NCMA TEK

National Concrete Masonry Association
an information series from the national authority on concrete masonry technology

PAVEMENT CONSTRUCTION WITH INTERLOCKING CONCRETE PAVERS

TEK 11-2
Pavers (1995)

Keywords: construction techniques, edge restraints, paving

INTRODUCTION

This TEK provides guidance on construction procedures for installing interlocking concrete pavements. It addresses the most common applications of interlocking concrete pavements, where the system is installed on a flexible gravel base for pedestrian areas, residential driveways and streets. While not specifically covered in this text, cement or asphalt stabilized bases may be used where suitable granular materials are not available, when the construction of a stabilized base proves more economical, or over weak or continuously saturated soils.

UNITS

Paving units are required to meet or exceed the minimum values set forth in *Standard Specification for Solid Interlocking Concrete Paving Units*, ASTM C 936 (ref. 10). The standard requires an average compressive strength of 8,000 psi (55 MPa), absorption of less than 5 percent, and resistance to at least 50 cycles of freezing and thawing.

Units manufactured in Canada are often required to meet or exceed Canadian Standards Association *Precast Concrete Pavers* (ref. 3). This standard requires an average compressive strength of 7,250 psi (50 MPa) and resistance to at least 50 freeze-thaw cycles with immersion in a 3% saline solution.

For pedestrian use, residential driveways, walks, and similar applications, $2^3/_8$ in. (60 mm) thick units are considered adequate. For other pavements, $3^1/_8$ in. (80 mm) thick units are recommended.

INSTALLATION

Installation includes planning and layout, preparation of the subgrade, spreading and compaction of the subbase and/or base course materials, placement of the edge restraints, placement and screeding of the bedding sand, and installation of the paver units.

Planning and Layout

Prior to excavation, the area should be staked and grade elevations established to ensure proper elevation of the paved surface. The minimum recommended slope is 1.5 percent to ensure proper drainage. Grade elevation markers should be periodically checked throughout the job to be sure they have not been inadvertently disturbed.

Utility companies should be contacted to verify that underground utilities are not located within areas to be excavated. If clearances of overhead wires restrict access for delivery of materials or equipment, then relocation must be scheduled prior to construction.

Subgrade Preparation

Following excavation, the area should be inspected to ensure that no organic material, roots, oversize rocks, or debris remain on or in the soil. If any of these are present, they must be removed and replaced with clean suitable backfill material. Saturated soil must be drained of freestanding water. Low, wet areas can be stabilized with crushed stone after excess water has been removed.

The subgrade soil is typically required to be compacted to at least 95 percent of Modified Proctor Density, as specified in *Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lb/ft3) (2,700 kN·m/m³)*, ASTM D 1557 (ref. 17). The soil moisture content must be carefully monitored to obtain maximum compaction. Compaction methods and choice of equipment vary with the type of soil. Consult manufacturers to determine the appropriate compaction equipment for given soil conditions. Figure 1 gives a general guide to the application of compaction equipment to various soils.

Base Installation

Geosynthetic fabric is often used to separate subgrade soil from the compacted gravel base, especially in soils subject to moisture saturation. The recommended minimum apparent opening size of the fabric should be No. 70 (250 mm) sieve. The geosynthetic fabric may be either woven or nonwoven, and should be placed so that the material extends up the side of the excavated area a sufficient distance to cover the base material. Although these fabrics do not substantially increase the bearing capacity of the soil subgrade, they can prevent intrusion of the soil subgrade into the gravel base and the subsequent erosion of the base by excess moisture. This extends the life of the base material and slows the rate of

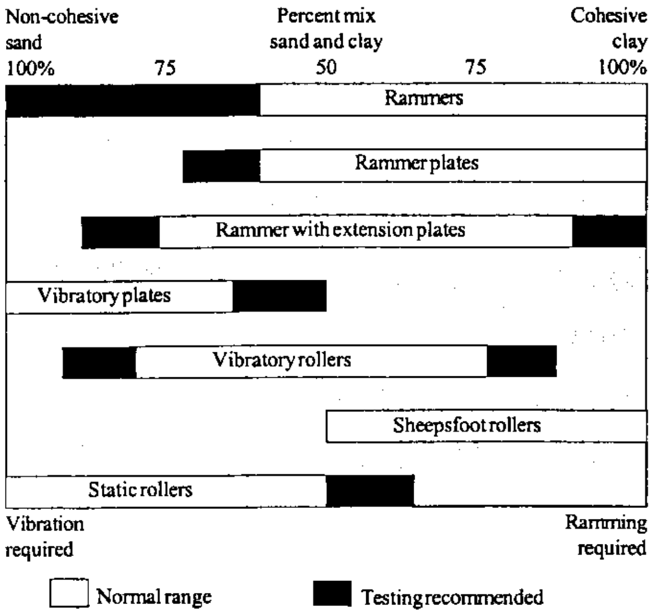

Figure 1—Guide to the Application of Compaction Equipment to Various Soils (Courtesy of J.I. Case Company, ref. 21)

deformation resulting from repetitive vehicle loads or periodic exposure to moisture from the soil.

Geosynthetic fabrics are placed after the soil has been adequately compacted and tested for the proper density and moisture content. The fabric should be smooth and overlap a minimum of 12 in. (305 mm). In very weak soils (soils having a CBR less than 2%) or soils subjected to free moisture, the overlap between pieces of fabric should be 24 to 36 in. (610 to 914 mm). The aggregate base should be placed and compacted in lifts of no less than 6 in. (152 mm). Vehicles should be kept from direct contact with the fabric while delivering the aggregate, since the tires will wrinkle the fabric.

Table 1 summarizes the minimum physical requirements of geosynthetic fabrics used for soil separation.

Geosynthetic soil reinforcement can substantially increase the load-carrying qualities of a gravel base, and thereby reduce the required thickness and/or extending its life under repeated heavy traffic. Contact suppliers for specific information.

Installation of geosynthetic soil reinforcement is similar to that for geosynthetic fabrics. Because the reinforcements are meant to structurally reinforce the base materials, it is important that slack is removed prior to placing the gravel base. Hand tensioning and pinning are usually sufficient. Overlap widths are similar to geosynthetic fabrics. No stitching or sewing is required. The gravel base may be placed, spread and compacted to a minimum of 4 in. (102 mm). Tracked equipment should not be operated directly on the geosynthetic soil reinforcement. On competent subgrades, rubber-tired equipment may drive directly over the soil reinforcement provided the speed is less than 5 mph (8 kph). Sudden starts, stops, and sharp turns should be avoided.

Table 2 lists the minimum physical requirements for geosynthetic soil reinforcement.

Table 1—Recommended Minimum Physical Requirements for Soil Separation Geosynthetic Fabrics

Property	Standard	Test method
Tensile strength, lb (N)	140 (623)	ASTM D 4632
Elongation, percent	15	ASTM D 4632
Puncture strength, lb (N)	70 (311)	ASTM D 4833
Burst strength, psi (MPa)	200 (1.4)	ASTM D 3786
Trapezoid tear, lb (N)	50 (222)	ASTM D 4533
Equivalent opening size, sieve no. (micron size)	70 (250 mm)	ASTM D 4751

Notes:

1. California Bearing Ratio (CBR) of the soil subgrade >2%

2. Acceptance of geotextile is to be determined according to ASTM D 4873. Contracting agency may require a letter from the manufacturer certifying that its fabric meets the required specification. Use test values in weaker principal direction of fabric. All numerical values represent minimum roll values. Stated values are for noncritical, non-severe conditions. Consult fabric manufacturer's recommendations for applications in low bearing strength soils (<2% CBR), or in pavements subject to highway or industrial loads. Fabric lots should be sampled according to ASTM D 4354.

Base Materials

Gravel base materials for vehicular traffic should conform to local or state specifications for highway bases. In the absence of these, recommendations are indicated in Table 3.

Base Thickness

Climate, frost potential, soil type, soil moisture, anticipated traffic, and drainage all affect the required base thickness. Patios and walks, including sidewalks, should have a base thickness of at least 4 in. (102 mm) on well-drained soils. For other pedestrian applications or residential driveways, a 6 in. (152 mm) minimum base thickness is recommended in well-drained soils. Thicker bases are required in very cold climates, or in low strength or wet soils.

Base thicknesses for streets should be designed accord-

Table 2—Recommended Minimum Physical Requirements for Geosynthetic Soil Reinforcement[a]

Property	Standard	Test method
Aperture size, in. (mm)	1.0x1.3 (25x33)	Calipered
Open area, %	70	COE CW02215
Rib & junction thickness in. (mm)	0.03 & 0.11 (0.76 & 2.8)	ASTM D 1777
Flexural rigidity, mg x cm	200,000	ASTM D 1388
Tensile modulus, lb/ft (kN/m)	14,000 (204)	GRI GG1[b]
Junction strength, lb/ft (kN/m)	750 (11)	GRI GG2
Junction efficiency, %	90	GRI GG2
Carbon black, %	0.5	ASTM D 4218

[a] Aperture size and rib and junction thicknesses are nominal.
[b] GRI (Geosynthetic Research Institute, Drexel University)

ing to local or state engineering design standards. In some non-freeze-thaw areas on well drained, strong soils, 6 in. (152 mm) is used as the minimum base thickness. Minimum thicknesses for low volume residential streets are typically 8 to 10 in. (203 to 254 mm). Minimum thicknesses can be greater in areas subject to numerous freeze-thaw cycles, expansive soils, or very cold climates.

Aggregate bases should be spread and compacted at their optimum moisture. Compaction equipment should be capable of providing compaction of no less than 95 percent of the density as determined by ASTM D 1557, Method D, or AASHTO T180 (refs. 17, 6). While 95 percent (or greater) compaction is desirable, it may not be attainable over weak or saturated soils. Bases should not be installed if the material is frozen or on frozen soil subgrade. The final compacted thickness should be within $+{}^{3}/_{4}$ to $-{}^{1}/_{2}$ in. (+19 to -13 mm). In-place density should be measured using the rubber balloon method (ASTM D 2167, ref. 12), nuclear density gauge, or other methods approved by the local, state, or provincial transportation department.

The surface of the compacted base course can be brought to finished elevation by blading or other equipment. Deviations should not exceed $^{1}/_{2}$ in. (13 mm) when tested with a 10 ft (3 m) straightedge.

A properly graded and compacted gravel base should have a tight surface so that the bedding sand does not migrate into it. If the surface is open after compaction, a choke course of fine material can be placed and compacted on the surface. A bitumen tack coat can be used as well. The entire base course surface and perimeter should be inspected for places where sand might migrate after installation. These can be joints in curbs, around utility structures, or drainage inlets. These areas should be covered with a small patch of geosynthetic fabric to prevent migration of the bedding sand.

Table 3—Grading Requirements for Dense Graded Material

Sieve size (square openings)	Design range[a] % passing Bases	Design range[a] % passing Subbases	Job mix tolerance % passing Bases	Job mix tolerance % passing Subbases
2 in. (51 mm)	100	100	-2	-3
$1^{1}/_{2}$ in. (37.5 mm)	95-100	90-100	±5	±5
$^{3}/_{4}$ in. (19 mm)	70-89	-	±8	-
$^{3}/_{8}$ in. (9.5 mm)	50-70	-	±8	-
No. 4 (4.75 mm)	35-55	30-60	±8	±10
No. 30 (600 mm)	12-55	-	±5	-
No. 200 (75 mm)	0-8[b]	0-12[b]	±3	±5

[a] Job mix formula should be selected with due regard to availability of materials in the area of the project. Job mix tolerances may permit acceptance of test results outside the design range.

[b] Determine by wet sieving. Where frost and free moisture are indicative of site conditions, a lower percentage passing the No. 200 (75 mm) sieve shall be specified.

Note: ASTM D 2940 corresponds closely to this National Crushed Stone Association developed specification. While local or state highway specifications may be substituted for the design ranges above, the fraction finer than the No. 200 (75 mm) sieve should be maintained.

Edge Restraints

Edge restraints are essential to the performance of interlocking concrete pavements. They provide lateral (horizontal) restraint to the pavement, thereby maintaining the interlock and load-spreading capabilities of the units. Edge restraints can be steel, aluminum, PVC, concrete, or wood.

Tops of edge restraints must be set at the correct elevation. They must be capable of resisting any movement caused by pedestrians or vehicles. Edge restraints are set and checked for appropriate elevations before placing the bedding sand and pavers. They are typically placed before the bedding sand is spread, although some edgings, such as PVC or concrete pavers backed with concrete, may be installed as the laying progresses. Consult *Edge Restraints for Concrete Pavers* (ref. 1) for complete recommendations.

Bedding Sand

Concrete sand conforming to *Standard Specification for Concrete Aggregate,* ASTM C 33 (ref. 9) is recommended for bedding sand. The bedding sand should be sharp, washed, and free from foreign material. Masonry mortar sand should not be used. Limestone screenings or stone dust will not compact as uniformly nor maintain an even profile over time, due to the shape of the particles and/or the presence of water soluble minerals.

Concrete sand should be spread and screeded to a thickness of 1 to $1^{1}/_{2}$ in. (25 to 38 mm) Frozen or saturated sand should not be installed. Sand should not be used to compensate for uneven elevations or an improperly compacted gravel base. These irregularities in elevation will reflect through to the surface over time, creating a washboard appearance. Low or high areas of base material must be brought to a smooth, consistent elevation.

Sand is typically screeded with a straight, true strike board. The board is pulled across pipe laid directly on the base prior to spreading the sand. Asphalt spreading machines and equipment specially made to screed sand have also been successfully used on larger installations for increased productivity. Once the sand is screeded it should not be disturbed. Place and screed sufficient sand to stay ahead of the laid pavers.

Installing Concrete Pavers

Place the paving units according to the desired pattern. Herringbone patterns interlock, thereby offering greater resistance to deformation. 90° or 45° herringbone patterns should be used in all street applications, as these patterns most effectively resist horizontal creep from braking and accelerating vehicles. Straight lines can be maintained by snapping a chalk line directly on the sand or pulling string lines just above the surface of the pavers. Sides of buildings or openings in the pavement, such as concrete collars or inlets, should not be used as a basis for establishing lines, as they generally are not straight.

Joints between paving units should be approximately $^{1}/_{16}$ to $^{1}/_{8}$ in. (1.6 to 3.2 mm) wide. Some pavers are made with spacer bars to create a minimum joint width, necessary for sand to enter.

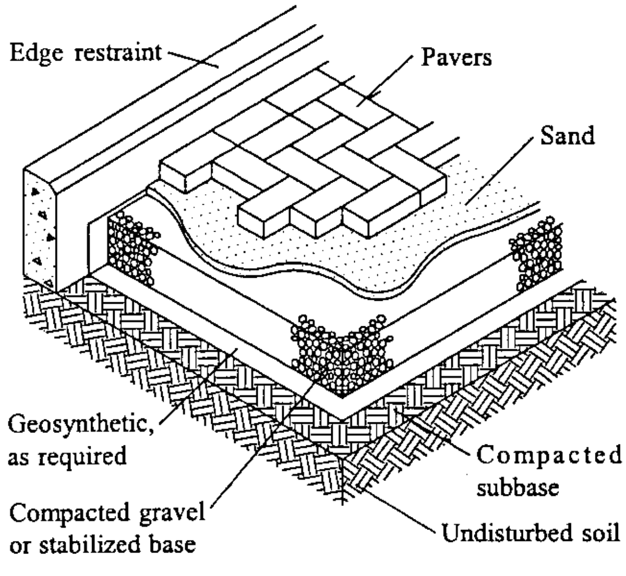

Figure 2—Typical Interlocking Concrete Pavement

Gaps at edges should be filled with cut pavers. They can be cut with a double bladed paver splitter or a masonry saw. A masonry saw gives the cleanliest appearance. Gaps less than $^3/_8$ in. (10 mm) should be filled with sand.

Once an area is installed, vibrate the pavers into the sand with a plate vibrator, capable of 3,000 to 5,000 lb (13.3 to 22.2 N) centrifugal compaction force, operated at a frequency of 80 to 90 hertz. At least two passes with the vibrator should be made across the surface.

Sweep dry sand into the joints and vibrate again until they are full. The joint sand may comply to either ASTM C 33 or ASTM C 144 (refs. 9, 8). This may take two or three passes of the plate vibrator. If the sand is moist, it can be spread on the pavers to dry before being swept and vibrated into the joints. Do not vibrate within 3 ft (0.9 m) of an unrestrained edge. All work within 3 ft (0.9 m) of the laying face must be fully compacted with sand-filled joints at the completion of each day. Cover the remaining uncompacted edge of the laying face and sand with a waterproof covering. Sweep off excess sand when the job is complete.

Unless otherwise specified, the final surface elevations should not deviate more than $^3/_8$ in. (10 mm) under a 10 ft (3 m) straightedge. The surface elevation of pavers shall be $^1/_8$ to $^1/_4$ in. (3 to 6 mm) above adjacent drainage inlets, concrete collars, or channels. The top surface of the pavers may be $^1/_8$ to $^1/_4$ in. (3 to 6 mm) above the final elevations to compensate for possible minor settling which is characteristic of all flexible pavements.

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