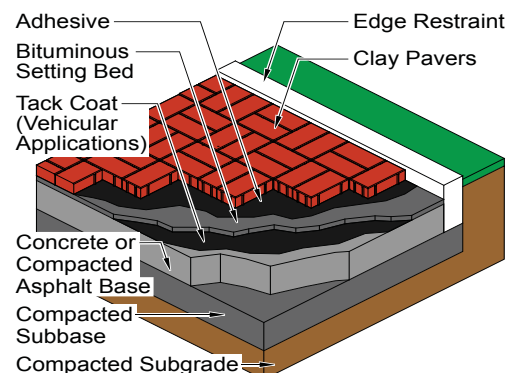


Figure 1
Typical Brick Pavement
on Bituminous Setting Bed

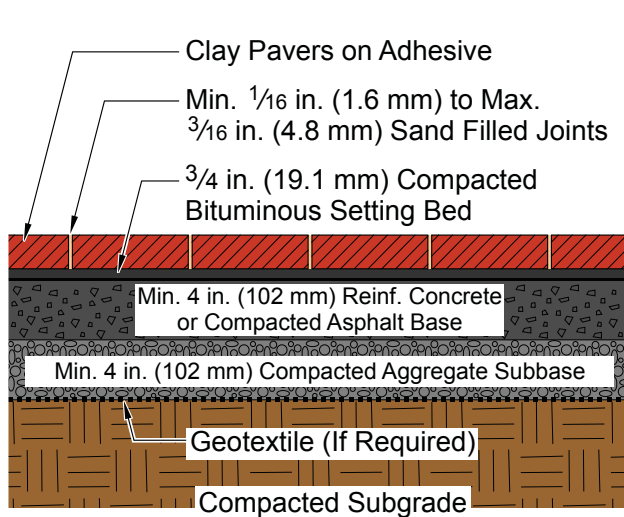


Figure 2

Typical Commercial/Public Plazas and Walkways

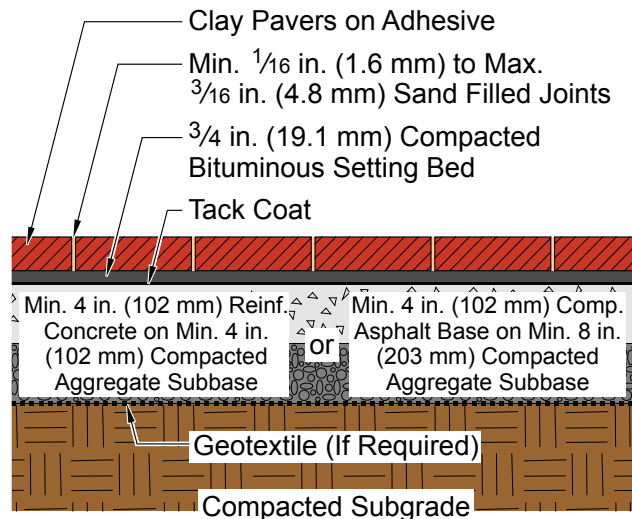


Figure 3

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.

Although not common, clay pavers on a bituminous setting bed can be used for larger residential applications and driveways (see [Figure 2](#)). Clay pavers should be set in an adhesive on a compacted bituminous setting bed $\frac{3}{4}$ in. (19.1 mm) in thickness. A minimum 4 in. (102 mm) concrete or asphalt base on a minimum 4 in. (102 mm) compacted aggregate subbase should be used. Alternatively, a minimum full depth 8 in. (203 mm) concrete or asphalt can be used as the base and subbase. Reinforced concrete should be considered where underlying soils are poor or where a more rigid base is desired.

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 $\frac{3}{4}$ 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 $\frac{3}{4}$ 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 patterns 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

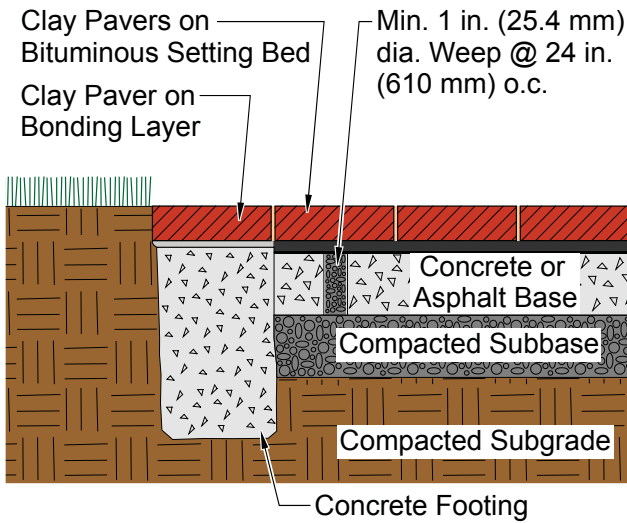
Bituminous-set pavers require edge restraints to prevent spreading of pavers at the pavement boundaries.

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.

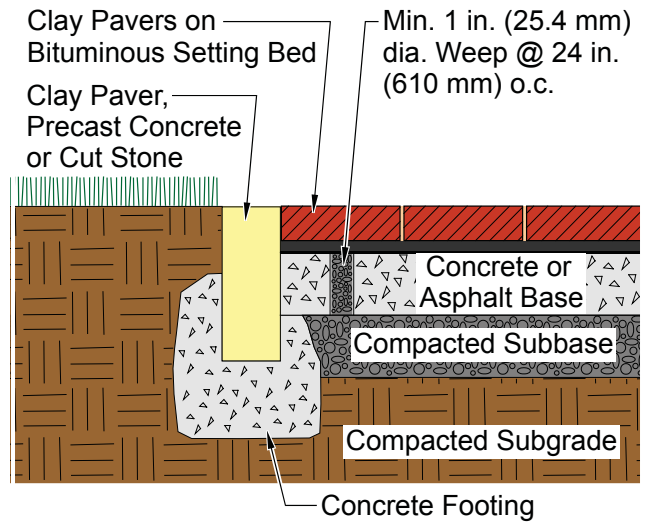
Drainage

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.

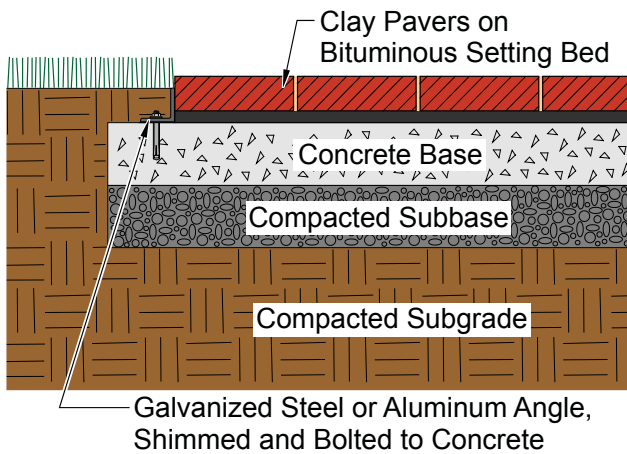
Drainage openings can be formed by drilling 1 in. (25.4 mm) or larger diameter holes through the concrete base or side walls of drain inlets. Drainage openings should be filled with an open-graded aggregate to prevent their filling with setting bed material. Heat resistant tubing and drain mat materials 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.



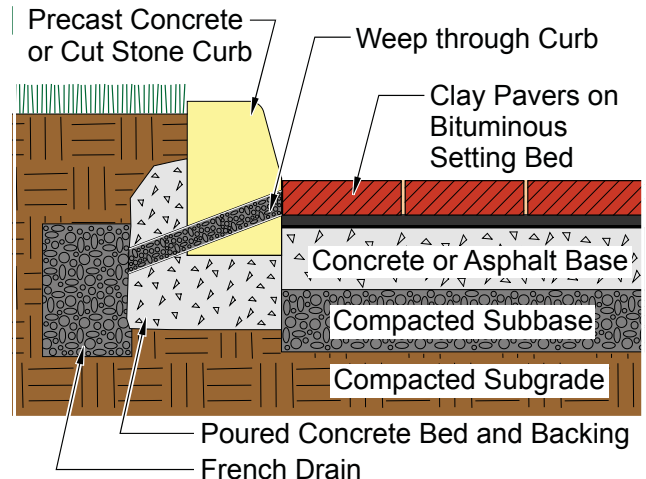
(a) Bonded Clay Paver Edge Restraint



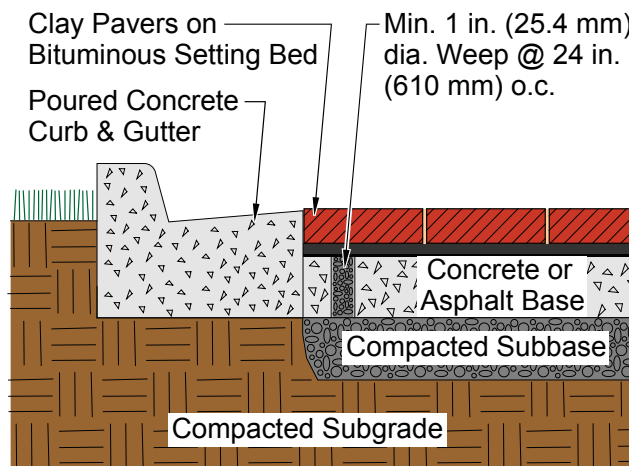
(b) Clay Paver, Precast Concrete or Cut Stone Edge Restraint



(c) Steel Angle Edge Restraint



(d) Curb Edge with Weep



(e) Poured Concrete Curb and Gutter Edge Restraint

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*.

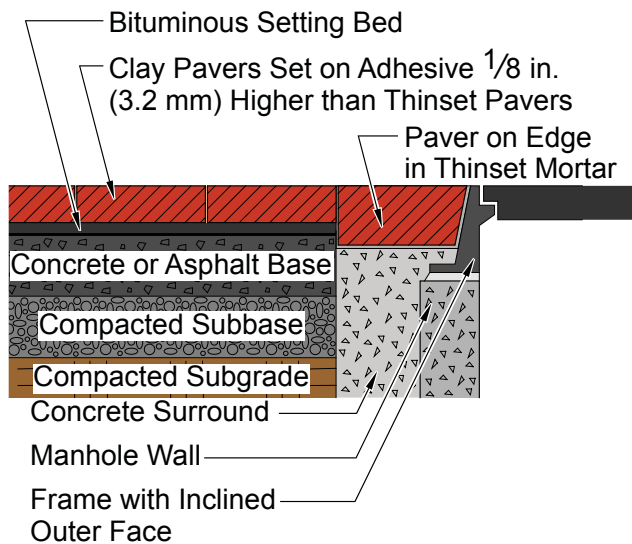


Figure 6
Large Penetration Through Pavement

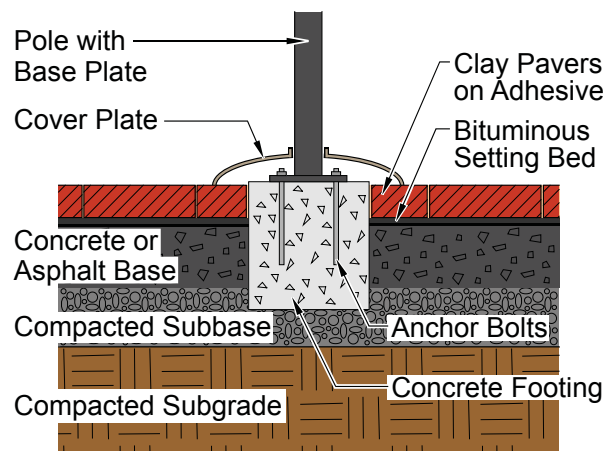


Figure 7
Small Penetration Through Pavement

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
¾ 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

A wide selection of colors and textures is available in clay pavers. Further information on clay pavers can be found in *Technical Note 14*.

Pavers generally are manufactured with their length equal to a module of their width. Two commonly specified clay paver sizes are 4 in. wide by 8 in. long (102 by 203 mm) and 3¾ in. wide by 7½ in. long (95 by 190 mm). Other similar sizes are available, such as 3⅝ in. wide by 7⅝ in. long (92 by 194 mm), and several manufacturers are able to provide custom sizes. Common specified thicknesses are 1½ in. (38 mm), 2¼ in. (57 mm) and 2¾ in. (70 mm). (For heavy vehicular paving brick, thickness excludes chamfer height.)

Clay pavers covered by ASTM C902, *Specification for Pedestrian and Light Traffic Paving Brick* and ASTM C1272, *Specification for Heavy Vehicular Paving Brick* [Ref. 1], can be installed on a bituminous setting bed. The designer should select the appropriate Application, Type and Class of the paver for the project based on aesthetics, use, abrasion resistance and the required resistance to damage from weather exposure. Paver thicknesses of 2¼ in. (57 mm) and greater are considered suitable for bituminous setting beds in pedestrian and light vehicular pavements. For pedestrian pavements with a concrete base, a paver thickness of 1½ in. (38 mm) or greater may be used. For more detailed information on specifying clay pavers, refer to *Technical Note 14*.

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 ¼ 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 ⅜ 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 ¼ in. (3.1 mm) and if the maximum interlock between pavers is required. If the joints are consistently less than ¼ 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
¾ 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

Joint Sand Stabilizers

Since pavers on a bituminous setting bed are not vibrated, joint sand may be relatively loose in the early life of a pavement and may be prone to settling or erosion. Conditions such as intensive cleaning practices, high surface water flows and flat areas with moisture-sensitive subgrades can also be a concern. Particularly where wider joints are present, a pretreated stabilized joint sand or applied liquid joint sand stabilizer is often beneficial. There are several different types of joint sand stabilizers. These include breathable polymeric liquids that can be sprayed onto the pavement surface and squeezed into the joints with a squeegee, as well as dry products that can be mixed with the joint sand before installation. Pretreated sands also are available for joint filling. Strict adherence to the stabilizer manufacturer's recommendations is required to achieve successful installations. When selecting a stabilizer, it is important to choose one with a proven history that does not discolor the surface or peel over time. A stabilizer should be water based as solvents can potentially harm the tack coat and setting bed materials. The paver manufacturer's recommendation regarding joint sand stabilizers should be followed. Joint sand stabilizers should be applied to the completed paver surface. Stabilizers should be applied to the pavement surface before the application of other coatings to enhance the appearance of the pavers or to protect against staining. Stabilizing joint sand by adding cement should be avoided to prevent cement deposits becoming embedded in the texture of the paver surface and for the reasons discussed above. For further guidance on selecting coatings for use on brick pavements, refer to *Technical Note 6A*.

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 ±¼ 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 1/8 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 3/8 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 ±1/8 in. (3.2 mm) of 3/4 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 1/4 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 $\frac{1}{16}$ 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 $\frac{1}{16}$ to $\frac{3}{16}$ in. (1.6 to 4.8 mm) wide joints. The optimum joint width for vehicular traffic is between $\frac{1}{16}$ and $\frac{1}{8}$ 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.

Joint Sand Stabilizers

The paver manufacturer's recommendation regarding joint sand stabilizers should be followed. Jointing sand that is pretreated with a stabilizer product should be brushed or blown off the pavement surface as soon as possible and not be allowed to become stuck in the surface texture of the pavers. If pretreated sand or a joint sand additive is used, then the stabilizer should be activated by lightly misting the surface with water. If a liquid joint sand stabilizer is used, it should be sprayed onto the pavement surface and forced into the joints with squeegees. It may be necessary to fill the tops of the joints with the liquid several times before it sets to achieve adequate penetration. The stabilizer manufacturer's instructions should be followed closely, because each stabilizer is slightly different. Probing several joints to verify that the sand is stabilized to an adequate depth of approximately two times the joint width — rather than just forming a crust — is recommended.

MAINTENANCE

Cleaning

Bituminous-set pavers can be kept clean in most environments by regular sweeping. In situations that lead to a greater degree of buildup of grease, tire marks or other stains, the pavers can be cleaned by pressure-washing. The sand-filled joints generally are resistant to this treatment if the water pressure is not excessive and the water jet is not directed along the joints. Aggressive pressure-washing can cause localized removal of the joint filling material and can even undermine the pavers. More stubborn stains, including paint and gum, can be cleaned by scraping off the hard residue and then scrubbing with a stiff-bristled brush and a proprietary cleaner or scouring powder. In damp or shady areas where moss and lichen have grown in the joints, these can be killed with a bleach-water mixture or with proprietary treatments. For more information on cleaning, refer to *Technical Note 14*.

Snow and Ice Removal

Snow removal can be accomplished by hand, by machine or by chemicals. Hand methods include shovels and brooms. Mechanical methods include snow blowers, snowplows, and buckets or brushes attached to tractors. Shovel and machine removal methods can chip the edges of the pavers, particularly if excessive lipping is present. This equipment should be properly adjusted so that it does not damage the pavement surface.

Skid-steer snow removal equipment also may move pavers, causing distortion of pattern lines and some chipping of the pavers if the equipment is driven aggressively. When tractor and particularly skid-steer mounted equipment is used, the pavement must be able to support the wheel loads without damage.

A range of anti-icing and deicing chemicals can be used for pavements. Deicing agents should be used with care, as chemical residue left on the surface can penetrate into the joints and result in staining and efflorescence. Class MX and NX pavers should not be used where subject to freezing. For more information on snow and ice removal, refer to *Technical Note 14*.

Repairs

Repairs to damaged pavers can be undertaken by forming a series of saw cuts across the width of the affected paver so that it can be removed without damaging adjacent units. It will be necessary to break the damaged paver with a hammer and chisel to remove all the pieces. It is then possible to work the adjacent pavers loose using a hammer and chisel in the joints and under the paver. During removal, some spalling of the pavers may occur resulting in the need for replacement pavers during reinstatement.

Matching the existing bedding material may be difficult. Hot mix asphalt is the optimal setting bed material for repair of large areas and pavements subject to vehicular traffic. However, it is rarely available in small quantities for small repairs. An alternative bedding material for small repairs is a dry mixture consisting of 1 part Portland cement and 3 to 5 parts washed ASTM C33 concrete sand. This mixture is placed in the area to be repaired and compacted. Pavers are installed as they would be in a sand setting bed installation. The joints should be filled

with stabilized joint sand or a dry mixture of 1 part Portland cement to 10 parts sand. The surface of the pavement should be rinsed after compaction to develop initial interlock and to prevent any residue from adhering to the paver surface.

Fine cold asphalt, available as a bagged product, is also an acceptable bedding material for small repairs and pavements not subject to vehicular traffic. The fine cold asphalt should be compacted properly in the repair opening and allowed to cure for several hours. The pavers should be replaced after spreading the neoprene modified asphalt adhesive over the setting bed. Bagged angular joint sand is the most convenient way to fill the joints.

SUMMARY

Clay pavers laid on a bituminous setting bed are appropriate for pedestrian and vehicular traffic applications. When properly constructed, the bond between the pavers and the base assist in resisting horizontal movement and uplift to ensure that the pavement meets design requirements. This *Technical Note* provides the basic information required to properly select materials, design, detail and construct brick pavements over bituminous setting beds. Further information about the properties of other brick pavements and concepts not unique to bituminous setting beds is discussed in the *Technical Note* 14 series.

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

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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”

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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”

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ASTM D698 “Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft³ (600 kN-m/m³))”

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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.