

Technical Design and Installation Guide



INTERLOCKING CONCRETE PAVERS TECHNICAL DESIGN AND INSTALLATION GUIDE



Table of Contents

SECTION 1 SUBGRADE PREPARATION

| | | |
|-----|-------------------------------|---|
| 1.1 | Soil Types | 2 |
| 1.2 | Assessment of Subgrade Soil | 2 |
| 1.3 | Compaction | 2 |
| 1.4 | Geotextiles | 2 |
| 1.5 | Field Identification of Soils | 3 |

SECTION 2 BASE DESIGN

| | | |
|-----|----------------------------------|---|
| 2.1 | Factors Affecting Base Thickness | 4 |
| 2.2 | Pavement Usage | 4 |
| 2.3 | Determining Base Thickness | 5 |
| 2.4 | Frost Action | 6 |
| 2.5 | Base Materials | 6 |
| 2.6 | Modified Base Materials | 6 |
| 2.7 | Drainage | 7 |
| 2.8 | Base Installation | 7 |
| 2.9 | Computer Aided Pavement Design | 7 |

SECTION 3 BEDDING SAND

| | | |
|-----|------------------------------------|----|
| 3.1 | Final Base Inspection | 8 |
| 3.2 | Purpose of the Bedding Layer | 8 |
| 3.3 | Bedding Layer Materials | 8 |
| 3.4 | Bedding Layer Thickness | 9 |
| 3.5 | Setting Grades and String Lines | 9 |
| 3.6 | Setting Screed Rails and Screeding | 10 |
| 3.7 | Compacting the Bedding Layer | 11 |

SECTION 4 PAVING STONE INSTALLATION

| | | |
|------|--|----|
| 4.1 | Material Placement | 12 |
| 4.2 | Laying Pattern and Shape | 13 |
| 4.3 | Determining the Starting Point | 13 |
| 4.4 | Alignment of Pavers | 14 |
| 4.5 | Installation of Paving Stones | 14 |
| 4.6 | Cutting Paving Stones | 15 |
| 4.7 | Compacting the Paving Stones | 15 |
| 4.8 | Mechanical Installation | 15 |
| 4.9 | Things to Consider Before Using a Mechanical Installer | 16 |
| 4.10 | Moulds Required for Mechanical Installation | 16 |
| 4.11 | Bedding Layer Preparation for a Mechanical Installer | 16 |

SECTION 5 EDGE RESTRAINTS

| | | |
|-----|-------------------------------|----|
| 5.1 | Types of Edge Restraints | 17 |
| 5.2 | Edge Restraint Applications | 17 |
| 5.3 | Edge Restraint Installation | 17 |
| 5.4 | Edge Restraint Cross Sections | 17 |

SECTION 6 JOINTING SAND

| | | |
|-----|-------------------------------|----|
| 6.1 | Job Inspection | 19 |
| 6.2 | The Purpose of Jointing Sand | 19 |
| 6.3 | Jointing Sand Materials | 19 |
| 6.4 | Installation of Jointing Sand | 20 |
| 6.5 | Final Inspection | 20 |
| 6.6 | Job Site Inspection Checklist | 21 |

SECTION 7 CLEANERS AND COATINGS

| | | |
|-----|--|----|
| 7.1 | Cleaning Interlocking Pavers | 23 |
| 7.2 | Reasons for Applying Chemical Coatings | 23 |
| 7.3 | Types of Coatings | 24 |
| 7.4 | When to Apply Chemical Coatings | 24 |
| 7.5 | How to Apply Chemical Coatings | 24 |
| 7.6 | Efflorescence | 25 |
| 7.7 | How to Remove Efflorescence | 25 |
| 7.8 | Cleaning Agents for Various Stains | 26 |

SECTION 8 SPECIAL PAVEMENTS

| | | |
|-----|---------------------------|----|
| 8.1 | Roof Deck Pavements | 28 |
| 8.2 | Gas Station Pavements | 28 |
| 8.3 | Airport Applications | 29 |
| 8.4 | Industrial Port Pavements | 30 |
| 8.5 | Permeable Pavements | 31 |

SECTION 9 REPAIR OF INTERLOCKING CONCRETE PAVEMENTS

| | | |
|-----|-------------------------------------|----|
| 9.1 | Pavement Repairs | 34 |
| 9.2 | Opening the Pavement | 34 |
| 9.3 | Removing the Paving Stones | 34 |
| 9.4 | Rehabilitation of Existing Granular | 34 |
| 9.5 | Excavation | 36 |
| 9.6 | Replacing the Material | 37 |
| 9.7 | Reinstating the Pavers | 37 |
| 9.8 | Municipal Utility Cuts | 37 |

SECTION 10 GLOSSARY OF TERMS

| | | |
|------|--|----|
| 10.1 | Concrete Paver Products and Production Terms | 38 |
| 10.2 | Engineering Terms | 39 |
| 10.3 | Terms Used in Architectural Design | 41 |
| 10.4 | Terms Used in Construction | 42 |
| 10.5 | Terms Used in Concrete Paver Testing | 44 |
| 10.6 | Chemical Terms | 44 |



SECTION 1

Subgrade Preparation

Virtually all paving projects need some amount of excavation to accommodate the installation of a suitable base. Proper preparation of the soil subgrade after excavation contributes to the success of any paving project.

1.1 SOIL TYPES

The characteristics of the soil found in the subgrade is a primary pavement design consideration. Different soil types respond differently when they are subjected to applied loads, frost cycles, or the presence of water. There are 5 fundamental soil groups:

Gravel - Individual grains varying in size from .08 to 3 inches (2.0 to 76.2 mm) in diameter and have a rounded appearance.

Sand - Small rock or mineral fragments smaller than .08 inches (2.0 mm) in diameter and semi-sharp.

Silt - Fine grains appearing soft and floury when dry. When moist, silt pressed between the thumb and forefinger will have a broken appearance.

Clay - Very fine texture soil which forms hard lumps or clods when dried. When moist, clay is very sticky and can be rolled into a ribbon between the thumb and forefinger.

Organic - This matter consists of either partially decomposed vegetation (peats) or finely divided vegetable matter (organic silts and clays).

Because each of these groups behave differently, it's very important to know what type of soil is present in the pavement subgrade.

1.2 ASSESSMENT OF THE SUBGRADE SOIL

An assessment of the subgrade soil type is recommended for all paving projects. For larger projects, a soils analysis should be performed by a qualified soils engineer. A determination of the soil's CBR (California Bearing Ratio) is required to produce an engineered pavement design. Field assessment of the subgrade can be done to determine which soil type is present (see Section 1.5 for a field guide to soil identification).

1.3 COMPACTION

Compaction of the subgrade increases its density, which increases its ability to support a load, prevents potential settlement, and reduces swelling and contraction that occur due to seasonal changes in moisture and temperature. Silt and clay

soils generally require more time to compact than sandy soils because they are made up of a narrow range of small particle sizes. These small particles are cohesive, so they stick together with moisture and hold their shape when compacted. Sandy and gravelly soils tend to take less effort to compact; however, their ability to increase density through compaction can be very sensitive to the amount of moisture in them. Each soil type has an optimum moisture level, which corresponds to its maximum density. "Proctor" density tests can be done in a laboratory to determine each soil's maximum density. Field density tests can be done (most commonly with a nuclear gauge) to determine the level of compaction achieved at the site. These density checks are strongly recommended, especially for large projects.



1.4 GEOTEXTILES

The installation of geotextile fabric should be considered once the site has been excavated and the subgrade has been compacted. While not necessary for all projects, geotextiles can delay pavement deformations caused by heavy loads. These fabrics are particularly useful over fine subgrade soils, such as silts and clays. Geotextiles prevent subgrade soils from being forced into the base material under repeated traffic loads. The type of geotextile may vary from project to project. Consult geotextile manufacturers or suppliers for specific information about various types of geotextile fabrics and their applications.

INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

1.5 FIELD IDENTIFICATION OF SOILS

| Soil Texture | Visual Detection of Particle Size and General Appearance of the Soil | Squeezed in Hand and Pressure Released | | Soil Ribbed Between Thumb and Finger When Moist |
|----------------------|---|---|---|--|
| | | When Air Dry | When Moist | |
| Sand | Soil has a granular appearance in which the individual grain sizes can be detected. It is free flowing when in a dry condition. | Will not form a cast and will fall apart when pressure is released. | Forms a cast that will crumble when lightly touched. | Cannot be ribboned. |
| Sandy Loam | Essentially a granular soil with sufficient silt and clay to make it somewhat coherent. Sand characteristics predominate. | Forms a cast that readily falls apart when lightly touched. | Forms a cast that will bear careful handling without breaking. | Cannot be ribboned. |
| Loam | A uniform mixture of sand, silt, and clay. Grading of sand fraction quite uniform from coarse to fine. It is mellow, has somewhat gritty feel, yet is fairly smooth and slightly plastic. | Forms a cast that will bear careful handling without breaking. | Forms a cast that can be handled freely without breaking. | Cannot be ribboned. |
| Silt Loam | Contains a moderate amount of the finer grades of sand and only a small amount of clay, over half of the particles are silt. When dry, it may appear quite cloddy, which can be readily broken and pulverized into a powder. | Forms a cast that can be freely handled. Pulverized, it has a soft flour-like feel. | Forms a cast that can be freely handled. When wet, soil runs together and puddles. | It will not ribbon, but it has a broken appearance, feels smooth, and may be slightly plastic. |
| Silt | Contains over 80% silt particles with very little fine sand and clay. When dry, it may be cloddy, readily pulverizes to powder with a soft flour-like feel. | Forms a cast that can be handled without breaking. | Forms a cast that can be handled freely. When wet, it readily puddles. | It has a tendency to ribbon with a broken appearance, feels smooth. |
| Clay Loam | Fine textured soil breaks into hard clumps when dry. Contains more clay than silt loam. Resembles clay in a dry condition; identification is made on physical behavior of moist soil. | Forms a cast that can be freely handled without breaking. | Forms a cast that can be handled freely without breaking. It can be worked into a dense mass. | Forms a ribbon that readily breaks, barely sustaining its own weight. |
| Clay | Fine textured soil breaks into very hard clumps when dry. Difficult to pulverize into a soft flour-like powder when dry. Identification made based on cohesive properties of the moist soil. | Forms a cast that can be freely handled without breaking. | Forms a cast that can be handled freely without breaking. | Forms long, thin, flexible ribbons. Can be worked into a dense, compact mass. Considerable plasticity. |
| Organic Soils | Identification based on the high organic content. Muck consists of thoroughly decomposed organic material with considerable amount of mineral soil finely divided with some fibrous remains. When considerable fibrous material is present, it may be classified as peat. The plant remains, or sometimes the woody structure can easily be recognized. Soil color ranges from brown to black. They occur in lowlands, in swamps or swales. They have high shrinkage upon drying. | | | |

INTERLOCKING CONCRETE PAVERS TECHNICAL DESIGN AND INSTALLATION GUIDE



SECTION 2

Base Design

Proper design and installation of the base course are the most neglected steps of pavement construction. The base course is the foundation for the paving stone installation. Without a strong, properly designed base the pavement is certain to fail.

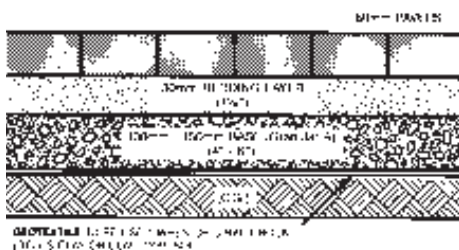
2.1 FACTORS AFFECTING BASE THICKNESS

The thickness of the base layer is determined by traffic loads, subgrade soil strength, drainage, moisture, and climate. Specific engineering design practices can be used to establish the required base course thickness based on these factors.

There are some general minimum base thickness (after compaction) guidelines that apply to most areas in North America:

Sidewalks, patios,
and pedestrian areas

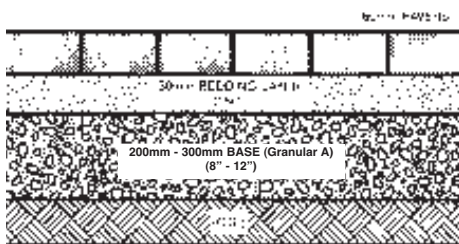
4" (100 mm) over
well-drained soils



Residential driveways

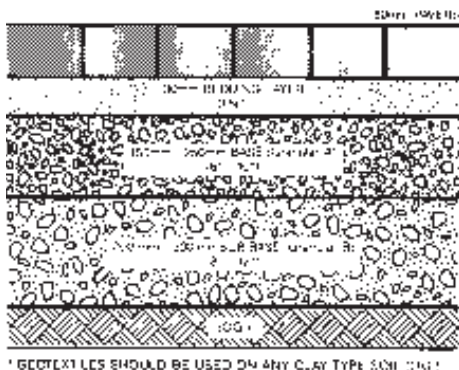
8" (200 mm)

add 2-4" (50-100 mm)
in continually wet
areas, weak soils, or
colder climates



Parking lots and
residential streets

6-10"
(150-250 mm)



2.2 PAVEMENT USAGE

Pavement usage can be grouped into 4 categories:

1. pedestrian (i.e.: sidewalks and patios)
2. residential (i.e.: driveways)
3. commercial/municipal (i.e.: parking lots, subdivision streets, loading docks)
4. industrial (i.e.: container terminals, ports, airport hard stands, bus terminals)

Each usage category includes traffic that is made up of different vehicle combinations (tractor-trailers, trucks, cars, etc.) and volumes (# of vehicles per day). For each type of pavement being designed, the vehicle combinations and volumes are equated to the number of passes of an 18,000 pound axle load over the intended life of the pavement (i.e.: 20 years). Typical design life axle loads for each pavement usage category are given below:

| TRAFFIC TYPE ¹ | DESIGN TRAFFIC DESCRIPTION | TYPICAL DESIGN LIFE 18,000 LB AXLE LOAD REPETITIONS |
|---------------------------|---|---|
| A | pedestrian paths, patios, swimming pool areas, bicycle pathways | - |
| B | multi-dwelling driveways, parking lots (cars only) | 50,000 |
| B | residential street cul-de-sacs (less than 15 vehicles/day commercial traffic) | 50,000 |
| C | minor residential streets (15 to 50 vehicles/day commercial vehicles), service stations | 150,000 |
| C | truck terminals, storage areas, light industrial floors ² , bus stops, residential streets (50 to 150 vehicles/day commercial traffic) | 500,000 |
| D | urban roads ² (150 to 500 vehicles/day commercial traffic), medium/heavy industrial floors ¹ and hardstands | 1,500,000 |
| D | urban roads ² (500 to 1500 vehicles/day commercial traffic), heavy industrial floors ¹ and hardstands | 5,000,000 |

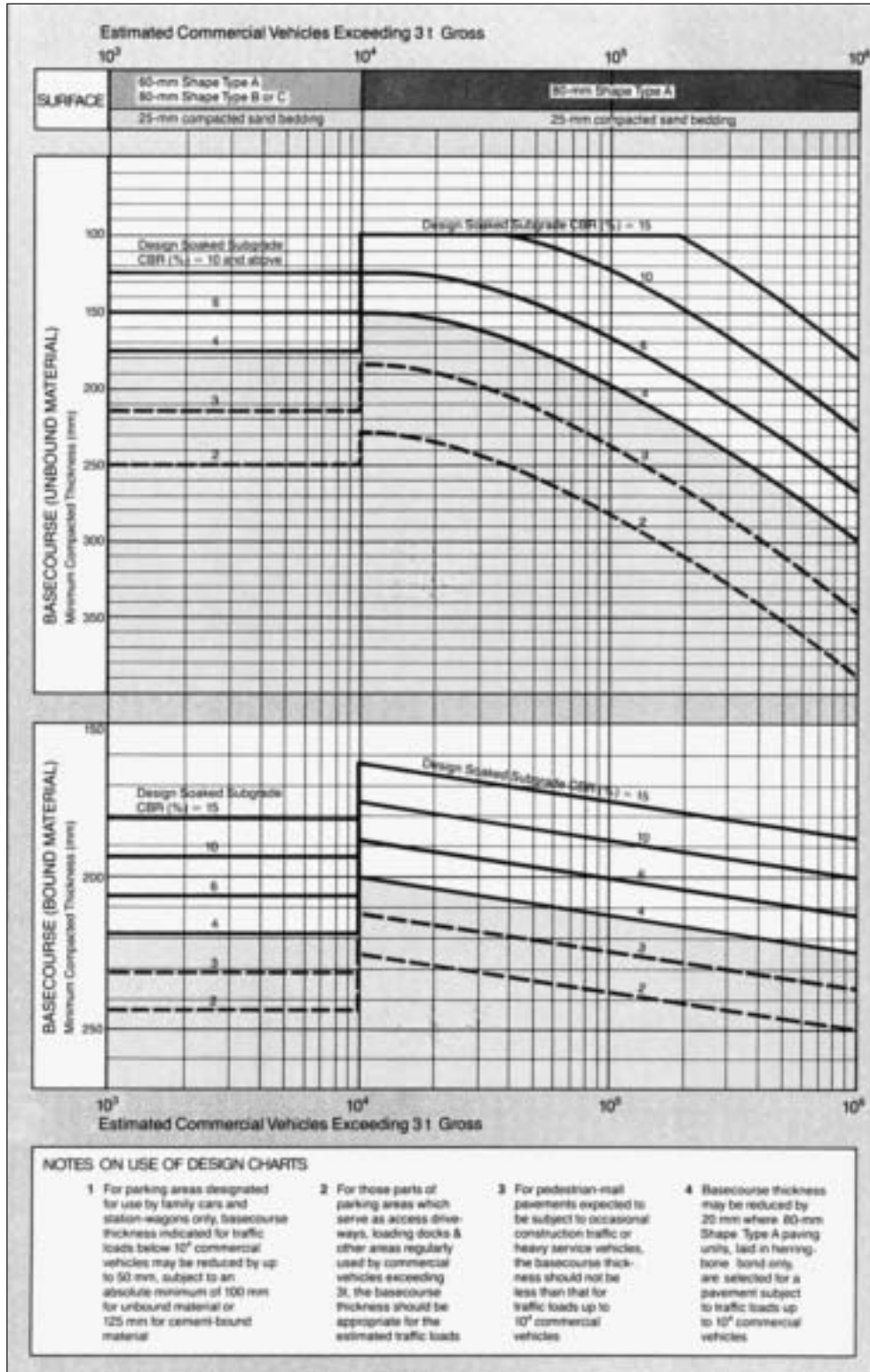
¹ if traffic is channelized increase traffic type by one category

² vehicle speed not to exceed 35 mph (60 km/hr)

INTERLOCKING CONCRETE PAVERS TECHNICAL DESIGN AND INSTALLATION GUIDE

2.3 DETERMINING BASE THICKNESS

Using the subgrade CBR value (Section 1.2) and the number of repetitions of an 18,000 LB axle load over the design life of the pavement (Section 2.2), establish the pavement base course thickness on the graph below.



INTERLOCKING CONCRETE PAVERS TECHNICAL DESIGN AND INSTALLATION GUIDE

2.4 FROST ACTION

In many areas of North America, frost penetration into the pavement structure is certain to occur. The action of frost must be considered when the pavement is designed.

Frost action is characterized by the following conditions:

- pavement heaving caused by the expansion of water in the base material during freezing;
- reduced material strength due to the thawing of frozen base material.

Frost susceptible soils are defined as those containing more than 2% (by weight) of their particles finer than 0.02 mm. A sieve analysis of the soil can readily determine the amount of a soil sample that is finer than 0.02 mm. The following soil categories have been established to indicate the relative severity of a soil's reaction to frost action:

| CATEGORY | FROST SEVERITY | DESCRIPTION |
|----------|----------------|---|
| NFS | no problem | non-frost-susceptible (less than 2% finer than 0.02 mm) |
| F1 | slight | gravely soils (3 to 20% finer than 0.02 mm) |
| F2 | slight | sands (3 to 15% finer than 0.02 mm) |
| F3 | slight | gravely soils (more than 20% finer than 0.02 mm) sandy soils other than silty sands (more than 15% finer than 0.02 mm) plastic clays (PI > 12) varved clays (with uniform condition) |
| F4 | highest | silts, sandy silts, fine silty sands (more than 15% finer than 0.02 mm) lean clays (PI < 12) varved clays with non-uniform condition) |

When determining the pavement base course thickness, the following subgrade CBR values should be used for frost susceptible soils:

- F1: CBR = 8
- F2: CBR = 6
- F3: CBR = 3

- If the depth of frost penetration does not go beyond the anticipated base thickness there is no need for further design considerations.
- When frost is expected to penetrate to a depth beyond the pavement base thickness, the base design should be altered.
- Pavements should never be constructed on Category F4 material. To prevent frost action, non-frost-susceptible material must be used to the entire depth of frost penetration.

2.5 BASE MATERIALS

Aggregate base materials typically used by municipalities, states, or provinces for flexible asphalt pavements are acceptable for interlocking concrete pavements. The gradation of the aggregate is an important characteristic that determines its suitability as a pavement base material. Base aggregates must have a variety of particle sizes to allow drainage and maintain density when compacted. The proper gradations for base materials are given below:

| % PASSING | | | |
|---|--------|----------|-------|
| SIEVE SIZE | BASE | SUB BASE | |
| 2" (53.0 mm) | | 100 | |
| 1 1/2" (37.5 mm) | | 95-100 | |
| 1" (26.5 mm) | 100 | 100 | 80-90 |
| 3/4" (19.0 mm) | 95-100 | 95-100 | 69-83 |
| 1/2" (13.2 mm) | 78-92 | 78-92 | 56-74 |
| 3/8" (9.5 mm) | 68-83 | 69-83 | 44-64 |
| #4 (4.75 mm) | 44-64 | 44-64 | 29-49 |
| #8 (2.36 mm) | 29-47 | 30-48 | 21-37 |
| #40 (425 mm) | 12-20 | 14-22 | 10-17 |
| #200 (75 micron) | 2-6 | 6-10 | 5-8 |
| Liquid Limit (max.) | 20 | 23 | 23 |
| Plasticity Index (max.) | 6 | 8 | 8 |
| Los Angeles Test % loss(max.) | 40 | 50 | 50 |
| CBR after soaking at 98% modified maximum dry density | 100 | 80 | 80 |

The aggregate supplier should be able to provide a sieve analysis for the base material being used.

2.6 MODIFIED BASE MATERIALS

When anticipated traffic loads, environmental conditions, or subgrade characteristics are severe, base aggregates can be fortified with other materials to ensure a stronger pavement base course. Base materials as described above can be mixed with small amounts (i.e.: 5% by weight) of cement or asphalt to create a base course that will stiffen after installation. Generally, these modified materials are used for commercial or industrial pavement applications; however, they can be considered on any site which contains frost susceptible soils categorized by a F3 or F4 soil type. Refer to Oaks Tech Note Number 1 for more detailed information about modified base materials.

INTERLOCKING CONCRETE PAVERS TECHNICAL DESIGN AND INSTALLATION GUIDE

2.7 DRAINAGE

It is extremely important to drain all moisture away from the base course during the life of the pavement. Drainage features must be considered before installation of the base has started. Proper grading and structural drainage appurtenances must be designed into the pavement before construction begins.

2.8 BASE INSTALLATION

Aggregate base materials should be spread and compacted in layers 4" (100 mm) thick. Saturated or frozen material should not be compacted. Each layer should be compacted completely before more material is installed. Adding a sprinkling of water to base material that is completely dry will promote effective compaction. Base compaction should be done with a vibratory roller or large plate tamper. Small plate compactors (such as those commonly used to compact the pavers into the bedding sand) are not recommended because they do not achieve sufficient base material densities efficiently. The base course should be compacted with a compactor capable of delivering 5000 lbs. (22 kN) of force. The final compacted thickness must be uniform. The base course thickness should not vary more than + 3/4" (19 mm) or - 1/2" (13 mm). Surface deviations should not exceed 3/8" (10 mm) over 10" (3 m). Large paving projects may include base course inspection and testing by an Engineering firm. Typically, this type of project specifies that minimum densities of 95% (Modified Proctor Density) are achieved before the next phases of pavement construction begin.



2.9 COMPUTER AIDED PAVEMENT DESIGN

The Interlocking Concrete Pavement Institute (ICPI) distributes a program that performs structural design calculations for interlocking concrete pavements. This comprehensive software can produce pavement designs for interlocking concrete pavers over various subgrade soil types, subjected to different vehicular and environmental conditions, using assorted base materials and as rehabilitative or new construction. The software is Windows™ based and includes a user's guide and technical information. To obtain additional information about the program please contact Oaks Pavers and Walls.





SECTION 3

Bedding Sand

A uniform, properly installed layer of bedding sand is a relatively small but important component of the interlocking concrete pavement system. The quality of materials and installation can directly influence the integrity of the finished pavement.

3.1 FINAL BASE INSPECTION

Final inspection of the base layer is critical to the success of any pavement. Any grade changes or repairs should be done before the bedding layer is installed. It is critical that all the grades have been checked and the base material is thoroughly compacted before the bedding sand layer is installed.

The bedding sand should be installed over an even base surface. Bedding sand should not be used to fill depressions in the base layer. Depressions that are filled with bedding material will eventually become visible in the pavement surface. Significant variations in the base course surface should be filled with suitable base material and compacted properly. Pavement surfaces ultimately tend to reflect the characteristics of the base surface below. A consistent thickness of bedding sand will contribute to a smooth, even pavement surface.

3.2 PURPOSE OF THE BEDDING LAYER

The bedding sand layer of an interlocking concrete pavement has 3 functions:

1. it ensures consistent final elevations of the pavement surface;
2. it helps ensure effective load transfer between paving units;
3. it acts as a drainage medium.

When properly installed, the bedding sand layer can accommodate subtle variations in base course elevation and paving unit thickness. Standard construction tolerances allow for maximum base course deviations of 3/8" (10 mm) over 10ft. (3 m). Manufacturing tolerances for interlocking concrete paving units allow for a maximum variation of +/- 1/8" (3 mm) from the specified paver thickness. The bedding sand layer, when properly installed, can accommodate these minor variations.

Effective load transfer between individual paving units is a critical factor in the success of the pavement system. Applied loads are distributed from individual paving units to surrounding units through the sand between the pavers. During compaction, bedding sand will fill the bottom portion of the joints between the pavers. This contribution to complete joint filling

helps ensure the proper structural performance of the pavement system.

During the early life of an interlocking concrete pavement, a moderate amount of water can filter through the joints between the pavers and enter the bedding sand layer. As the pavement is used, the joints seal, allowing progressively smaller amounts of water to enter the pavement structure. The ability of the bedding sand material to compact tightly and still permit drainage during the early months of the pavement is important to its success.

3.3 BEDDING LAYER MATERIALS

Four characteristics should be considered when selecting a sand as bedding layer material:

1. gradation
2. particle shape
3. hardness
4. moisture content.

Bedding sand should be natural or manufactured from crushed rock and screened to the proper gradation. Proper gradation ensures the sand's ability to allow drainage and become dense under compaction. Gradation specifications for bedding sand are given below:

| ASTM Specification C33 | | CSA Specification A23.1 | |
|------------------------|-----------|-------------------------|-----------|
| Sieve Size | % Passing | Sieve Size | % Passing |
| 3/8" | 100 | 10 mm | 100 |
| #4 | 95-100 | 5.0 mm | 95-100 |
| #8 | 80-100 | 2.5 mm | 80-100 |
| #16 | 50-85 | 1.25 mm | 50-90 |
| #30 | 25-60 | 630 um | 25-65 |
| #50 | 10-30 | 315 um | 10-35 |
| #100 | 2-10 | 160 um | 2-10 |

Bedding sand particles should be sharp and symmetrical (not flat or elongated). Non-symmetrical particles do not compact completely and tend to settle unevenly over time. In addition,

INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

the bedding sand must not include any particles of clay, dirt or foreign matter.

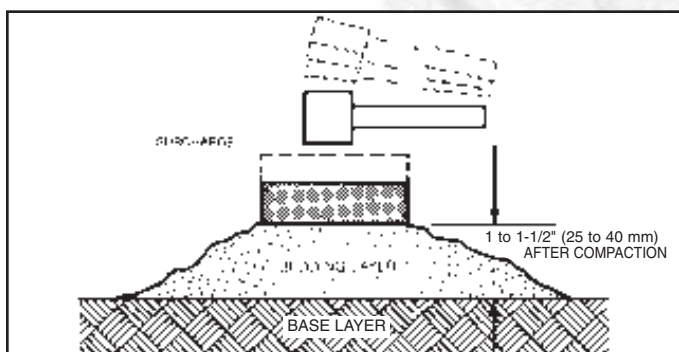
Pavement deformations can occur as a result of bedding sand material that is too soft. Durable particles, such as those derived from crushed rock, don't break down under repeated traffic loads. Limestone screenings are not recommended because they often contain soft particles that will deteriorate over time. The bedding sand's composition can give an indication of its suitability under traffic loads; however, a definitive indication of the material's durability cannot be given by its name. Broadly defining a bedding material as "granite", "limestone", or "silica" does not ensure certain characteristics, because there are both hard and soft granites, limestones, and silicas. The hardest sand that is economically available should be used as the bedding layer material, especially for heavy duty pavements.

Moisture content in the 4-8% range will ensure optimum compaction. Saturated sands should never be used. Material that is too dry will not compact efficiently. The addition of small amounts of water will aid compaction in extremely dry conditions.

3.4 BEDDING LAYER THICKNESS

The bedding sand layer should have a consistent thickness of 1" to 1-1/2" (25 mm to 40 mm) after compaction.

TESTING FOR THE COMPACTION RATE OF BEDDING SAND MATERIAL



The ability of the pavement to promote effective rainfall runoff is often affected by its surface elevation relative to adjoining surfaces. Consideration must be given to the amount of settling that will occur as the pavers are compacted into the bedding sand layer. The easiest way to determine this is to spread 30 mm (1-1/4") of bedding material on the base and place a paver on top of it. Measure from the top of the paver to the base. After

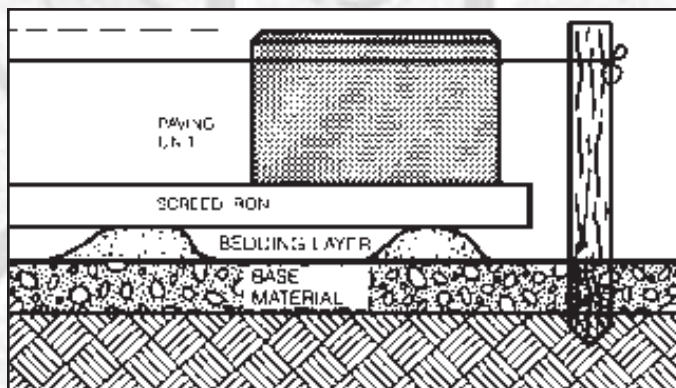
doing this, hit the top of the paver with a rubber mallet, using short, sharp blows. After the bedding layer is compacted, measure again from the top of the paver to the base. The difference between the two measurements will give you an accurate compaction rate. The bedding sand layer will generally reduce in thickness by approximately 1/4" (6 mm) after compaction.

A bedding layer that is sufficiently thick will encourage effective drainage and smooth surface elevations. Excessive bedding sand will create the risk of inconsistent compaction and an uneven pavement surface.

3.5 SETTING GRADES AND STRING LINES

After all the site work is completed, you can begin setting the final grades. Often, drainage considerations will determine the final pavement elevations. If paving between two hard surfaces, such as curbs, buildings or existing pavement, outside grades will be preset. The use of string lines will help to ensure the proper grades and will help in determining drainage requirements.

SETTING SCREEDING IRON TO STRINGLINE



Water will run over an interlocking concrete pavement surface the same as it will on any other hard pavement. The proper pitch of the pavement is critical to the success of the project. The setting of grades is achieved with the use of string lines and grade stakes. Setting strings to represent the top of the paver surface will determine the elevation of the finished grade. This will also provide a reference line needed to inspect the pitch of the pavement so water will run off. A minimum of 1" (25 mm) per 10 ft. (3 m) is recommended for effective water run-off and to decrease the chances of ponding.

INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE



A 2% slope for water run off is ideal, however local standards should be followed. Consulting with an engineering firm is recommended when establishing grades on larger projects. The setting of grades is achieved by using a line level or survey transit. The line level may be used when a uniform grade is required over the entire surface or when water does not have to run to a specific area. A survey transit should be

used when water run off is critical and exact drainage requirements must be met. Keeping in mind that string lines represent the top of the paver surface, final inspection of grades should be performed.

3.6 SETTING SCREED RAILS AND SCREEDING

The bedding sand layer is installed by a method called screeding. Screeding is typically done using 1-1/4" to 1-3/4" (30 mm to 45 mm) pipes or bars set on the compacted base.



Set the initial screed rail on the base material, just below the existing string line, so that the rail runs parallel with the string. The top edge of the screed rail represents the finished grade of the bedding layer. With the paver resting on top of the screed rail, adjust the height of the rail to accommodate for settlement by using the compaction established for the bedding layer (Section 3.4).

Each screed rail should be set, one end at a time, and supported on well-compacted base material along its entire length. Height adjustments can be made at this time by adjusting the amount of compacted base material being used between the bottom of the rail and the base. Once set, the top of the first screed rail will now represent the exact thickness of the bedding layer and ensure the consistency of this layer.

Set the next screed rail parallel 10 ft. (3 m) apart from the first rail. Lay a board or straight edge across both rails. Use a level to ensure that the second rail is at the same grade as the first rail. For areas wider than 10 ft. (3 m), additional rails can be set parallel to existing preset rails. A 10 ft. (3 m) spacing will prevent the board or straight edge, (which will be used for screeding), from bowing in the middle.

Once the screed rails are set, fill the areas between the rails with bedding material. It is essential that the bedding layer be as consistent as possible; preferably the thickness should be 1-1/4" (30 mm). It is critical to the success of the project that these tolerances are adhered to.

Starting at one end of the screed rails, place a 2x4 or equivalent screed bar across two rails and begin screeding by pulling the material along the length of the rails. The resulting layer should be level to grade and consistent throughout the entire area. Any voids or irregularities should be filled and screeded a second time. Be sure to screed an area large enough to stay well ahead of the paver installers, thereby decreasing the possibility of having to rescreen any disturbed areas. This layer should be left untamped so that the pavers can settle into the bedding layer when compacted.

Prior to the removal of the screed rails, a final inspection should be done to ensure that all areas of the bedding layer are consistent and free of any voids. Excess bedding material along the edges of curbs or buildings should be removed. Screed rails should be removed and their depressions should be filled with additional bedding material. Using a trowel or straight edge, blend in these filled areas to conform to the surrounding grade.

Screeded areas should be large enough to stay well ahead of the ensuing paver installation; however, areas should not be screeded and left exposed if there is a threat of inclement weather. All screeded areas should be paved by the end of each work day.

INTERLOCKING CONCRETE PAVERS

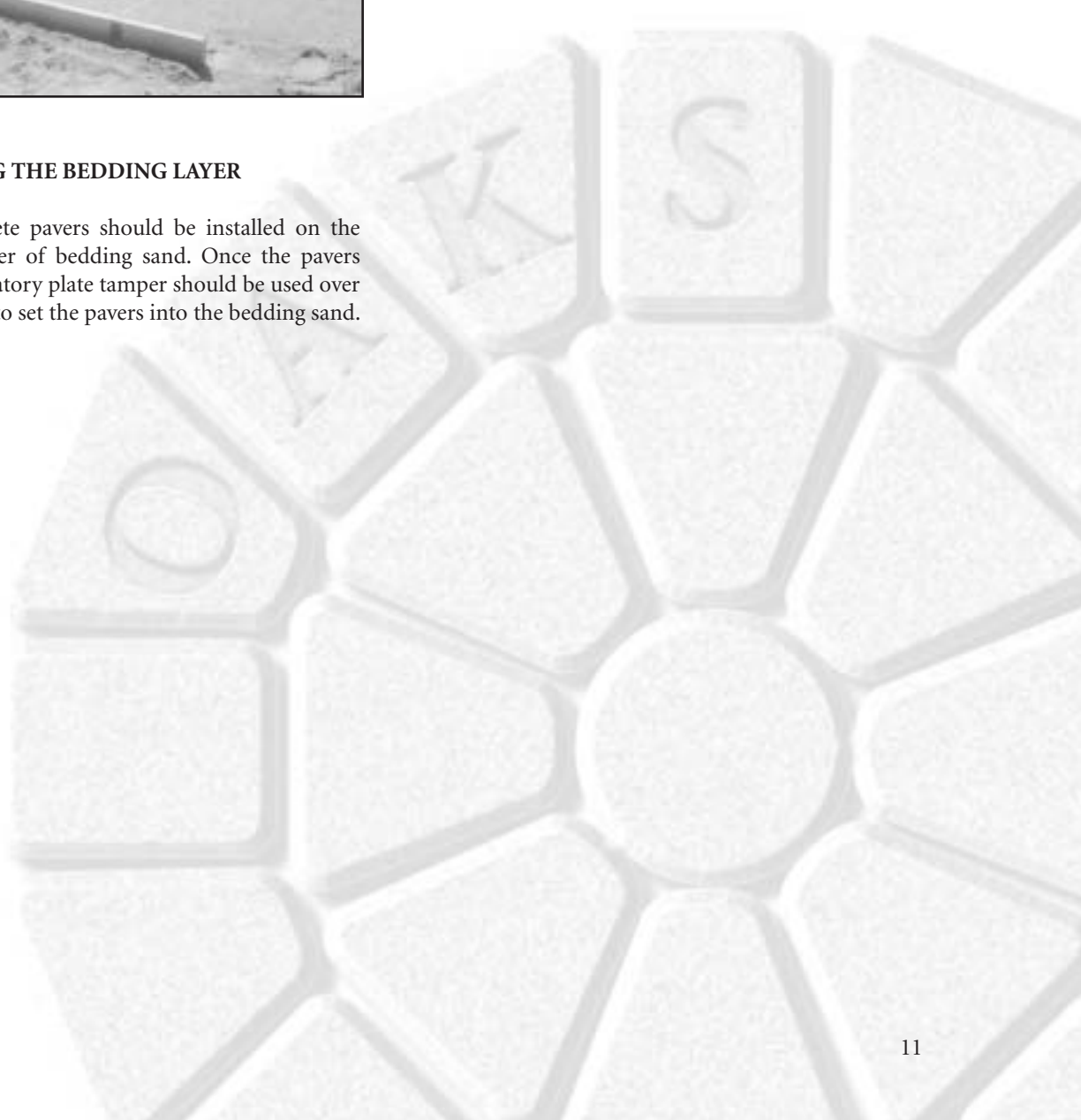
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All screeded areas should not be subjected to any form of traffic. Even pedestrian traffic can do enough harm to the bedding layer to minimize its effectiveness.



3.7 COMPACTING THE BEDDING LAYER

The interlocking concrete pavers should be installed on the loose, uncompacted layer of bedding sand. Once the pavers have been placed, a vibratory plate tamper should be used over the entire paver surface to set the pavers into the bedding sand.





SECTION 4

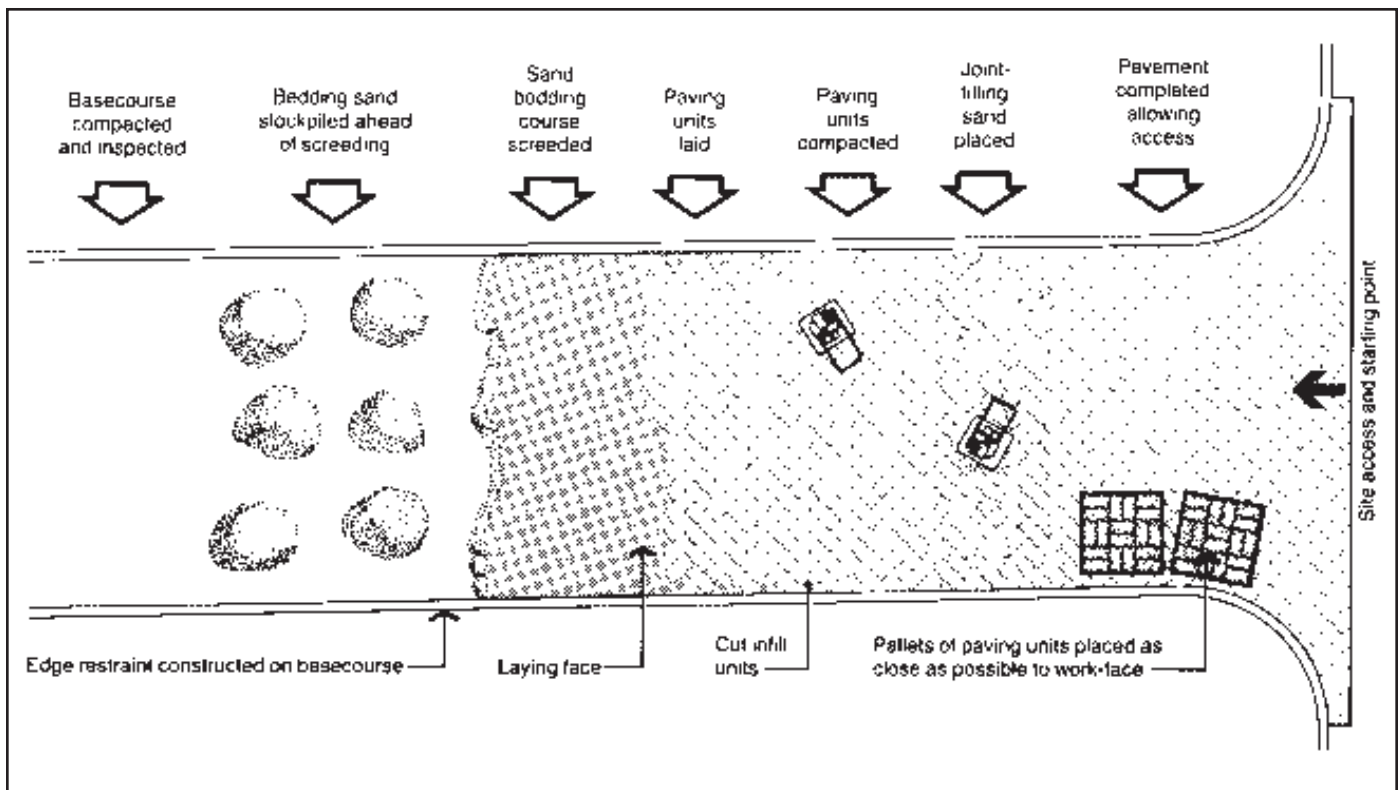
Paving Stone Installation

The required time to complete a project will vary depending on weather, site conditions, access, project size, and the timing of the other construction trades on the project. Manual installation is labor intensive, therefore sufficient time should be allocated to ensure the completion of the project on time. Timing is critical in project planning, so be sure to allow enough time to ensure a quality job.

4.1 MATERIAL PLACEMENT

Careful consideration should be given to determine the proper time to start the installation of the pavers. Material should be distributed around the job site for easy access, and to avoid disturbing prepared areas. It's best to avoid traffic on prepared areas until the paver installation has been completed.

Bundles of pavers (cubes) should be placed around the job site so as not to interfere with the installation of the paving stones or general construction traffic. Proper bundle placement will make the actual installation easier and quicker. See diagram for typical placement.



INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

4.2 LAYING PATTERN AND SHAPE

The laying pattern and shape of the paver is very critical in the performance of the pavement. Take into consideration the type of traffic weight loads. Traffic direction is not critical when using “A” shape pavers laid in a herringbone pattern. Other shapes and patterns are available but less effective when being used for heavy commercial or industrial traffic.

Any shape paver in a 60 mm (2-3/8”) thickness is suitable for pedestrian traffic. When pavers are going to be used for industrial or commercial purposes with heavy vehicular traffic, theoretical studies recommend that you use an 80 mm (3-1/8”) thick paver in the “A” shape category, laid in a herringbone pattern. Type “A” pavers have demonstrated excellent performance in road applications because they tend to control the spread of joints in two directions and resist rutting and creeping of the paver surface. Practical experience worldwide has shown that other shapes of pavers laid in a herringbone pattern have performed adequately, i.e.: 100 mm x 200 mm x 80 mm thick (4” x 8” x 3-1/8” thick).

| | |
|----------|--|
| TYPE “A” | |
| TYPE “B” | |
| TYPE “C” | |

Shape “Type A” are dentated chamfered units which key into each other on four sides, are capable of being laid in herringbone bond, and by their plan geometry when interlocked, resist the spread of joints parallel to both the longitudinal and traverse axes of the units.

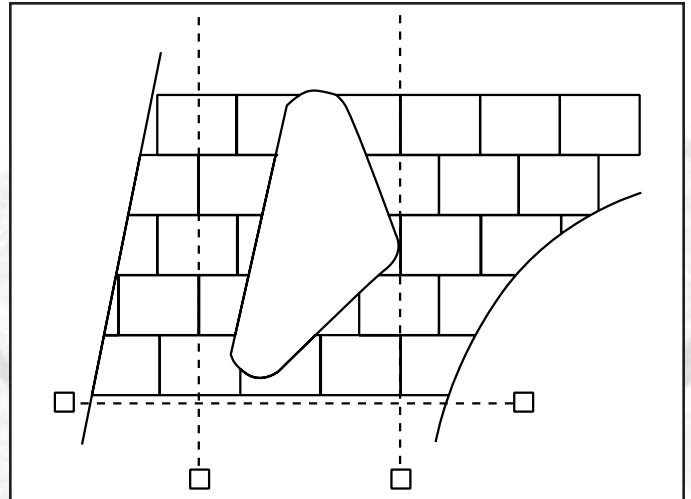
Shape “Type B” are dentated units which key into each other on two sides, are not (usually) laid in herringbone bond, and by their plan geometry, when keyed together, resist the spread of joints parallel to the longitudinal axis of the units and rely on their dimensional accuracy and accuracy of laying interlock on the other faces.

Shape “Type C” are units which do not key together and which rely on their dimensional accuracy and accuracy of laying to develop interlock.

4.3 DETERMINING THE STARTING POINT

There are a number of conditions that determine the starting point of a paving stone project. The pavers should be installed from adjoining hard surfaces or buildings and continue out and away from these surfaces, in only one direction. Whenever there is a steep incline, the paving stones should be installed “uphill” to prevent the units from creeping as they are being placed.

When paving against an existing hard surface or building, the use of string lines is essential to determine the straightness of the edge.

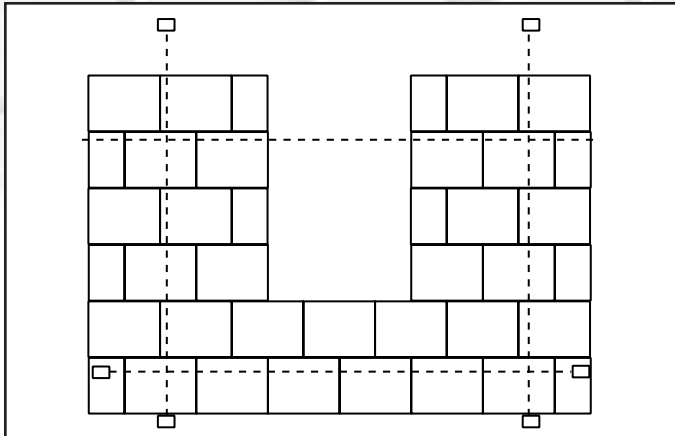


The use of string lines allows the installer to make adjustments in the alignment of pavers. As the installation progresses, this will help to minimize the use of small trim pieces which are likely to fail under heavy loads.

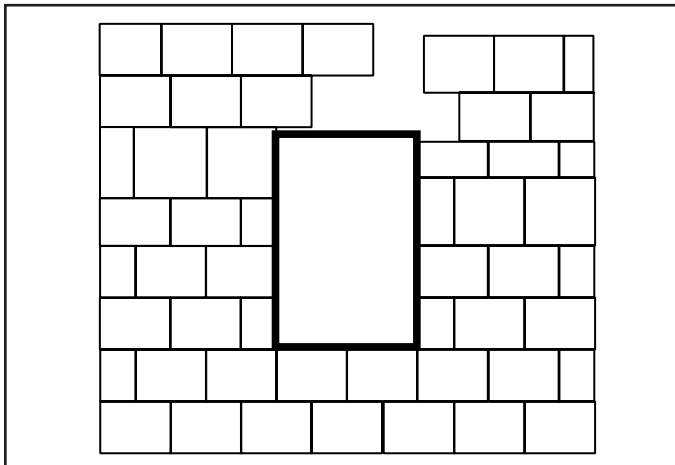
INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

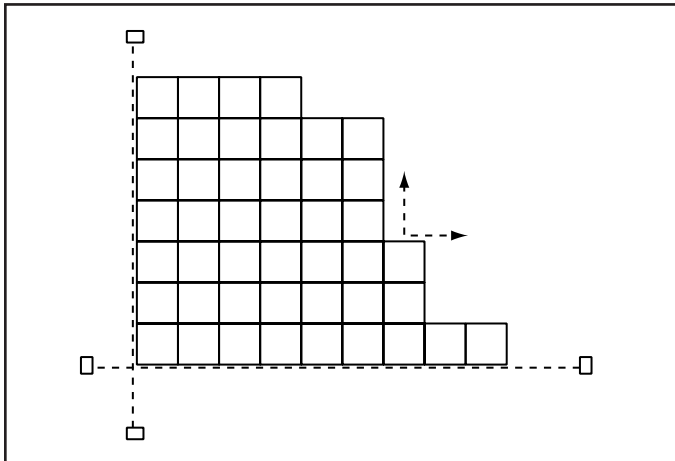
TREATMENT OF ISLAND FEATURE
USE STRINGLINE GRID TO CHECK ALIGNMENT



ERROR IN ALIGNMENT



LAY PAVING STONES EXACTLY TO STRING LINES



4.4 ALIGNMENT OF PAVERS

The use of string lines is crucial for the alignment of pavers, and without their use it is difficult to keep the pavers from drifting out. When pavers start to drift a number of things can happen:

1. Existing pavers pinch in. Once this happens, the only solution is to remove the pavers and start over. Once a large area has been installed you will not be able to adjust or move the paved area to compensate for the drift.
2. The alignment of the pavement will not be acceptable because of irregular lines or large gaps in the joints.

Be sure to check string lines and pavers frequently. This will allow the immediate detection and correction of any drift and avoid having to make major adjustments in alignment.

It is essential that string lines be used when paving around a fixed object. Never pave from two sides of an island or boulevard. Set string lines and square up the pavers using the lines. This will allow the installation of pavers around a fixed object with true lines and an exact fit.

4.5 INSTALLATION OF PAVING STONES

When starting the installation of the paving stones, it is best to run a single row under one of the string lines. This will give you a straight and true row to work from.

When placing pavers, a maximum space of 1/8" (3 mm) between the pavers must be maintained. Most pavers manufactured today have spacer bars provided on the sides and ends of each paver to automatically provide this space. Pavers that do not have spacer bars should be laid hand tight. Do not try to tap or kick pavers tight against each other. The best method is to simply place a paver lightly against another one and let it slide down into position. Pavers that are laid tightly together will chip and crack under heavy loads.



INTERLOCKING CONCRETE PAVERS TECHNICAL DESIGN AND INSTALLATION GUIDE

4.6 CUTTING PAVING STONES

Start cutting pavers as soon as the installation is far enough ahead to allow room for cutting. In doing so, the potential for lateral creep will be minimized.

There are basically two types of cutting tools: the guillotine splitter and the diamond blade power saw. The diamond blade will provide a cleaner more accurate cut. When using a wet saw be sure to keep the saw away from the paving stone surface because the slurry from the water will stain any paving stones underneath.

Pavers that have been cut and laid against a hard surface should not fit tight. Sufficient spacing should be provided for jointing sand.



4.7 COMPACTING THE PAVING STONES

After installation, all paved areas must be compacted. Before compaction, the entire area should be swept clean of any debris such as stones, paver chips and dirt. Typically, a plate compactor capable of delivering 3000 lbs. (13 kN) of force should be used. It is recommended that the compaction is done in two directions over the paved area to ensure that all areas are compacted.

It is important that compaction takes place before any jointing sand is applied to the pavers. If jointing sand is spread over the pavers before compaction, this will cause bridging and will not allow the joints to be completely filled, and will prevent the

pavers from being properly set into the bedding layer.



The compaction of the pavers is critical to the final performance of the pavers. The compaction sets the pavers into the bedding layer. Failure to do this can result in surface deformations and pavement failures.

4.8 MECHANICAL INSTALLATION

The most widely used method of installing interlocking concrete pavers is by hand placing each unit. Because this method can be very labor intensive, especially on large jobs, mechanical installers have been developed and used in various situations. The use of mechanical laying machines has contributed to a more efficient and economical method of paving stone installation. Most machines available are small, lightweight, and very maneuverable. They are equipped with a clamp capable of lifting and placing an entire layer from a bundle of paving stones, resulting in approximately 10 square feet (1 m²) of pavers being installed in one pass. After the area has been prepared (base and bedding layers have been installed), a crew of about

INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

4 people (including the machine operator) can install approximately 6000-7000 square feet (600-700 m²) in one day. Mechanical laying machines can be used effectively on any project over 1000 square feet (100 m²). The benefits of using a mechanical installer are most apparent on larger projects.



4.9 THINGS TO CONSIDER BEFORE USING A MECHANICAL INSTALLER

There are certain items that must be considered before mechanical installation can proceed:

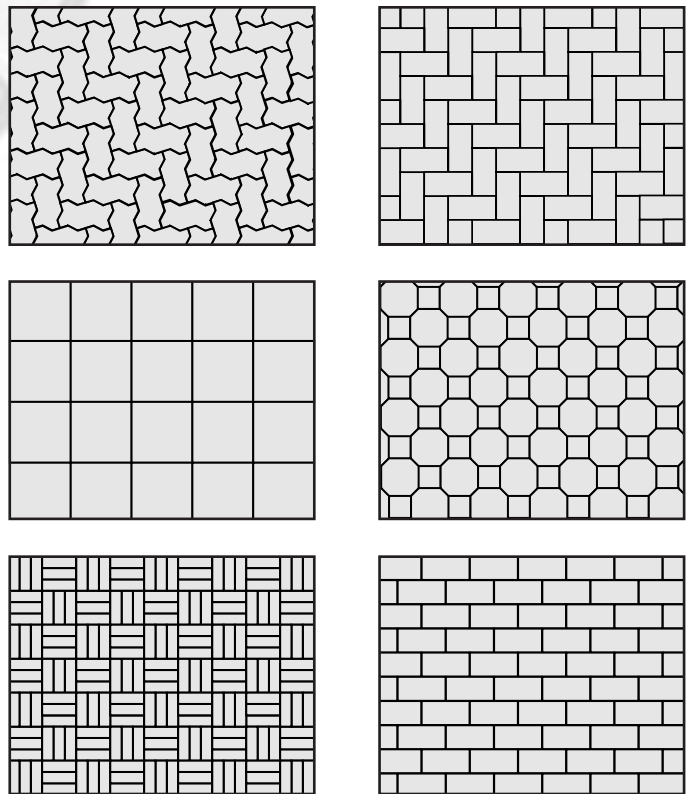
1. The paving stone manufacturer must have production moulds capable of producing the desired paving stone shape and pattern.
2. Color-blended pavers must be manufactured uniformly. Products that are not properly blended will result in a pavement that looks patchy.
3. Pavers must be of high quality. Bundle layers that “stick” together will seriously slow down the installation.
4. Pavers must have tight dimensional tolerances. Mechanical installers cannot effectively lift layers of paving stones from bundles when the pavers do not have consistent heights.

If all of these items are assured, mechanical installation should be seriously considered as an economical method of installing interlocking concrete pavements on large scale projects.

4.10 MOULDS REQUIRED FOR MECHANICAL INSTALLATION

In most cases, the paving stone manufacturer must be capable of producing the desired paving stone shape and pattern in the manner to be laid.

Typical moulds for mechanical use:



4.11 BEDDING LAYER PREPARATION FOR A MECHANICAL INSTALLER

When using a mechanical laying machine, the base preparation is done the same way as it would have been done if the pavers were to be laid manually. However, it is recommended that the bedding layer undergo some degree of compaction before paving stone installation begins. This will reduce the possibility of any deformations in the bedding layer caused by the placement of pavers by the machine. Once the bedding layer has been compacted, the bedding sand can be slightly loosened with a rake to correct minor irregularities. After placement of the paving units, normal compaction procedures should be followed to ensure pavement lock-up.



SECTION 5

Edge Restraints

The success of an interlocking concrete pavement relies heavily on the elimination of lateral movement. Edge restraints provide a means of preventing any rotation or lateral creep of paving units, especially at the perimeter of the pavement.

5.1 TYPES OF EDGE RESTRAINTS

There are a wide variety of edge restraints. They may be installed individually as manufactured segments or cast in place at the project site.

Manufactured Edge Restraints:

- plastic edging
- aluminum or steel edging
- partial depth precast concrete edging
- precast concrete or cut stone
- timbers

Cast in Place Edge Restraints:

- poured-in-place concrete curbs
- troweled concrete

Each type of edge restraint has advantages and disadvantages, some aesthetic and some functional. Restraints are installed so they are exposed at the surface or concealed beneath the surrounding finished grade. Either method is acceptable, and is strictly an aesthetic consideration.

5.2 EDGE RESTRAINT APPLICATIONS

For pavements that will be exposed to heavy vehicular traffic, such as municipal streets or parking lots, a poured-in-place concrete curb is recommended as the edge restraint. Pavements designed for pedestrian traffic or light vehicular use may employ any type of restraint, provided it is installed properly.

5.3 EDGE RESTRAINT INSTALLATION

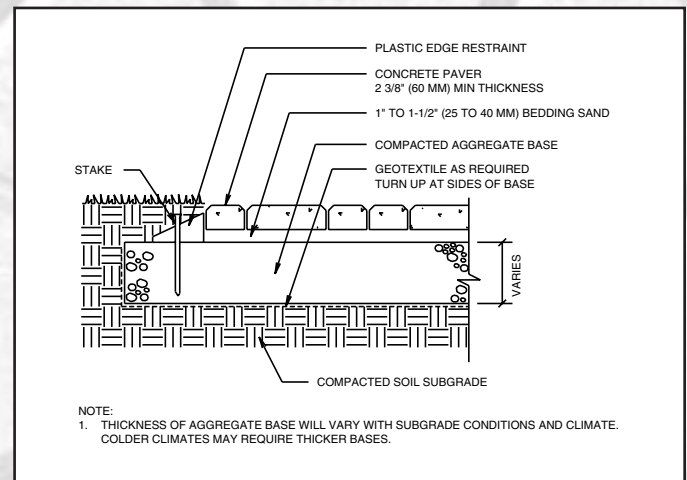
Many types of edge restraints rest directly on, or are secured in place through the base course. The base course should extend beyond the perimeter of the pavement surface by at least the dimension of the base course thickness (i.e.: if the base course is 6" (150 mm) thick, compacted base material should extend at least 6" (150 mm) beyond the edge of the pavement). This will allow for the installation of most types of edge restraints. Some

edge restraints extend deeper into the base course (i.e.: curb-and-gutter) or beyond the base course into the prepared subgrade (i.e.: precast or poured-in-place curbs). Some restraint types rely primarily on their size and mass to prevent paver movement, while others are kept in position with spikes. In any case, the edge restraint should be properly backfilled after it has been installed to provide additional stability.

If there is a possibility of bedding sand loss between the joints of an edge restraint, geotextile or filter cloth should be used to prevent its migration. A 12" (300 mm) strip of fabric should be placed on the compacted base material and turned up along the sides of the edge restraint. Geotextile is generally not required across the entire surface of the base course, and it should not be placed on top of the bedding sand layer.

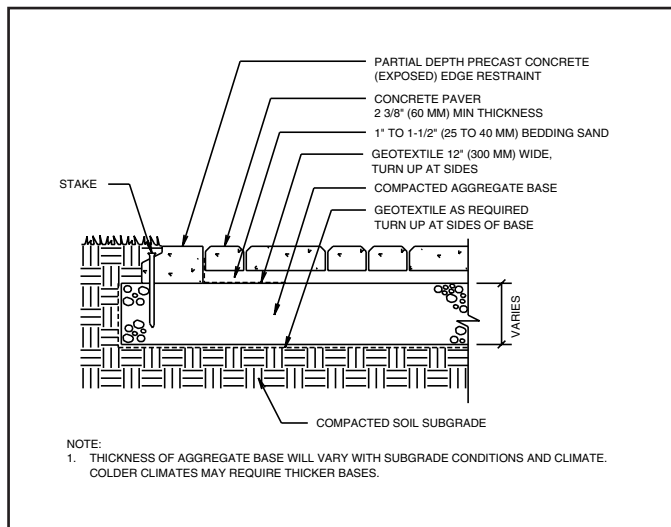
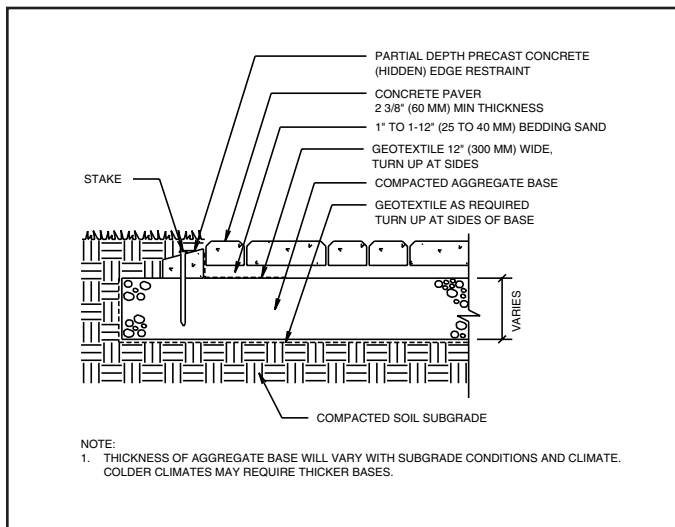
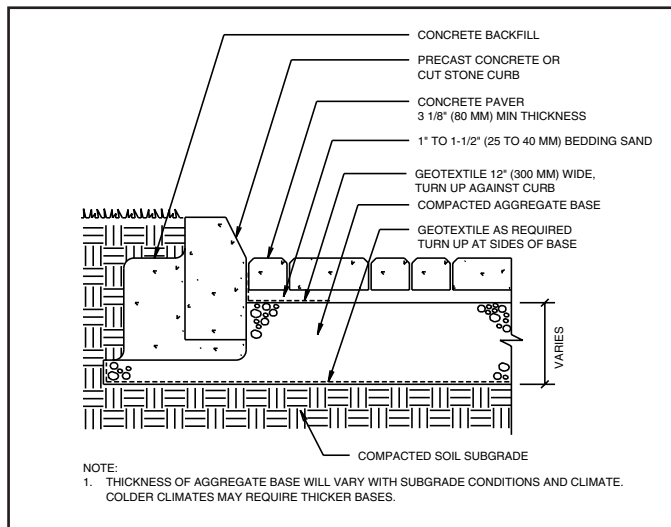
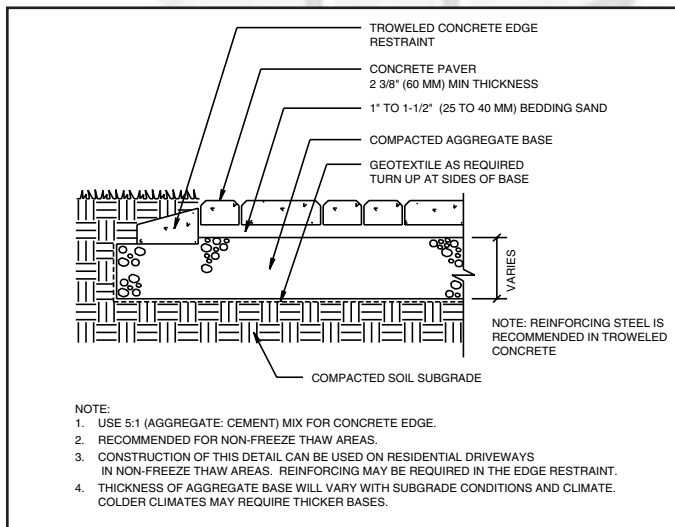
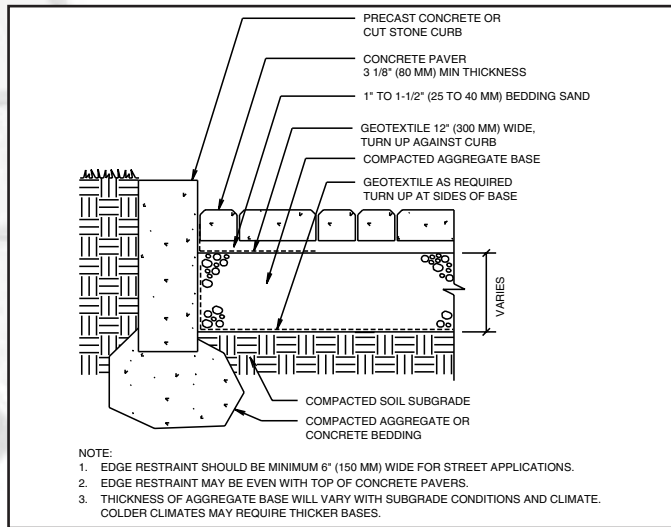
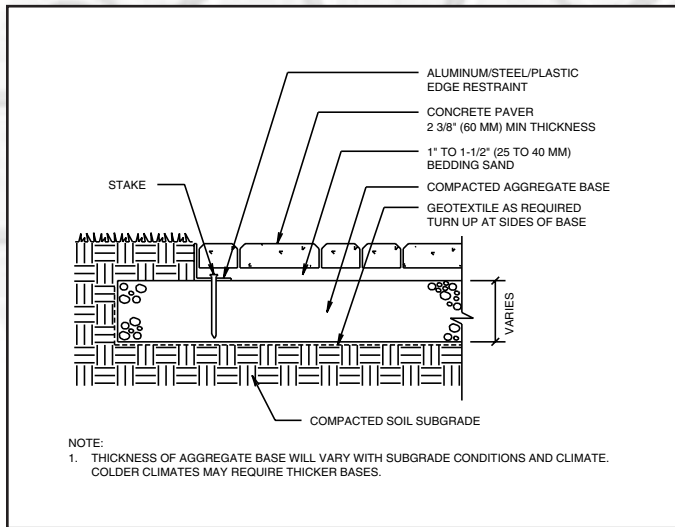
In many cases, the edge restraint will provide the installer with a means of starting the pavement laying pattern and setting the finished grade of the pavement. It is therefore necessary that special care is taken to ensure that both the location and elevation of the edge restraint is accurate.

5.4 EDGE RESTRAINT CROSS SECTIONS



Continued next page

INTERLOCKING CONCRETE PAVERS TECHNICAL DESIGN AND INSTALLATION GUIDE





SECTION 6

Jointing Sand

Applying jointing sand is the final step of an interlocking concrete pavement installation. The jointing sand “locks” the paver surface and prevents them from binding or pinching together. Neglecting to install jointing sand can result in the failure of the pavement.

6.1 JOB INSPECTION

Before applying jointing sand it is important that a final inspection of the completed pavers take place. During this inspection any cracked or chipped pavers should be replaced. Removing paving stones is much easier before jointing sand is applied. At this time, grade accuracy should be checked.

6.2 THE PURPOSE OF JOINTING SAND

The jointing sand in an interlocking concrete pavement has three functions:

1. acts as a medium through which applied loads are transferred between paving units
2. exerts friction between paving units to prevent movement
3. prevents paving units from pinching together.

When the joints between pavers are completely filled with jointing sand, loads applied to each paving unit are effectively transferred to the surrounding pavers. This function enables the individual units to act together as a load bearing pavement system. Joints that are not completely filled with sand will cause the adjacent pavers to act independently, which may result in cracked pavers and eventual pavement failure.

Concrete pavers will shift and rotate when exposed to traffic loads. Eliminating or minimizing the movement of individual paving units under applied loads is essential to the success of the pavement. Joints that are completely filled with sand prevents the pavers from shifting and rotating.

Many paving stone shapes are manufactured with spacer bars that create gaps between the pavers when they are installed. These spacers allow for the installation of jointing sand. Pavers that are installed without gaps between them will tend to pinch together under loads, which results in chipping. Paver chipping can be eliminated if proper sand filled joints are provided.

6.3 JOINTING SAND MATERIALS

Like bedding sand, four characteristics are important when selecting sand to fill the joints:

1. gradation
2. particle shape
3. hardness
4. moisture content.

Jointing sand should conform to the following specifications:

| ASTM Specification C144 | | CSA Specification A82.46 | |
|-------------------------|-----------|--------------------------|-----------|
| Sieve Size | % Passing | Sieve Size | % Passing |
| #4 | 100 | 5.0 mm | 100 |
| #8 | 95-100 | 2.5 mm | 95-100 |
| #16 | 70-100 | 1.25 mm | 60-100 |
| #30 | 40-75 | 600 um | 35-80 |
| #50 | 20-40 | 300 um | 15-50 |
| #100 | 10-25 | 150 um | 2-15 |
| #200 | 0-10 | | |

The supplier of the jointing sand should be able to provide gradation information.

The jointing sand particles should be angular and symmetrical. Particles that are too round or too close to the same gradation will not stay in the joints. Jointing sand that is too soft will not transfer loads effectively. The sand should be completely dry for installation. Wet jointing sand will not fill the joints easily, and will tend to bridge the gaps between pavers. If bridging occurs, the joints will not fill completely. Bagged sand should be considered to ensure that the product is dry.

Alternate materials are available that stabilize the jointing sand, such as sand binders, dual action sealants or specially formulated joint stabilizing sands. Polymeric sand is useful on pavements where the joint sand is not expected to immediately stabilize on its own, under weather or repeated traffic use. These are often sloped surfaces that are subject to erosion from runoff, or pavers with wide joints (>5mm). It will accelerate the joint stabilization process, and help to prevent washout, weed growth and insect infestation. If it is used incorrectly, polymeric sand may cause unsightly staining of the pavement surface. Please consult with supplier for proper installation and use.

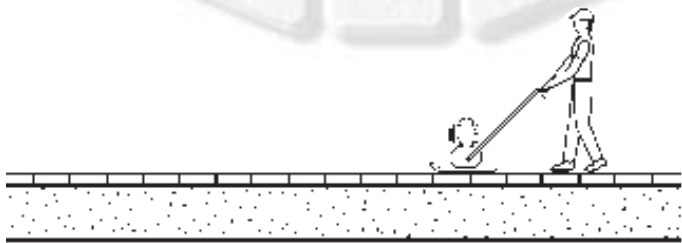
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6.4 INSTALLATION OF JOINTING SAND

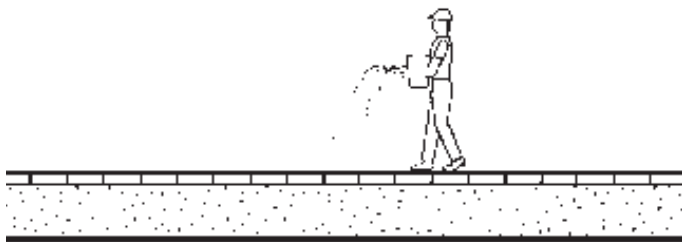
Spread jointing sand liberally across the entire pavement surface. Sweep the sand into the joints. After sweeping, vibrate the surface with a plate tamper. This will force the sand down into the joints and lock up the pavers. After vibrating, jointing sand should be applied to the entire area again. Ensure that all the joints are completely filled with sand. Repeat this sequence as many times as needed to fill all the joints.

SEQUENCE OF OPERATION

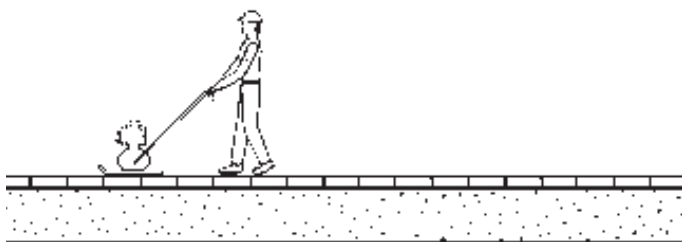
VIBRATE



SAND AND SWEEP



VIBRATE



6.5 FINAL INSPECTION

In the final inspection, general overall appearance is critical. It is recommended that excess sand and all debris be swept from the site before final inspection takes place. During inspection it is important to pay particular attention to the following:

1. paver joints are completely filled
2. pavers are level and true to the grades that are shown on the drawings
3. there is positive drainage to all drains and channels
4. damaged pavers are marked and replaced.

Have the general contractor and/or the designer present to clarify any repairs that must be performed.

Refer to the "Job Site Inspection - Check List" (Section 6.6) to assist in a proper job site inspection.

INTERLOCKING CONCRETE PAVERS TECHNICAL DESIGN AND INSTALLATION GUIDE

6.6 JOB SITE INSPECTION - CHECKLIST

| | |
|---|----------------------------|
| EXCAVATION: | |
| UNDERGROUND LOCATES HAVE BEEN MARKED BY ALL UTILITIES | |
| EXCAVATED TO PROPER DEPTH | |
| TYPE OF SOIL IDENTIFIED - ORIGINAL GROUND (O.G.) INSPECTION | |
| DATE | |
| SUB-BASE INSTALLATION (IF NEEDED) | |
| ADDITIONAL EXCAVATION REQUIRED | |
| GEOTEXTILE/FILTER CLOTH REQUIRED | |
| TYPE OF SUB-BASE MATERIAL USED | |
| COMPACTED WITH MOISTURE | |
| INSPECTION AND APPROVAL | |
| DATE | |
| BASE INSTALLATION | |
| GEOTEXTILE/FILTER CLOTH REQUIRED | |
| BASE MATERIAL MEETS GRADATION SPECIFICATIONS | |
| DRAINAGE TILE INSTALLED (IF REQUIRED) | |
| COMPACTED TO PROPER DENSITY | |
| CONTOUR OF BASE VERIFIED | |
| SURFACE DRAINAGE HAS BEEN CONSIDERED | |
| INSPECTION AND APPROVAL | |
| DATE | |
| EDGE RESTRAINTS | |
| BASE EXTENDS BEYOND EDGE RESTRAINTS | |
| TYPE OF EDGE RESTRAINT | |
| EDGE RESTRAINT PROPERLY INSTALLED | |
| DATE | |
| SCREEDING | |
| SCREEDING MATERIAL MEETS GRADATION | |
| SPECIFICATIONS | |
| SCREEDING APPROVED | |
| DATE | <i>Continued next page</i> |



SECTION 7

Cleaners and Coatings

Today people are investing large sums of money into the paving of parking lots, sidewalks, and driveways using interlocking paving stones. Similar to most other large investments, some amount of maintenance and protection may be required.

7.1 CLEANING INTERLOCKING PAVERS

Many different contaminants exist that cause staining on pavers. Some are easily removed by using household cleaning products, while others are more difficult requiring the use of industrial chemicals. Special care must be used when applying these chemicals. It is recommended that you consult a qualified contractor before taking on any cleaning operations.

Most paving stone manufacturers' warranties are void after chemicals have been used on the surface of the paving stones.

General precautions:

Follow all directions when using chemicals, as there may be harmful effects if not properly used.

1. Wear eye protection and protective clothing when using any chemicals. (i.e. long gloves, apron, pants, and boots.)
2. Maintain proper ventilation.
3. Tools should be non-metallic. (i.e. heavy-duty plastic bucket for cleaning agents, a long-handled, stiff, bristle brush and wooden or plastic scrapers.)
4. After applying acidic chemicals, always keep the surface wet. Do not let the chemical dry, this will cause staining and etching to the pavement surface.
5. When diluting acid, pour the acid into the water - do not pour water into the acid.

Plan to clean an area that has multiple stains by starting at the bottom of the slope. As you move up the slope, the runoff will not cover up the untreated stains or risk further dilution of the cleaner.

After each stain is identified, apply a small amount of cleaner to test its strength. In most cases, if the improper treatment is used, the outcome is often worse than the original stain. If the stain does not disappear, check accuracy of dilution (if required), reapply the cleaner or use an alternate treatment.

After the stain has been removed, thoroughly rinse the area with clean water to remove any harmful residue left on the pavement. Allow the pavement to dry, inspect, and repeat cleaning process if necessary.

Upon completion, thoroughly wash hands, protective gear and tools before storing.

7.2 REASONS FOR APPLYING CHEMICAL COATINGS

A transparent coating can be applied to pavers in order to preserve and protect their original beauty. A coating acts as a sealant for the tiny pores on the surface of a paver, preventing grease, oil, salt, and other contaminants from penetrating and staining the paver. Once a coating is applied, it will make future cleaning much easier and less costly.

Many coatings will enhance the color of the pavers, giving them a wet appearance. In most applications, a coating will give the pavers a glossy appearance without making them slippery. This coating will often highlight the color without changing the texture of the paver.

It is essential to note that applying a coating is neither a necessity, nor will it strengthen or extend the life of a paver. Pavers are a high quality product manufactured to withstand loads and climate change without the application of chemical coatings. Even though chemical coatings provide a durable film that expands and contracts with the climatic changes, unfortunately it will wear over time. To retain a uniform finish, reapplication will be necessary every two or three years depending upon use.



INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

7.3 TYPES OF COATINGS

There are many different types of coatings available for concrete on the market today. When selecting a coating, make sure to choose one that has been formulated for exterior use on interlocking paving stones. For best results, it is strongly recommended to use only transparent coatings, unless absolutely necessary. Transparent coatings commonly used on pavers are silicone, water-based acrylics, and solvent-based acrylics.

Silicones in their pure form are film-type surface coatings that deposit water-repellent solids on the surface of the paver. Since penetration is limited, moisture migrates through the paver from the base or by condensation, and could attack the adhesive bond that holds the solids in place. If this takes place, peeling or blistering could occur. Silicones will resist staining by most water-based products, but liquids that contain phosphoric acids (i.e. some soft drinks) will attack silicone coatings. Silicones will not enhance the abrasion resistance of a paver, and the film-type coating often becomes slippery when wet.

Coatings that penetrate concrete are more desirable and will last longer than those that do not penetrate. Two types of penetrating coatings are solvent and water-based acrylic sealants. The water-based acrylics provide a good level of stain and abrasion resistance for pavers. They provide excellent resistance to water, petroleum, and fat/oil based stains. Water-based acrylics are a non-yellowing coating that will not provide a glossy finish and are practically invisible. Water-based products do not produce toxic or irritating fumes during application, so they are ideal for poorly ventilated areas. These coatings are not recommended for exposure to high temperatures; therefore, are not ideal for use in tropical climates. When using a roller or high-pressure sprayer, the water-repellent solids are not as soluble in water-based sealant, so it is sometimes necessary to filter the solution first to ensure easy and even application. Clean up is easily done with warm water. If clean up is delayed, xylene may be required.

Solvent-based acrylics are the most common type of coatings available for the use on pavers. There are two types of solvent-based acrylic sealers, one contains co-polymer resins, and the other contains homo-polymer resins. Co-polymers are very popular, but are generally less stain resistant than homo-polymer. Coatings containing homo-polymer resins are usually more expensive. Both types of solvent-based acrylics will penetrate concrete to give the paver an excellent chemical and abrasion resistance. They provide a glossy finish that remains extremely hard at high outdoor temperatures. Unlike silicones and water-based acrylics, they have a low flash point and are highly flammable. They must be used in a well-ventilated area. If a sprayer is used, they require a neoprene hose and washers.

Solvent-based acrylics are easy to apply, but clean up is difficult if it is not done immediately after use. Clean equipment with xylene, acetone, or lacquer thinner immediately after use.

7.4 WHEN TO APPLY CHEMICAL COATINGS

Most paving stone manufacturers recommend that chemical coatings be applied only after certain conditions have been met. Two of the most important conditions to be met are:

1. The removal of all contaminants from the surface
2. The absence of moisture in both the pavers and granular materials being used.

Contaminants may take the form of a whitish, powder-like deposit known as efflorescence. Before sealing allow for total evaporation of all moisture (min. 24 hours) and for all contaminants on the paving surface to wear off.

If the pavers are sealed prior to having met these conditions, the outcome may be disastrous. The manufacturer will take no responsibility for efflorescence since it is a natural occurring phenomenon. If a chemical coating is applied that impedes the natural wearing process, the manufacturer is not responsible for its removal.

7.5 HOW TO APPLY CHEMICAL COATINGS

Before application of sealant, ensure that all contaminants such as dirt, oil, grease, rust, tire marks, paint, chewing gum, efflorescence, are removed from the pavement surface. Refrain from the use of sand blasting. Instead, use a combination of a high-pressure washer with an effective and safe cleaning agent. Once all areas have been cleaned and thoroughly rinsed, allow the pavement to dry (min. 24 hours) before applying sealant.

Ensure the coating chosen is resistant to oil spills, food stains, de-icing, and any type of aromatic solvents.

Mix the chemical coating to manufacturers specifications. **Read all directions.**

Coating can be applied with a brush, a heavy pile roller, or by spraying. For deeper penetration, apply two even coats using a 2000 p.s.i. sprayer. Application of the sealant should be at the rate of 700 to 900 square feet (65 to 85 m²) per 5 gallons (20 litres) of sealer. Before the second coat is applied, the first must be thoroughly dry. One flood coat using a deep pile or split-foam roller can also be effective.

INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

General precautions:

1. Do not apply over wet surfaces.
2. Do not apply at temperatures below 55° F or (13° C).
3. Ensure proper ventilation.
4. Keep away from sparks, flames, or cigarettes.
5. When spraying, guards must be used to protect all areas not to be coated. Coating will kill all vegetation.
6. Avoid eye and skin contact.
7. Store material above freezing temperatures.



7.6 EFFLORESCENCE

Efflorescence is a white crystalline deposit that may develop on the surface of any concrete product. This phenomenon occurs periodically after installation, often having an undesired affect on the overall appearance of the paving stone installation. Efflorescence by itself in no way affects the structural integrity of a paving stone.

Three conditions must be present for efflorescence to occur:

1. Water soluble salts must exist in the concrete unit.
2. Water must be present to transport the soluble salts to the surface.
3. Hydrostatic pressure or evaporation must occur to transport the salt solution to the surface.

During the curing process of concrete, water traveling through the concrete due to hydrostatic pressure, picks up soluble salts, mainly calcium hydrosilicates and calcium hydroxide, and deposits them on the surface of the pavers. The salts react rapidly with the carbon dioxide in the atmosphere to form a liquid calcium carbonate solution. When the water contained in the solution evaporates, a white, crusty film is left behind. This film, called efflorescence, can build up to varying thicknesses.

Efflorescence is especially affected by the climate. In the summer months, efflorescence is less common due to the accelerated rate of evaporation. In the winter, efflorescence is more common due to the slower rate of evaporation. Over time, efflorescence becomes lighter and less noticeable. Since there are so many different variables that affect the formation of efflorescence, it is difficult to predict when it will or will not appear. Research is being conducted to minimize the occurrence of efflorescence in the concrete industry. At present, there are no definite preventative solutions for this on-going problem of efflorescence.

7.7 HOW TO REMOVE EFFLORESCENCE

The paving stone industry recommends efflorescence be allowed to wash or wear off naturally. Since the natural removal time may not be desirable, efflorescence can be removed more rapidly by using one or more of the following methods:

- dry brushing;
- water rinsing;
- light water blasting;
- premixed chemical detergents, followed by flushing with clean water.

General precautions:

1. Prior to application of cleaner, wet the entire surface with clean water and then wait for the pavers to dry. The jointing sand should still be saturated, which will prevent over absorption of the cleaner into the pavement joints. This will facilitate an easier and quicker removal of the cleaner from the surface.
2. Before use, carefully read product container label or consult with supplier for safe and proper usage.
3. When diluting acid, pour the acid into the water - do not pour water into the acid.
4. Protective clothing must be worn. (i.e. rubber gloves, thick coveralls, safety glasses, and boots)
5. Test an inconspicuous area, or on pavers not yet installed, to make sure there are no altering affects on colored pavers before proceeding with the entire job.
6. The solution should be applied on small areas beginning at the bottom of the slope. Do not let the cleaner dry on the surface.
7. The area should be brushed using a scouring brush with plastic bristles.
8. Thoroughly rinse the area with clean water, down the entire slope.
9. Repeat rinsing (min. 3 times) or until all contaminants and cleaner have been removed from the surface.
10. Final inspection should occur when the surface is totally dry (min. 24 hours).

INTERLOCKING CONCRETE PAVERS TECHNICAL DESIGN AND INSTALLATION GUIDE

7.8 CLEANING AGENTS AND PROCEDURES FOR CLEANING CONCRETE PAVING STONES

*NOTE: The following is for treatment on paving stones which have not been chemically coated.

| STAIN | APPEARANCE | CLEANING AGENTS AND PROCEDURES |
|---|-----------------|--|
| Aluminum | White deposit | 1 a) 10-20% muriatic acid (hydrochloric) scrub on acid on wet surface with hard bristle brush. b) Rinse with clear water to prevent etching. Note: weaker solutions should be used on coloured surfaces. |
| Asphalt | Black | 1 a) Ice – Cool until hard then scrape off surface layer. b) Scouring powders – scrub with hard bristle brush to remove excess. |
| Coffee | Tan | 1. Mix sodium hypochlorite (bleach) or glycerine: 1 part with 4 parts water. Apply absorbent cloth saturated with solution then rinse with water. |
| Copper Oxide | Green or Brown | 1. Ammonium Chloride: 1 part, powdered talc: 4 parts. Mix liquids and solids into a paste then apply to stain (1/4" to 1/8"). Let dry completely, then scrape off excess and rinse with water. |
| Creosote | Brown | 1. a) Mix benzene and powdered talc into a paste then apply to stain. Let dry, then scrape off excess and rinse with water. b) Scouring powder – Scrub with brush and chemical above if Step 1 is unsuccessful. |
| Efflorescence | White Deposit | See Section 7.7 |
| Grease | Black | 1. a) Scrape off surface layer then scrub with scouring powder, soap, trisodium phosphate or detergent. b) If stain persists, try a solvent and an inert powder filler to make a paste. Solvent can be benzene, refined naphtha solvent, or a chlorinated hydrocarbon solvent such as trichloroethylene. Apply paste to stain. Let dry then scrub with strong soap and rinse with water. Note: Avoid gasoline or kerosene since they only increase penetration. 2. Any concrete cleaners containing petroleum distillates, trisodium phosphate or sodium metasilicate are also very effective. Follow directions carefully. 3. Engine block degreaser is also effective but may effect colour. Test first. |
| Gum (chewing) | Black | 1 a) Ice – Cool until hard then scrape off surface layer. Note: A freon spray is also an effective way to harden gum. b) Scouring powder – Scrub with a hard bristle brush to remove excess, but will stain if they are not absorbed and washed away immediately after use. |
| Iron Oxide | Brown or Yellow | 1. Make a paste using 1 part lime-free glycerine (frequently found in hand lotion), 1 part sodium citrate, 6 parts lukewarm water. Mix with talc or whiting. Apply paste and let dry. Scrape off excess and repeat as needed. Rinse thoroughly with water. 2. Any concrete cleaning chemical containing phosphoric acid is also effective. Follow directions carefully. |
| Linseed Oil, Lubricating Oil or Petroleum | Dark Grey | With any oil spill you can minimize staining by immediately soaking up free oil with an absorbent material such as paper towel or cloth. Wiping should be avoided since it aids penetration. 1. a) Cover the spot with a dry inert powder (hydrated lime, whiting, powdered talk or portland cement). Let sit and repeat until no more oil is absorbed by the powder. b) Scrub the area with a strong soap, scouring powder, or trisodium phosphate. Rinse with hot water. 2. A water softener from the laundry room (eg. calgon) works extremely well. Make a paste of trisodium phosphate (calgon) 1 lb. with 1 gallon of warm water or benzene with hydrated lime or talc. Apply paste for at least 1 hour after solvent has been evaporated. Remove and scrub. Repeat if necessary. |

INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

| STAIN | APPEARANCE | CLEANING AGENTS AND PROCEDURES |
|---|-----------------|---|
| Linseed Oil, Lubricating Oil or Petroleum - <i>Continued</i> | | <ol style="list-style-type: none"> 3. Engine block degreaser is also effective but it may fade the colour. Test it first and follow directions carefully. 4. Make a poultice with a solution of 5% sodium hydroxide (caustic soda) eg: Drano. Let dry for 20 to 24 hours. Remove and scrub the surface with clean water. Repeat if necessary. |
| Mortar Smears | Grey | <p>Easiest cleaned when freshly hardened.</p> <ol style="list-style-type: none"> 1. a) Remove large particles with a chisel and the small particles with a wire brush or steel wool. b) For light deposits, try scrubbing using 1/2 cup of trisodium phosphate in 1 gallon of water. c) For heavier deposits, try scrubbing using muriatic acid 1 part to 10 parts of water. Do not use steel brush, use a stiff bristle brush. <p>Caution: Muriatic acid will affect the colour. Do sample area first. Thoroughly rinse area before and after application. Do not allow acid to dry. You should always use a stiff bristle brush or broom in final wash down to dislodge all acid that may have penetrated. Note: Acid solutions lose their strength after 5 to 10 minutes of contact with mortar particles, so only clean small areas at one time.</p> |
| Paints: Enamel, Lacquer, and Linseed Oil Based Varnish | Varies | <p><i>Wet:</i> Do not use paint thinners since they increase penetration. Absorb with soft cloth or paper towel followed by vigorous scrubbing.</p> <p><i>Dry:</i> (after 3 days), can be removed by most commercial paint removers. The best are methylene dichloride based paint removers. Do not use acetic acid paint removers since they will etch the surface. Apply remover for 20 to 30 minutes. Gently scrub surface to loosen film. Wash with water. Remaining residue can be scrubbed with scouring powder or washed out with diluted hydrochloric or phosphoric acid. Note: For shellac stains, the paint remover is replaced by alcohol.</p> |
| Plant Growth | Green, Brown | <ol style="list-style-type: none"> 1. Ammonium sulfamate (certain weed killers have a suitable substitute if this compound is not available at your local garden center). 2. Household bleach used in full strength (great for moss and mold); allow to dry then rinse thoroughly with water. This may effect colour, therefore, do test area first. |
| Organic/ Leaf Stains | Dark impression | <ol style="list-style-type: none"> 1. Ensure that the surface is dry and free of all debris and dirt. 2. Mix efflorescence cleaner as per supplier instruction label (usually 4 parts water: 1 part cleaner) 3. Apply solution directly on to the stain. 4. Scrub with hard plastic bristle brush. 5. Rinse thoroughly with clean water. 6. Repeat, if necessary. |
| Rubber | Black | <ol style="list-style-type: none"> 1. Follow the same procedures used for grease stains; 1a and 1b. 2. Any generic concrete cleaners containing petroleum distillates are very effective. Read directions carefully. |
| Tobacco | Brown | <p>Make a paste of calcium chloride and water together then separately mix trisodium phosphate, 2 lbs. to 5 quarts water. Combine the liquid and paste together and stir. Add talc and stir again. Apply paste 1/4" to 1/8" thick. Let dry then scrape off excess and wash thoroughly.</p> |
| <p>The chemicals and materials mentioned above are readily available through your local pharmacies, hardware stores, paint stores, garden centers and building supply centers. There are also many other proprietary compounds specially formulated for cleaning concrete pavers. They are very effective and are designed and packaged for the do-it-yourselfer. Consult a qualified cleaning contractor or a paving stone manufacturer about the availability of such products.</p> | | |

INTERLOCKING CONCRETE PAVERS TECHNICAL DESIGN AND INSTALLATION GUIDE



SECTION 8

Special Pavements

Interlocking concrete paving stones have been used for typical pedestrian and vehicular pavements for many years. Pavers do, however, offer distinct structural and aesthetic advantages in an ever-increasing variety of paving applications.

8.1 ROOF DECK PAVEMENTS

Advantages:

1. provides a durable surface for both pedestrian and vehicular traffic on roof slabs over inhabited and uninhabited space.
2. pavers allow for an aesthetically pleasing surface especially in applications like condominium/apartment structures.
3. unlike paving slabs (2 ft. (600 mm) square), pavers will accept loads from vehicular traffic.
4. pavers reduce thermal stress on the roofing membrane.
5. chamfered joints improve roof deck drainage toward the necessary drains.
6. easy removal and reinstatement for deck repairs and maintenance.

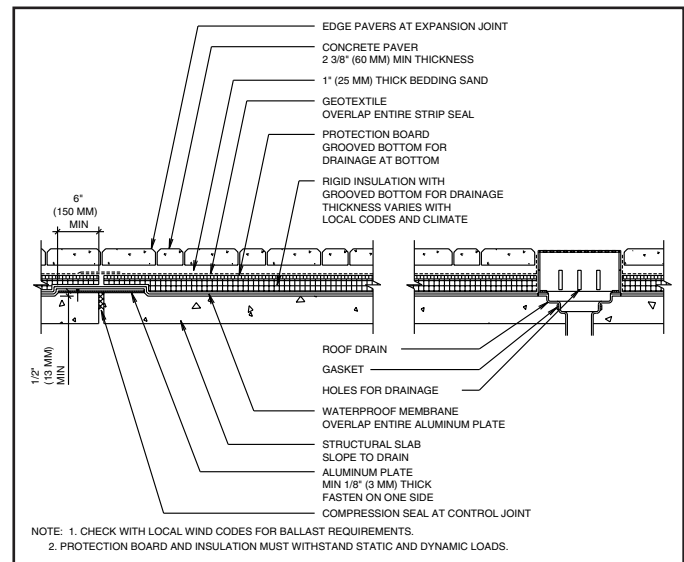
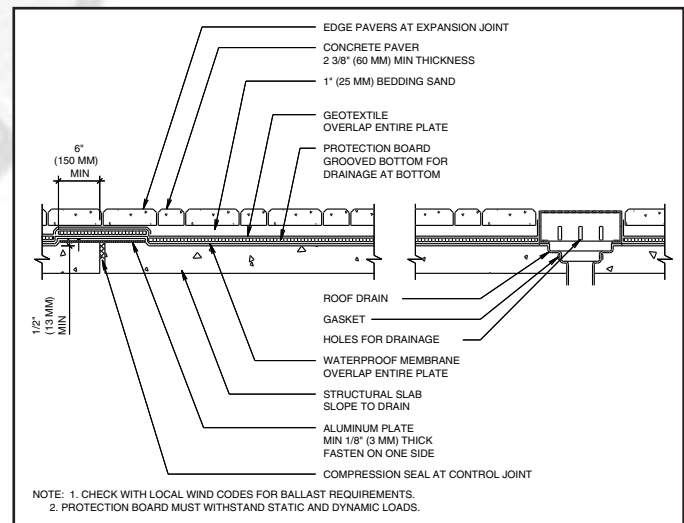
Design Requirements:

1. roof decks need to be waterproofed with a waterproofing membrane.
2. the substructure (typically concrete) should be designed to withstand loads.
3. the substructure should be sloped to provide the drainage requirements.
4. a protection board/insulating layer should be applied to the manufacturer's requirements.
5. roof drains require drain holes at the level of the water proof membrane to allow subsurface water drainage.
6. geotextile needs to be applied around roof drains to prevent migration of bedding sand.
7. paver shape, colors, laying pattern to be determined.
8. edge restraint considerations required.

8.2 GAS STATION PAVEMENTS

Advantages:

1. excellent resistance to traffic with minimal rutting or deformation of pavement.
2. immediate use for traffic with no delay for curing and hardening
3. resistance to abrasion, freeze/thaw cycles, deicing salts and a high resistance to spillage of petroleum products.
4. low life-cycle costs as a result of reduced maintenance and



Above information from: David R. Smith, "Concrete Pavers", reprinted from the Construction Specifier, Interlocking Concrete Pavement Institute, Sterling Virginia.

5. repair costs (local damaged areas).
5. can be lifted, repaired and reinstated with existing pavers.

INTERLOCKING CONCRETE PAVERS

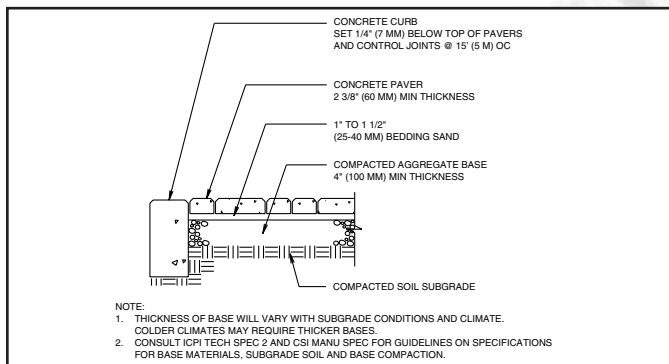
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- improved skid resistance for pedestrians and vehicular traffic.
- aesthetically pleasing because of the range of shapes and colors.
- use of different colors and surface finishes to permanently demarcate traffic lanes.

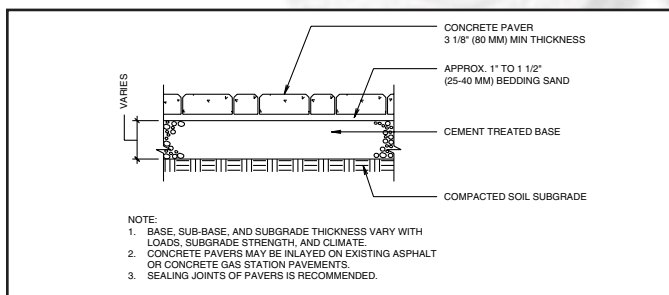
Design Requirements:

- interlocking concrete pavements for service stations consist of 80 mm thick units for vehicular areas and 60 mm for pedestrian areas.
- minimum compressive strength (crushing strength) in excess of 8,000 psi (55 MPa).
- tests have shown that the herringbone pattern provides greater structural capacity and resistance to lateral movement.
- standard base design methods for flexible pavements are used.
- 1-1/8" (approx. 30 mm) bedding sand
- paver shape, colors, laying pattern to be determined, edge restraint considerations required.

60 mm Pavers on Granular Base



80 mm Pavers on Cement Treated Base



For detailed design information, specifications, construction, life-cycle costs, and maintenance of gas station applications contact ICPI or Oaks Concrete Products.

8.3 AIRPORT APPLICATIONS

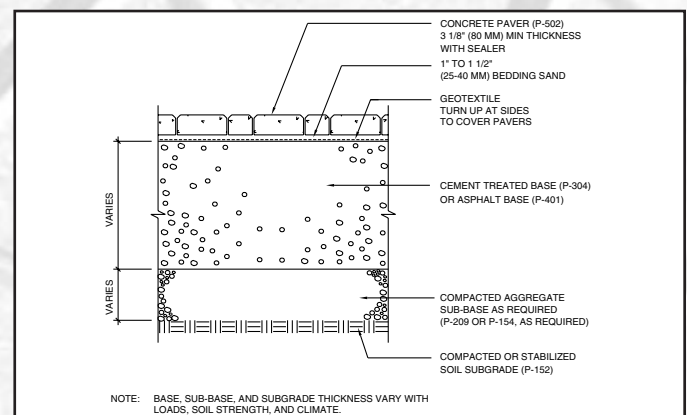
Advantages:

- will not crack under loading
- resists rutting due to static loads
- rapid repair in all weather with minimal interruptions in airport operations
- conserves useable base material
- repaired sections are more durable than asphalt
- lower life-cycle cost than concrete
- provides skid resistance
- joint material does not deteriorate and result in cracking
- decrease costs to local airports
- less initial construction time required when compared to conventional concrete pavement
- variety of paver shapes, installation patterns and pavement colors
- edge restraint considerations required.

Design Requirements:

- determine the CBR of subgrade soils
- assess air traffic vehicle types, wheel configurations, loads, and traffic volumes
- use flexible pavement design procedures to determine base and sub-base thickness
- consider the use of de-icers, fuels, spills.

Cross section drawing: use ICPI drawing # ICPI-35 "Airfield Pavement with Cement treated or Asphalt Base"



For detailed design information, specifications, construction, life-cycle costs, and maintenance of airport applications contact ICPI and ask for:

"Port and Industrial Pavement Design With Concrete Pavers"

A Comprehensive Guide

John Knapton, PhD., John Emery, edited by David R. Smith, ICPI

INTERLOCKING CONCRETE PAVERS TECHNICAL DESIGN AND INSTALLATION GUIDE

8.4 INDUSTRIAL PORT PAVEMENTS

Interlocking Concrete Pavers have been used at some of the largest and busiest port terminals worldwide. In recent years, interlocking concrete pavements have been chosen for many port pavement projects in North America.

Several factors contributing to the increased use of interlocking concrete pavements are primarily based on the successful performance of pavements in both British and European ports over the past thirty years. Some of the factors include, lower life-cycle costs and maintenance costs over their predicted service life of forty years, ability to support highly concentrated loads, resistance to freeze/thaw cycles and their ability to withstand differential settlement without cracking.

Examples of More Notable Installations:

- European Container Terminal, Rotterdam the Netherlands, over 21.5 million square feet (over 2 million m²)
- Port of Felixstowe, England, 2 million square feet (186,000 m²)
- Canadian Pacific Internodal Yard, Edmonton, Alberta, 1 million square feet (93,000 m²)
- Port of New Orleans, New Orleans, Louisiana
- Port of Tampa, Tampa, Florida
- Massey Coal Terminal, Shell Pier 9, Newport News, Virginia,
- Port of Baltimore, Baltimore, Maryland, 850,000 square feet (80,000 m²)
- Berth 30, Port of Oakland, Oakland, California, 325,000 square feet (30,200 m²)
- Freeport Harbour, Grand Bahama Island, Bahamas, 1.2 million square feet (111,000 m²)

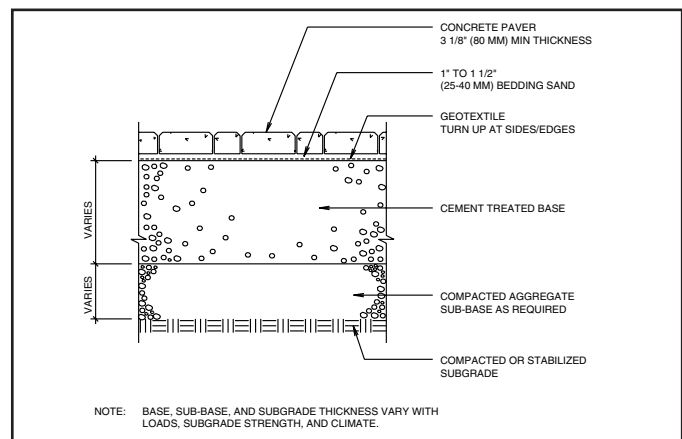
Advantages:

1. high-strength concrete units are resistance to high static loads (corner castings, dolly wheels)
2. resistance to lateral loads and their ability to withstand braking and cornering of yard equipment
3. high abrasion resistance to tires and tracked vehicles
4. no detrimental affects from hydraulic oils
5. pavers can be installed as an overlay on existing pavements or inlay on existing base.
6. high resistance to freeze/thaw cycles and deicing salts
7. mechanically installed methods reduce labor costs over vast pavement areas.

8. a flexible pavement surface settles with unstable soils, still providing a serviceable pavement
9. colored units can be used to permanently demarcate traffic lanes and stacking areas.
10. pavers can be removed and replaced after underground utility or base repairs.
11. improved life-cycle costs compared to other forms of pavement.

Design Requirements:

1. assessment of the cargo handling equipment and wheel load calculations need to be determined.
2. determine traffic demands.
3. determine the California Bearing Ratio of the subgrade soils
4. determine base and sub-base thickness.
5. drainage considerations, including details regarding under ground services, storm water
6. management and environmental factors need to be addressed.
7. paver shape, colors, laying pattern to be determined.
8. edge restraint considerations required.



For detailed design information, specifications, construction, life-cycle costs, and maintenance of airport applications contact ICPI and ask for:

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INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

8.5 PERMEABLE PAVEMENTS

The term “Permeable Pavement” refers to not only the concrete paving unit, but also the base layer and an optional filtration membrane. Permeable pavements are constructed by excavating the installation area to a predetermined depth, typically 0.15-0.30 m (6-12 inches), and backfilling with a gravelly material. The depth of excavation is dependent on a number of factors, including cost, location of the water table and frequency of rainfall. The purpose of the gravel filled section is twofold; it will allow a section of nearly infinite hydraulic conductivity for the rainwater and overland runoff to flow into and through, and will also act as a temporary storage reservoir. This section, called the base, will store water until it can naturally percolate into the native soil and eventually pass through to the water table as groundwater recharge.

Impacts from Impervious Surfaces

Urbanization brings an increasing concentration of pavements, buildings, and other impervious surfaces. They generate additional runoff and pollutants during rainstorms, causing stream bank erosion, as well as degenerating lakes and polluting sources of drinking water. Increased runoff deprives proper ground water recharge, decreasing the amount of available drinking water in many communities. Runoff water traveling along the impervious surface, can drastically change in temperature, absorbing heat from the surface as it travels over the asphalt or concrete. Once this runoff empties into a stream or river, it can significantly raise the water's temperature, consequently killing aquatic life that cannot handle a temperature change of more than a few degrees Celsius.

Uses for Permeable Pavements

If the infiltration capacity of the soil is exceeded, or there are particularly high levels of pollutants, the pavement base can be designed to filter, partially treat, and slowly release water into a storm sewer or watercourse. When conditions allow, returning rainfall to the soil through infiltration is preferred over retaining the water and slowly releasing it into a sewer or watercourse. Permeable interlocking concrete pavements may be effective in new development where local regulations limit the total amount of impervious cover.

Permeable interlocking concrete pavements are especially effective in existing urban development where there is a need to expand parking, and where there is not sufficient space for ponds. Therefore, the pavement can be used to conserve land

because parking, storm water infiltration and retention are combined into one facility.

The pavements are also effective in areas where sewers flow at capacity during certain rainstorms. In these situations, replacing existing pipes with larger ones due to an increase in impervious cover from parking or buildings is often not economical. This solution merely transfers the additional runoff downstream and increases erosion and flooding potential. Urbanized areas with an existing minimum of 50% impervious cover are typically where economics help decide the use of permeable pavement to conserve land or the capacity of the drainage system. Economics suggest that design professionals should study the trade-offs between permeable interlocking concrete pavements and other drainage concepts for the area.

Benefits and Limitations of Permeable Interlocking Concrete Pavements

This type of pavement essentially functions as an infiltration and retention area that can accommodate pedestrians, vehicular parking, and traffic. This combination of functions offers the following benefits:

- Conservation of space on the site.
- Reduction of runoff by as much as 100% from frequent, low-intensity and short duration storms.
- Reduction of retention requirements in other parts of the drainage system.
- Filtration through the base and soil for improvement of water quality.
- Reduction of runoff temperature.
- Slowing the release of runoff.
- Increased recharge of groundwater.
- Reduction of downstream flows and bank erosion due to decreased peak flows and volumes.
- Reduced overall project development costs due to a reduction in storm sewers and drainage appurtenances.

Limitations are listed below:

- Greater site evaluation and design effort.
- A higher level of construction skill, inspection, and attention to detail.
- Use by physically challenged persons.
- Maintenance to minimize clogging to ensure long-term performance.

INTERLOCKING CONCRETE PAVERS TECHNICAL DESIGN AND INSTALLATION GUIDE

Installation Practice

A geotextile layer should be placed along the bottom of the base layer, at the gravel/native soil interface. The purpose of the geotextile layer is to prevent clogging of the base due to capillary suction, and to filter out contaminants that are carried into the base from surface waters. The geotextile layer will not hinder the groundwater recharge rate as it will have a higher porosity than the native soil and studies have shown that the presence of a geotextile layer reduces the concentrations and amount of contaminants reaching the groundwater aquifer.

Listed below is the general installation method for laying permeable pavements:

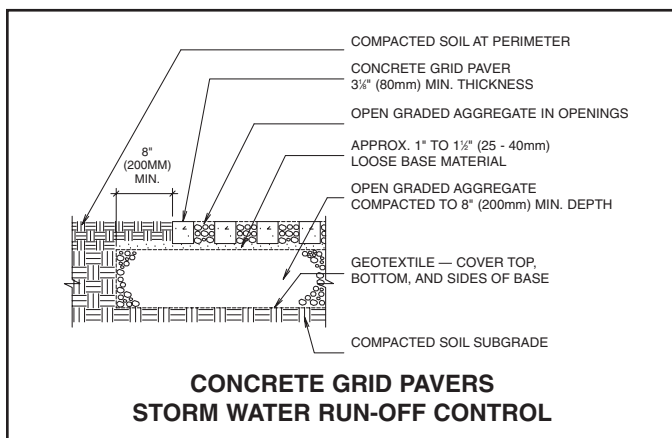
1. Keep area where pavement is to be constructed free from sediment during entire job. Geotextile, base and bedding materials contaminated with sediment shall be removed and replaced with clean materials.
2. Place and compact No.8 base material.(See chart)
Compact with a minimum [10] ton static roller. Make at least [4] passes. No visible movement should occur in the base material when compaction is complete.
3. The elevation of the compacted surface should not deviate more than 1 1/2 in. (13 mm) over a 10ft. (3 m) straightedge.
4. Loosen and evenly level 3/4 to 1 in. (20 to 25 mm) of the compacted surface of the No.8 base material.
5. Lay the pavers in the pattern(s) and joint widths shown on the drawings. Maintain straight pattern lines.
6. Fill gaps at the edges of the paved area with cut pavers.
7. Cut pavers to be placed along the edges with a double-bladed splitter or masonry saw.

| GRADING REQUIREMENTS FOR ASTM No. 8 | | |
|-------------------------------------|-----------|-----------------|
| SIEVE SIZE | | PERCENT PASSING |
| 1/2 in. | (12.5 mm) | 100 |
| 3/8 in. | (9.5 mm) | 85 to 100 |
| No. 4 | (4.75 mm) | 10 to 30 |
| No. 8 | (2.36 mm) | 0 to 10 |
| No. 16 | (1.16 mm) | 0 to 5 |

8. Compact and seat the pavers into the loose base material using a low amplitude, 75-90 Hz plate compactor capable of at least 5,000 lbs. (22 kN) centrifugal compaction force.
9. Vibrate and compact the pavers again, sweeping No. 8 aggregate into the openings until it is within 1/2 inch (13 mm) from the top surface. This will require at least two or three passes with the compactor in opposite directions.
10. Do not compact within 3 ft (1 m) of the unrestrained edges of the paving units.
11. Remove excess aggregate by sweeping pavers clean.
12. All pavers within 3 ft (1 m) of the laying face must be left fully compacted at the completion of each day.
13. The final surface elevations shall not deviate more than +/-3/8 in. (+/- 10mm) under a 10ft (3 m) long straight-edge.
14. The surface elevation of pavers shall be 1/8 to 1/4 inch (3 to 7 mm) above adjacent drainage inlets, concrete collars or channels.

Maintenance

Permeable interlocking concrete pavements can become clogged with sediment over time, thereby slowing their infiltration rate and decreasing storage capacity. Clogged openings are a major cause of failure. The rate of sedimentation depends on the amount of traffic and other sources that wash sediment into the joints, base and soil. Since the pavement is detaining runoff that contains sediment, there may be a need to eventually remove and replace the base material when the infiltration is reduced to such a degree that the pavement is no longer performing its job in storing and ex-filtrating water. All permeable interlocking concrete pavements with an open-graded base should have a surface cap alongside the pavers at least 1 in. (25 mm) that can be removed to observe the rate of ex-filtration. The cap should lock and be vandal-resistant. The depth to invert should be



INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

marked on the lid. The observation well is located in the furthest down slope position within 3 ft (1 m) from the sides of the pavement. Snow removal with plows can be achieved as with other pavements provided the surface and individual pavers remain true to the grades set originally during initial construction. Deicing salts are not recommended due to infiltration into the sub soil. If a unit cracks from soil or base settlement, it can be removed and replaced. Likewise, the same units can be reinstated after repairs to the base, drainpipes, liners, or to underground utilities. Sealers should never be used.

Long-Term Performance and Maintenance Agreements

When carefully constructed and regularly maintained, permeable interlocking concrete pavements should provide 20 to 25 years of service. Their service life is measured by the extent to which they continue storing runoff. At some point later in the life of the pavement, it may no longer store the required amount of water to control runoff. In such cases, the pavers will need to be removed, the base materials and geotextile removed and replaced. Clogged or broken drainpipes will require replacement. Once new materials are in place, the same pavers can be reinstated. Removal and replacement of the base and pavers is an expensive operation. Other lower-cost alternatives may be possible such as cleaning or replacing selected clogged

pipes (rather than the entire base and pipe system) or diverting drainage to another system. Ongoing maintenance and inspection are important to tracking drainage performance, sources of problems, and deciding on possible solutions. The owner of permeable interlocking concrete pavement plays a key role in maintenance and successful long-term performance of permeable interlocking concrete pavements. The owner should have long-term ownership and administration of the property and be aware of maintenance requirements. A growing trend to ensure proper management is a maintenance agreement. This agreement is typically between the property owner(s) and the local city or county, and the agreement is recorded and attached to the deed for the property. It can be edited to suit local situations and customized for the maintenance of permeable interlocking concrete pavement. A list of maintenance items should be included as an attachment to this agreement, as well as an inspection schedule. The list of items to be inspected can be developed from the in-service inspection checklist in this section, as well as from requirements established by the local government. A growing number of local governments are creating databases which can incorporate inspection data. This provides continual documentation of care and performance requirements.



SECTION 9

Repair of Interlocking Concrete Pavements

Interlocking concrete pavements have certain structural and aesthetic advantages over other types of pavements. One major advantage which is often overlooked is the ability to remove an area of pavers to conduct underground repairs and replace the same pavers after the repairs have been completed.

9.1 PAVEMENT REPAIR

Throughout the life of a pavement, the need to carry out underground utility repairs or pavement settlement re-profiling will likely occur. The segmental nature of interlocking concrete pavements allow the removal of only the area of pavement that is affected without disturbing adjacent pavement areas. For large pavements, it may be advantageous to stockpile paving stones (approximately 2% of the original pavement area) for use in future repairs.

9.2 OPENING THE PAVEMENT

If the area of pavement to be removed has been in place for some time, or if it has been regularly trafficked by vehicles, it may be quite difficult to remove the first few paving stones. It is helpful to remove as much sand from the joint around the first paver as possible. A trowel or putty knife can be used to do this. Generally, two large screwdrivers can be used on opposite sides of the paver to pry it upward. Once the paving stone is high enough, it is loose enough to be removed by hand. Specially designed paver extractors are also available. These extractors are adjusted to the size of the paving stone to be removed, and tightly clamp the paver so it can be pulled up by its two long handles. It may be necessary to damage or break the first two or three pavers before the remaining area can be removed. In this case, a mallet and chisel, or a small pick can be used to break the pavers into small pieces. These pieces can be easily removed by hand until the bedding sand is completely exposed.

9.3 REMOVING THE PAVING STONES

After the first few paving stones have been dislodged, the adjacent pavers can be removed relatively easily. A pry bar or a pick can be used to lift the remaining pavers. The width of the area being removed should extend at least two rows of pavers beyond the excavation and at least 3 feet (1 metre) wide to allow sufficient room to work.

Reusable pavers should be cleaned of sand and stockpiled for subsequent reinstatement. Any sand that clings to the bottom



and sides of the displaced pavers can be easily removed with a trowel, putty knife, or another paver. Removed paving stones should be stockpiled in a location that won't interfere with other site activities. Mechanical paving stone installers (see Section 4.8) can be used to remove large areas of interlocking pavers. The edges of the remaining pavement should be held in place with some form of edge restraint secured into the existing base layer (see Section 5) to prevent the undisturbed paving stones from shifting while other work is being done. This will assist in the successful reinstatement of pavers after the work has been completed.

9.4 REHABILITATION OF EXISTING GRANULAR BASES

This procedure will result in the rehabilitation of an unacceptable existing pavement base without adding material to increase the base thickness or completely removing and replacing the existing base material.

Advantages

This stabilization procedure can save up to 50% of the cost of new pavement base construction by rehabilitating the base material that's already in place. Introducing Portland cement into an existing base layer that isn't thick enough, or isn't made up of good quality material, can provide a strong, durable base that will hold up under vehicle loads for many years. The cost savings are a result of the following advantages:

- Additional base material will not be required to increase

INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

the existing base layer thickness;

- This procedure decreases the amount of time required with heavy machinery at the jobsite, as well as the cost of transporting additional base material to the site;
- By using the existing base material, you save the work of base layer removal, dumping fees, the cost of new base material, and the associated labour costs.

Procedure

Step 1) Assess the existing pavement

If the pavement surface appears to be in good condition (doesn't have any ruts, bulges or cracks), and has not moved in many years, then it's resting on a good base. In this case, no base rehabilitation is necessary. Simply lift and remove the pavement surface, compact the existing base, screed a layer of bedding sand, and install the concrete pavers.

If the pavement surface shows signs of uneven movement or cracking, the base layer is unsatisfactory. An existing base layer that isn't thick enough, or isn't comprised of good quality material, can be rehabilitated with Portland cement to create a strong foundation for interlocking concrete pavers.

Step 2) Plan the project

Measure the desired pavement area and establish the various grades and elevations required for the project. Remember to consider the various factors that could affect the pavement elevation in certain areas (doors, steps, sidewalks, etc.) and slope the pavement to provide drainage. At this stage, it's also important to prepare for any curbs or paver edge restraints that will not rest directly on top of the stabilized base layer.

Step 3) Calculate the number of cement bags needed

Using 40 kg (88 lb.) bags of regular Portland cement, calculate one bag of cement for every 2 square metres (21.5 sq.ft.) of pavement base area. Figure in two or three extra bags for margin of error.

| AREA OF BASE SQ.FT. (SQ.M) | AMOUNT OF CEMENT REQUIRED LBS (KG) | BAGS REQ'D | EXTRA BAGS | TOTAL BAGS OF CEMENT |
|-------------------------------|--|---------------|---------------|----------------------------|
| 100 (9.25) | 400 (180) | 5 | 2 | 7 |
| 200 (18.50) | 800 (360) | 9 | 2 | 11 |
| 300 (27.75) | 1200 (540) | 14 | 2 | 16 |
| 400 (37.00) | 1600 (720) | 18 | 2 | 20 |
| 500 (46.25) | 2000 (900) | 23 | 2 | 25 |
| 600 (55.50) | 2400 (1080) | 27 | 3 | 30 |
| 700 (64.75) | 2800 (1260) | 32 | 3 | 35 |
| 800 (74.00) | 3200 (1440) | 36 | 3 | 39 |
| 900 (83.25) | 3600 (1620) | 41 | 3 | 44 |
| 1000 (92.50) | 4000 (1800) | 45 | 3 | 48 |

Step 4) Remove the existing pavement

A backhoe is usually used to excavate the existing pavement surface.

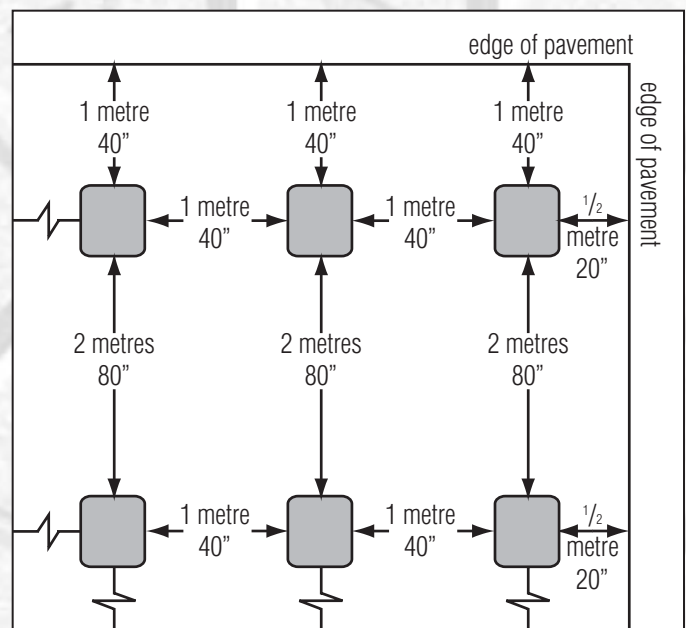
Step 5) Loosen the existing base material

The base layer is usually too well compacted to allow the cement powder to be mixed in right away. In order to loosen the soil, it's necessary to:

- Saturate the base layer by spraying over the entire area with water;
- Loosen the base layer surface with a rotary garden tiller. Make sure you use a model that has a blade that turns in the opposite direction of its wheel rotation.

Step 6) Distribute the cement powder

- If there is a risk of strong rain, cover the project and perform this step when the base is dry;
- Place the cement bags as follows:
 - ⇒ Across: 1 bag spaced every metre (40")
 - ⇩ Down: 1 bag spaced every 2 metres. (80")



- Open the bags with a shovel and spread the cement with a rake so the cement powder covers the entire pavement base area evenly.

Step 7) Mix the cement with the base material

- Thoroughly mix the Portland cement with the granular base material using the rotary garden tiller. Use the tiller twice

INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

over the entire base surface, first across, then up-and-down. Mix the entire base area to a depth of 8 inches.

b) Dampen the entire pavement base area with water, using a gentle spray from a garden hose. Be careful not to use too much water. You will know if you have added the right amount of water if you can form a ball of the base material in your hand without it sticking to your fingers.

c) Check your grades and elevations, but don't delay because the base layer starts to harden right away.

Step 8) Compact the base layer

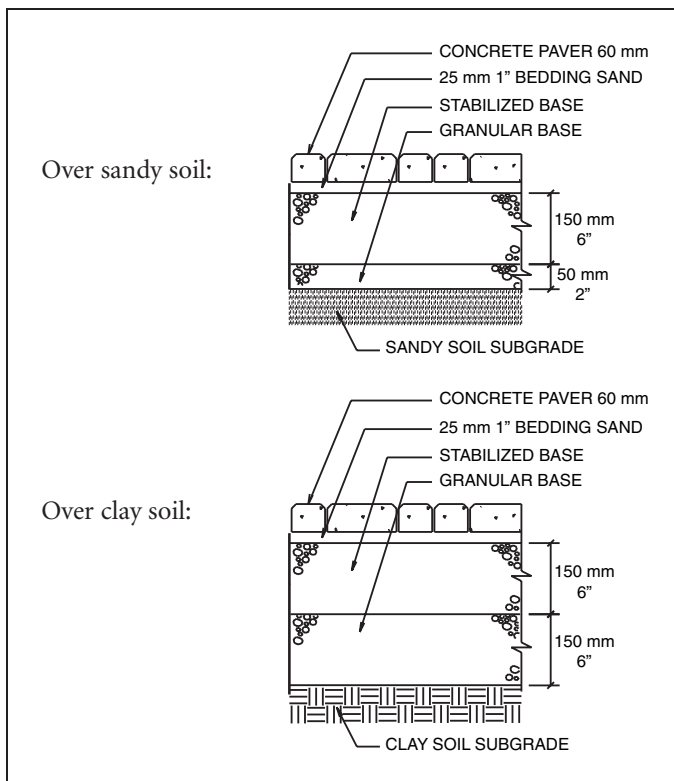
Immediately after mixing with the garden tiller, compact the base with a smooth vibrating roller. In small areas, a plate tamper can be used.

a) Roll the entire surface the first time without vibration

b) Check the grade again. In order to have a uniform surface, it may be necessary to fill some low spots. Prepare a cement / granular mixture using the extra bags of cement from Step 3. Mix 1 part cement for every 10-12 parts granular base material. Fill the low spots and even out the material with a rake.

c) Compact the entire surface twice, using vibration. Once the compaction has been completed, make sure that no vehicles travel on the compacted base for 4 days until the base has had a chance to cure.

Finished pavement cross sections:



Step 9) Install the pavers

Pavers can be installed the next morning (or in some cases, later in the same day) after the base has had a chance to harden.

- Screed a 25 mm (1") layer of bedding sand over the compacted base
- Install the pavers using accepted industry practices (see Section 4 for more detailed information).
- Provide edge restraints around the pavement surface. Nails for the edging can be driven into the stabilized base layer for several days after installation.

Step 10) After installing the pavers and edge restraint

Compact the pavers using a plate tamper and fill the joints with sand. The plate tamper should only be used if 24 hours have passed since the base layer was compacted. In addition, it is recommended that you should wait 4 hours after the paving has been completed before parking a vehicle on the driveway.

9.5 EXCAVATION

If the bedding sand layer is to be removed for future excavation, measure the thickness of the sand so the replacement layer can be reinstated to the same thickness. The bedding sand material can be stockpiled and reused, provided it does not become contaminated with other materials. Often, the bedding sand is excavated along with the base material if underground work is going to be done. If base material is going to be removed, it should be kept separate from subgrade soils so it can be reused. Excavation close to utilities, such as gas, electric, or phone lines, should be done by hand. Always have these services located before excavation begins.



INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

9.6 REPLACING THE MATERIAL

If the excavation has extended into the soil subgrade, the subgrade should be compacted before any material is replaced. Subgrade soil that is replaced should be compacted in lifts no greater than 3" (75 mm). Base material should be installed using the procedures outlined for original base layer installation (see Section 2.8), with strict attention to compaction. Because this area has been disturbed, it will tend to rut or deform while the original pavement maintains its elevation, unless thorough compaction has taken place. If new base material or bedding sand is used, it should be of the same type used in the original pavement. Lean mix concrete or flowable fill is often used as a replacement for aggregate base materials around underground utilities. This material is mixed and delivered in ready mix trucks, and flows around piping and fittings where compaction is virtually impossible. This material cures quickly, resists rutting, and can be re-excavated later using conventional excavation equipment. Check the level of the reinstated base layer with the surrounding original base layer to assure consistent elevations. The bedding sand layer should be replaced using the procedures outlined in Section 3. Temporary edge restraints must be removed prior to installing the bedding sand. Spread the bedding sand over the base layer, but do not use bedding material to fill depressions in the base layer. Fill these areas with base material and compact. Screed the sand layer about 1/4" (6 mm) higher than the adjacent undisturbed bedding sand. This will allow for settling during final paving stone compaction. The reinstated area should be crowned slightly to allow for minor settling that may occur as the area is trafficked.



9.7 REINSTATING THE PAVERS

The pavers around the edges of the repaired area must be tightly aligned with the pavers in the rest of the pavement. Edge pavers that are loose will force subsequently installed units to be misaligned and cutting will be necessary to fit pavers into the pattern. Remove any loose pavers and start reinstating paving stones from a secure, aligned edge. It is recommended that pavers are installed from the lower elevation to the higher, so creeping during installation is minimized. String lines should be used to check alignment frequently. Joint spaces should be maintained so alignment is assured. If new pavers are used along with removed units, each type should be used intermittently to blend colours as evenly as possible. Compact the pavement with two or three passes of a plate tamper. Fill the joints with jointing sand and compact the pavement again. Repeat this process until the joints are completely full.

9.8 MUNICIPAL UTILITY CUTS

In municipalities across North America, pavements are routinely opened up to work on underground utilities. Repairing municipal pavements constructed with interlocking concrete pavements has obvious advantages:

1. no cutting equipment is required
2. the pavement material can be reused
3. less waste material is generated
4. the pavement can be opened to traffic immediately after the work has been completed (no curing time is needed).
5. cuts in monolithic pavements tend to reduce the overall life of that pavement.

Over the life of the pavement, these factors contribute to make interlocking concrete pavements an economically viable alternative to conventional municipal pavements.



Glossary of Terms

Terms used in the manufacture, design, construction, and testing of interlocking concrete pavements.

10.1 CONCRETE PAVER PRODUCTS AND PRODUCTION TERMS

Admixture: Premixture chemicals added to the concrete mix immediately before or during mixing water, cement and aggregate to improve properties such as density, durability and strength.

Aspect Ratio: The overall length of a paver divided by its thickness. Example, a 4 inch (100mm) wide by 8 inch (200mm) long by 3-1/8 inch (80mm) thick paver has an aspect ratio of 2.5.

ASTM C 936: American Society for Testing and Materials, Standard Specification for Solid Interlocking Concrete Pavers. This product standard defines dimensions, dimensional tolerances, maximum absorption, minimum compressive strength, maximum abrasion, and freeze-thaw durability through various test methods.

CSA-CAN3-A231.2: Canadian Standards Association product standard for Precast Concrete Pavers (interlocking units) that defines standards for dimensions, minimum compressive strength, and durability under freeze-thaw cycles with deicing salt through various methods.

Cement-Aggregate Ratio: The proportional weight of cement to fine and coarse aggregate in concrete.

Cement, Portland: A hydraulic cement produced by pulverizing clinker consisting essentially of hydraulic calcium silicates, and usually containing one or more forms of calcium sulfate.

Chamfer: A 45° beveled edge around the top of a paver unit usually 1/16 to 1/8 inch (2-3mm) wide. It allows water to drain from the surface, facilitates snow removal, helps prevent edge chipping, and delineates the individual paving units.

Concrete Grid Pavers: Concrete units (generally small slabs) that have up to 50 percent open area. The units are generally

no larger than 16 inches (400mm) by 24 inches (600mm). Aggregate or grass can be placed in the openings to promote infiltration of storm water. Generally used for intermittent parking, access lanes, abating runoff and/or controlling erosion.

Cube(s): Pavers stacked at the factory, strapped or wrapped, with or without a wooden pallet, for shipping and for transfer around the site. The cube has several layers of pavers. The number of layers and pavers on a cube varies with their thickness and shape.

Dentated Paver: A unit that is not rectangular or square in shape.

Dummy Grooves: False joints in concrete pavers that contribute to the installed joint pattern. Dummy grooves can enhance the appearance of the pattern and speed installation when compared to placing separate (sub) units.

Efflorescence: A white deposit of calcium carbonate on concrete surfaces. It results from the reaction of calcium hydroxide with carbon dioxide from the air. The calcium hydroxide is a byproduct when cement hydrates. It is slightly soluble in water and migrates to the surface through capillary action. The calcium hydroxide remains on the surface, reacts with carbon dioxide, which forms calcium carbonate and water. This conversion, depending on weather conditions, will dissipate over time.

Half Stone: A half of a paver.

Multi-Coloured Paver (Colour Blend): A paver with two or more colours. The appearance is usually variegated.

Paving Slab (or Flag): A paving unit larger than an interlocking concrete paver and with maximum length and width dimensions of 36 inches by 36 inches (915mm x 915mm). Paving slabs do not rely on interlock as the principal means of load distribution.

INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

Permeable Interlocking Pavement: Concrete pavers with wide joints (10mm-30mm) or a pattern that creates openings in which rainfall can infiltrate. The openings are filled with aggregate or topsoil and grass. The pavers are typically placed on an open-graded aggregate base which stores runoff.

Plan Ratio: The overall length of a paver divided by its width.

Pozzolanic Materials: Flyash, pozzolan, silica fume, or blast furnace slag used as substitutes for cement. They are generally used in the concrete mix to increase density and durability of concrete pavers.

Slump: A measure of consistency and water content of freshly mixed concrete. Slump is the subsidence measured from a specimen immediately after removal of a cone shaped mold. See ASTM C 143. Unlike ready-mixed concrete, pavers are zero slump concrete because of low water content. They are not tested for slump.

Solid Colour Paver: A paver with one colour created by adding iron oxide, metal oxide, or other mixed metal oxide pigment to the concrete mix.

Spacer Bars, Spacers or Nibs: Small protrusions on each side of the paver used to keep them uniformly spaced so that sand can fill into the joints. Spacer bars help prevent edge chipping and spalling. Some spacer bars stop short of the top surface, and are known as “blind spacers.” They can not be seen once the pavers have been installed.

Spall: A fragment, usually in the shape of a flake, detached from the edge or surface of a paver by a blow or sudden force, the action of weather, or pressure from adjacent pavers.

Textured or Architectural Finish: Paver surfaces altered by the manufacturing mold or mechanical means, such as shot blasting, bush hammering, tumbling, grinding, polishing, flame treated, or washing. The purpose of such treatments is to provide a contrast in surface texture.

Top Coat or Hard Facing: The application of a thin layer of fine aggregate and cement to the top surface of a concrete paver. The layer is often coloured and is used to provide a more intense appearance, greater abrasion resistance, or provide a base for a textured finish.

Water-Cement Ratio: The weight of water divided by the weight of cement in a concrete mixture. Concrete pavers typically have a water-cement ratio of 0.27 to 0.33, lower than ordinary concrete, which contributes to strength and durability.

10.2 ENGINEERING TERMS

California Bearing Ratio (CBR): The ratio of: (1) the force per unit area required to penetrate a soil mass with a 3 in.² (19cm²) circular piston (approximately 2" (51mm) diameter) at the rate of 0.05" (1.3mm)/min, to (2) that required for corresponding penetration of a standard material. The ratio is usually determined at 0.1" (2.5mm) penetration, although other penetrations are sometimes used. See ASTM D 1883.

Creep: Slow lateral movement of pavers from horizontal forces such as braking tires. The movement is usually imperceptible except to observations over a long duration.

Crown: The slightly convex shape of a road cross section. It is beneficial to surface drainage and interlock.

Deflection: The temporary movement of a pavement structure due to traffic loads.

Deformation: A change in the shape of the pavement.

Drainage Coefficient: Factor used to modify layer coefficient of pavements. It expresses how well the pavement structure can handle the adverse effect of water infiltration. (See layer coefficient.)

Equivalent Single Axle Loads (ESALs): Summation of equivalent 18,000 pound force (80 kN) single axle loads used to combine mixed traffic to design traffic for the design period.

Failure: The point at which a pavement does not adequately service its intended use. For flexible pavements, rut depth is often a criteria for failure.

Flexible Pavement: A pavement structure which maintains intimate contact with and distributes loads to the subgrade. The base course materials rely on aggregate interlock, particle friction, and cohesion for stability.

Frost Action: Freezing and thawing of moisture in pavement materials and the resultant effects on them.

INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

Frost Heave: The raising of a pavement surface due to the accumulation and expansion of ice in the underlying soil or rock.

Gradation: Soil or aggregate distributed by mass in specified particle-size ranges. Gradation is typically expressed in percent of mass of sample passing a range of sieve sizes. See ASTM C 136.

Interlock: The three kinds transfer of loads in a segmental pavement. They include vertical interlock, horizontal interlock and rotational interlock. *Vertical interlock* is achieved by shear transfer of loads to surrounding units through sand in the joints. *Horizontal interlock* is primarily achieved through the use of laying patterns that disperse forces from braking and accelerating vehicles. The most effective laying patterns for maintaining horizontal interlock are herringbone patterns. *Rotational interlock* is maintained by the pavers being of sufficient thickness, placed closely together, and being restrained by a stationary edge such as a curb.

Layer Coefficient: From the American Association of State Highway and Transportation Officials (AASHTO) pavement design procedure, it is a dimensionless number that expresses the material strength per inch (25mm) of thickness of a pavement layer (surface, base, or sub-base). Example: The layer coefficient of 3½ inch (80mm) thick pavers and 1 inch (25mm) bedding sand is 0.44 per inch (25mm), therefore, the Structural Number (SN) = $4\frac{1}{2} \times 0.44 = 1.82$.

Life-cycle cost: An analysis tool to calculate all costs anticipated over the life of the pavement. Discounted cash-flow methods are generally used, typically calculation of present worth and annualized cost. Factors that influence the results include the initial costs, assumptions about maintenance and periodic rehabilitation, pavement user and delay costs, salvage value, inflation, discount rate, and the analysis period. A sensitivity analysis is often performed to determine which variables have the most influence on costs.

Modulus of Elasticity: The ratio of stress to strain for a material under given loading conditions.

Pavement Performance: The trend of serviceability under repetitive loads.

Pavement Rehabilitation: Work undertaken to extend the service life of an existing pavement. This includes placement

of additional surfacing material and/or other work necessary to return an existing roadway to a condition of structural or functional adequacy. This could include the complete removal and replacement of the pavement structure.

Pavement Structure: A combination of sub-base, base course, and surface course placed on a subgrade to support the traffic load and distribute it to the roadbed.

Performance Period: The period of time that an initially constructed or rehabilitated pavement structure will last (perform) before reaching its terminal serviceability. This is also referred to as the design period, expressed in years. Twenty years is normally used in North America.

Plastic Limit: (1) The water content corresponding to an arbitrary limit between the plastic and the semisolid states of consistency of a soil (2) Water content at which a soil will just begin to crumble when rolled into a thread approximately ¼" (3.2mm) in diameter.

Poisson's Ratio: The ratio of transverse (lateral) strain to the corresponding axial (longitudinal) strain resulting from uniformly distributed axial stress below the proportional limit of the material; the value will average about 0.2 for concrete.

Present Serviceability Index (PSI): A rating, usually between 0 (completely non-functional) and 5 (new/perfect), that generalizes several measurements of the condition of pavement. It is a convenient method of rating the overall condition and usefulness of a pavement over time.

Progressive Stiffening: The tendency of pavements to stiffen over time. Interlocking concrete pavement stiffens as it receives increasing traffic loads. Also referred to as "lock-up."

Rutting: Permanent deformation from repetitive traffic loading that exceeds the ability of the pavement structure to maintain its original profile.

Skid Resistance: A measure of the frictional characteristics of a surface with respect to tires.

Structural Number (SN): The basis of the flexible pavement design method developed by the American Association of State Highway and Transportation Officials (AASHTO). It is a dimensionless number expressing the relative strength of a

INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

pavement structure. The SN is calculated from an analysis of traffic, roadbed soil conditions, and environment. The SN equals the sum of layer coefficients, with each coefficient quantifying the material strength and thickness of each pavement layer.

Sub-base: The layer or layers of specified or selected material of designed thickness placed on a subgrade to support a base course.

Subgrade: The soil upon which the pavement structure and shoulders are constructed.

Strain: The change in length per unit of length in a given direction.

Stress: The force per unit area.

10.3 TERMS USED IN ARCHITECTURAL DESIGN

Basket Weave or Parquet: A laying pattern where two or more pavers are placed side-by-side. Adjacent pavers are placed side-by-side, but turned 90° and alternated 90° throughout the pattern.

Engraved Pavers: Pavers that have been engraved with letters or images by molding during or after manufacture, shot blasting, wet cutting or that have a cast metal plate set into the surface.

Hard Edges: A field of pavers that is restrained against a visible edge restraint or curb, thus visually reinforcing the edge of pavement.

Herringbone Pattern: A pattern where joints are no longer than the length of one and one-half pavers. Herringbone patterns can be 45° or 90° depending on the orientation of the joints with respect to the direction of the traffic.

Human Scale: Using paver sizes, patterns, colours and textures next to large buildings or open areas with the intent of reducing the user perception of being overwhelmed by the large scale of these spaces.

Markers: Marking underground utilities, traffic direction, parking stalls, lanes, pedestrian/vehicular areas, etc., with pavers of different colours, textures or shapes.

Mosaics: Pavers used as pictorial maps, murals, or geometric patterns as a landmark, to emphasize an area, or suggest movement.

Reflecting: Using pavers to mirror geometric patterns, shapes, colours or textures in the surrounding site.

Running Bond Course: A paver course or two where lengths abut against the edge restraint. Also known as a “sailor course.”

Running or Stretch Bond: A laying pattern with continuous joint lines in one direction and pavers are staggered from one row to the next.

Slip Resistance: Resistance against pedestrian slipping, defined as the ratio of a minimum tangential force necessary to initiate sliding of a pedestrian’s shoe or related device over a surface. Non-mobility impaired persons require minimum coefficient of friction values ranging from 0.2-0.3. Wheelchair users require friction values ranging from 0.5-0.7. Crutch users and those with artificial limbs require values from 0.7 to 1.0. Clean concrete pavers generally have values exceeding 0.7.

Stack Bond: A laying pattern in which the joints in both directions are continuous.

Soft Edges: A field of pavers with no visible edge restraint that meets grass or other vegetation, thus giving a soft appearance to the edge.

Soldier Course: A paver course where widths abut against the edge restraint.

Tactile Pavers: A paver detectable by sight-impaired persons due to change in colour or texture from surrounding surfaces. Changes in texture are achieved with detectable warnings.

Zoning: Using different paver colours, textures, shapes, laying patterns, and surface elevations to delineate pedestrian and vehicular areas or districts.

INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

10.4 TERMS USED IN CONSTRUCTION

Aggregate: Sand, gravel, shell, slag, or crushed stone used in base materials or mixed with cement to make concrete.

Base Course: A material of a designed thickness placed on a sub-base or a subgrade to support a surface course. A base course can be compacted aggregate, cement or asphalt stabilized aggregate, asphalt or concrete.

Bedding Sand: A layer of coarse, clean sand that is screeded smooth for bedding the pavers. The sand can be natural or manufactured, i.e., crushed from larger rocks, and should conform to the grading requirements of ASTM C 33. This layer is 1 to 1½" (25 to 40 mm) thick.

Bentonite Clay: A clay with a high content of the mineral montmorillonite, usually characterized by high swelling on wetting that can be used to help seal paver joints.

Bishop's Hat: A five-side paver often used as an edge paver with a 45° herringbone pattern.

Bitumen: A class of asphalts that is combined with neoprene and used as an adhesive under unit paving.

Blending Pavers: Mixing of coloured concrete pavers from three or four cubes to insure even colour distribution.

Clay: Fine-grained soil or the fine-grained portion of soil that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. The term can designate the percentage finer than 0.002 mm (0.005 mm in some cases).

Coarse Aggregate: Aggregate predominantly retained on the U.S. Standard No. 4 (4.75mm) sieve; or that portion of an aggregate retained on the No. 4 (4.75mm) sieve.

Course: A row of pavers.

Crushed Stone: A product used for pavement bases made from mechanical crushing of rocks, boulders, or large cobblestones at a quarry. All faces of each aggregate have well-defined edges resulting from the crushing operation.

Crusher Run: The total unscreened product of a stone crusher.

Dense-Graded Aggregate: An aggregate that has a gradation that, when compacted, yields very small voids between the particles.

Edge Paver: A paving unit that is made with a straight, flush side, or cut straight for placement against an edge restraint.

Edge Restraint: A curb, edging, building or other stationary object that contains the sand and pavers so they do not spread and lose interlock. It can be exposed or hidden from view.

Fineness Modulus: A factor obtained by adding the total percentages by weight of an aggregate sample retained on each of a specified series of sieves, and dividing the sum by 100; in the United States the standard sieve sizes are No.100 (150 μ m), No. 50 (300 μ m), No. 30 (600 μ m), No. 16 (1.18mm), No. 8 (2.36 mm) and No. 4 (4.75 mm), and ¾" (9.5 mm), 1½" (37.5mm), 3" (75mm), and 6" (150mm).

Flowable Fill: A low strength concrete mix used to fill utility trenches and other excavated pavement openings. Also known as unshrinkable fill.

Geogrids: Geogrids are two dimensional or three dimensional. The two dimensional type are flat and have small, "TV screen" shaped openings. The material is generally placed between the soil and the base to reduce rutting. Three dimensional geogrids are 4-8" (100-200mm) high and provide stability under loads for cohesionless soils.

Geotextiles: Woven or non-woven fabrics made from plastic fibers used for separation, reinforcement, or drainage between pavement layers.

Gravel: Rounded or semirounded particles of rock that will pass a 3" (75mm) and be retained on a No. 4 (4.75mm) U.S. standard sieve.

Joint Sand: Sand swept into the openings between the pavers.

Joint Spacing: The distance between pavers subsequently filled with joint sand.

Layer or Cluster: A group of pavers manufactured in a laying pattern, generally placed by mechanical equipment.

INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

Laying Face: The exposed, vertical face of a row of pavers on bedding sand.

Laying Pattern: The sequence of placing pavers such that a repetitive geometry is created by the installed units. Laying patterns may be selected for their visual or structural benefits.

Lean Concrete: Concrete of low cement content used as a structural base material or as flowable fill in utility trenches.

Mechanical Installation: The use of machines to lift and place layers of pavers on screeded bedding sand in their final laying pattern. It is used to increase the rate of paving.

Modified Proctor Test: A variation of the Standard Proctor Test used in compaction testing which measures the density-moisture relationship under a higher compaction effort. See ASTM D 1557.

Moisture Content: The percentage by weight of water contained in the pore space of soil, sand or base, with respect to the weight of the solid material.

Mortar: A mixture of cement paste and fine aggregate.

Open-Graded Aggregate: An aggregate that has a gradation that, when it is compacted, has relatively large spaces between the particles. It can be used as a drainage course in base design.

Optimum Moisture Content: The water content at which a soil can be compacted to a maximum dry unit weight by a given compactive effort.

Organic Soil: Spongy, compressible soils usually consisting of peat humus or vegetive matter that have undesirable construction characteristics.

Paver Extractor: A tool used to grab a paver and remove it from the laying pattern.

Paver Splitter: (Also called a guillotine splitter.) A hand operated machine, sometimes hydraulically assisted, for cutting concrete pavers.

Plate Compactor: Also known as a plate vibrator, which is used

to compact pavers into bedding sand in order to promote interlock among the individual units.

Prepared Roadbed: In-place roadbed soils compacted or stabilized according to provisions of applicable specifications.

Proctor Compaction Test: A test which measures the relationship of soil density with respect to soil moisture content under a standard compaction effort. This test identifies the maximum density obtainable at an optimum moisture content. See ASTM D 698.

Pumping: The ejection of bedding and joint sand, either wet or dry, through joints or cracks, or along edges of pavers when a load is applied.

Sand: Granular material passing the 3/16 inch (5mm) and retained on the No. 200 (75 μ mm) sieve, made from the natural erosion or rocks, and consisting of sub-angular or rounded particles. Sands made by crushing of coarse aggregates are called Manufactured Sands.

Screed Board or Strike Board: A rigid, straight piece of wood or metal used to level bedding sand to proper grade by pulling across guides or rails set on the base course or edge restraints.

Screed Guides: Grade strips such as pipe that will guide the screed in producing the desired elevation of the bedding sand.

Screenings: A residual product not suitable for bedding sand. It is a by-product from the crushing of rock, boulders, cobble, gravel, blast-furnace slag or concrete. Most of the aggregate passes the No. 4 (4.75mm) sieve.

Sealer: A material usually applied as a liquid that is used to waterproof, enhance colour, or stabilize joint sand in interlocking concrete pavements.

Silt: Soil finer than 0.02mm and coarser than 0.002mm (0.5mm and 0.005mm in some cases).

Soil Separation Fabric: A layer of fabric typically placed between the subgrade and the base to reduce rutting, also called a geotextile.

INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

Soil Stabilization: Chemical or mechanical treatment designed to increase or maintain the stability of a mass of soil or otherwise to improve its engineering properties. Lime, flyash or cement are typical chemical stabilization materials. Geotextiles and geogrids are typical mechanical materials for soil stabilization.

Stabilized Base: An aggregate base where either cement, asphalt or other material is added to increase its structural capacity. The soil subgrade can be stabilized with cement, lime, flyash or other materials.

Topsoil: Surface soil, usually containing organic matter.

10.5 TERMS USED IN CONCRETE PAVER TESTING

Abrasion: The mechanical wearing, grinding, scraping or rubbing away (or down) of paver surfaces by friction or impact, or both.

Absorption: Weight of water incorporated by a concrete paver unit during immersion under prescribed conditions, expressed as a percentage in relation to the dry weight of the unit.

Bedding Sand Degradation Tests: Evaluation of the degree of attrition of sand. Tests are conducted with steel balls or other abrading devices agitated with a sand sample in a container. Pre- and post- testing sieve analysis are conducted to determine the increase in fines. The tests are used to evaluate the durability of bedding sand under heavy loads or channelized traffic.

Compressive Strength: The measured maximum resistance of a concrete paver to loading; expressed as force per unit cross-sectional area (in pounds per square inch or megapascals).

Density: The mass per unit volume.

Durability Testing: Tests in which paver units are exposed to cycles of freeze and thaw, partially or totally immersed in water, and with or without salt in the water.

Flexural Strength: A property of a paver or slab that indicates its ability to resist failure in bending.

Macro Texture: The deviations of a pavement surface from a

true planar surface with dimensions generally 0.5mm or greater or those that no longer affect tire-pavement interaction.

Micro Texture: The deviations of a pavement surface from a true planar surface with dimensions generally less than 0.5mm.

Tensile Strength: Maximum unit stress which a paver is capable of resisting under axial tensile loading, based on the cross-sectional area of the specimen before loading.

10.6 CHEMICAL TERMS

Absorbent: To take up or suck up. Common absorbents that will soak up chemicals are Fullers Earth, sawdust, kitty litter, talcum powder, corn starch, Absorb All, etc.

Ammonium Chloride: A naturally occurring ammonia salt used as a bleaching agent in some cleaning powders. One such cleaner is Lysol Brand Tub and Tile Cleaner (aerosol).

Benzene: A hydrocarbon obtained commercially from coal tar. Used as a cleaning solvent for gums, resins, fats and grease. Also known as Benzol, carbon oil or mineral refined naphtha. Used in paint removers and other degreasing cleaners, as well as in lacquers, insecticides and pesticides. Energine Spot Remover (D-Con) is one generic product containing 100% naphtha. Amway Prewash is an aerosol containing mineral spirits and naphtha.

Chlorinated Hydrocarbon Solvent: A synthetic product obtained by replacing one or more of the hydrogen atoms of a hydrocarbon with chlorine. Chlorinated hydrocarbons are used as solvents in cleaning fluids, insecticides and fumigants. Degreasing liquid drain cleaners such as Amway Drain Mate or Kitchen Drano may contain up to 100% 1,1,1 - trichloroethane which is a chlorinated hydrocarbon often used as a dry cleaning fluid.

Glycerine: A solvent that absorbs and holds moisture so as to keep thick liquids from drying out. Can be bought at most drug stores and when mixed 1:1 with liquid dish soap and 8 parts water will make an excellent wet spotter.

Sodium Citrate: non-toxic, white, odourless, crystals or powder with a slightly salty taste. Used as a water softener

INTERLOCKING CONCRETE PAVERS

TECHNICAL DESIGN AND INSTALLATION GUIDE

and detergent. Not soluble in alcohol.

Sodium Hydroxide: A white, corrosive alkaline powder also known as caustic soda, lye and sodium hydrate. Powder drain cleaners may be 100% sodium hydroxide while liquid drain cleaners contain a less concentrated form of the ingredient. Red Devil Lye (Rasco) and Indco Lye (Independence Chemical Company) are two drain cleaners comprising only of sodium hydroxide.

Sodium Metasilicate: An alkali used in laundry and dishwashing detergents, as well as aluminum cleaners. It is a toxic corrosive crystalline salt used as a substitute for phosphates in detergent formulations.

Trichloroethylene: A heavy, colourless liquid solvent that smells something like chloroform. It is used as a solvent in drycleaning fluids and rug cleaners. Also referred to as trichloran, trilene and TRI. Sold under various trade names as a nonflammable cleaning fluid for grease.

Trisodium Phosphate: Colourless or white alkaline crystals used in all purpose powder cleaners and as a water softener in laundry products. Also known as TSP. Prime ingredient of Oakite (Clorox) and Spic and Span (Proctor and Gamble).

Xylene: A flammable colourless petroleum distillate with a characteristic odour. A mixture of xylene (also known as thylene) and ethyl-benzene is used chiefly as a solvent in paint brush cleaners.

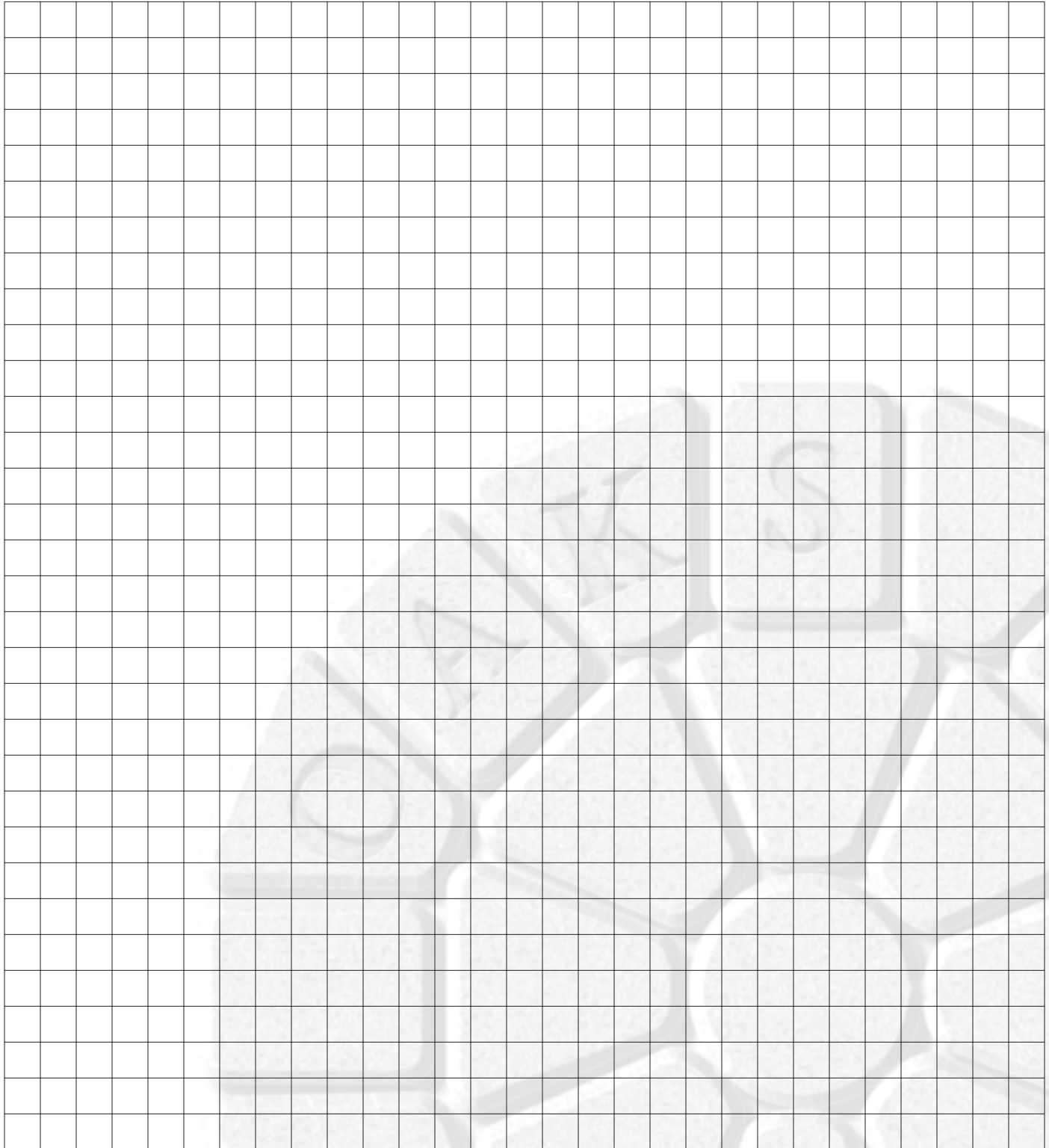
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