icpi

Interlocking Concrete Pavement Institute

Interlocking Concrete Pavement: Attractive, Resilient, Economical

Robert Bowers, P. Eng.

Director of Engineering

Introduction to Interlocking Concrete Pavement – Module 1

About ICPI

Who is ICPI?

- Interlocking Concrete Pavement Institute
- Founded in 1993
- The trade association representing the interlocking concrete paving industry in U.S. and Canada
- Develop and distribute technical information for design professionals and installers
- Over 1,000 members.

icpi

Interlocking Concrete Pavement Institute

Pavers in Every Project!

- ICPI engages in a broad range of technical, marketing, educational, government relations and communications activities

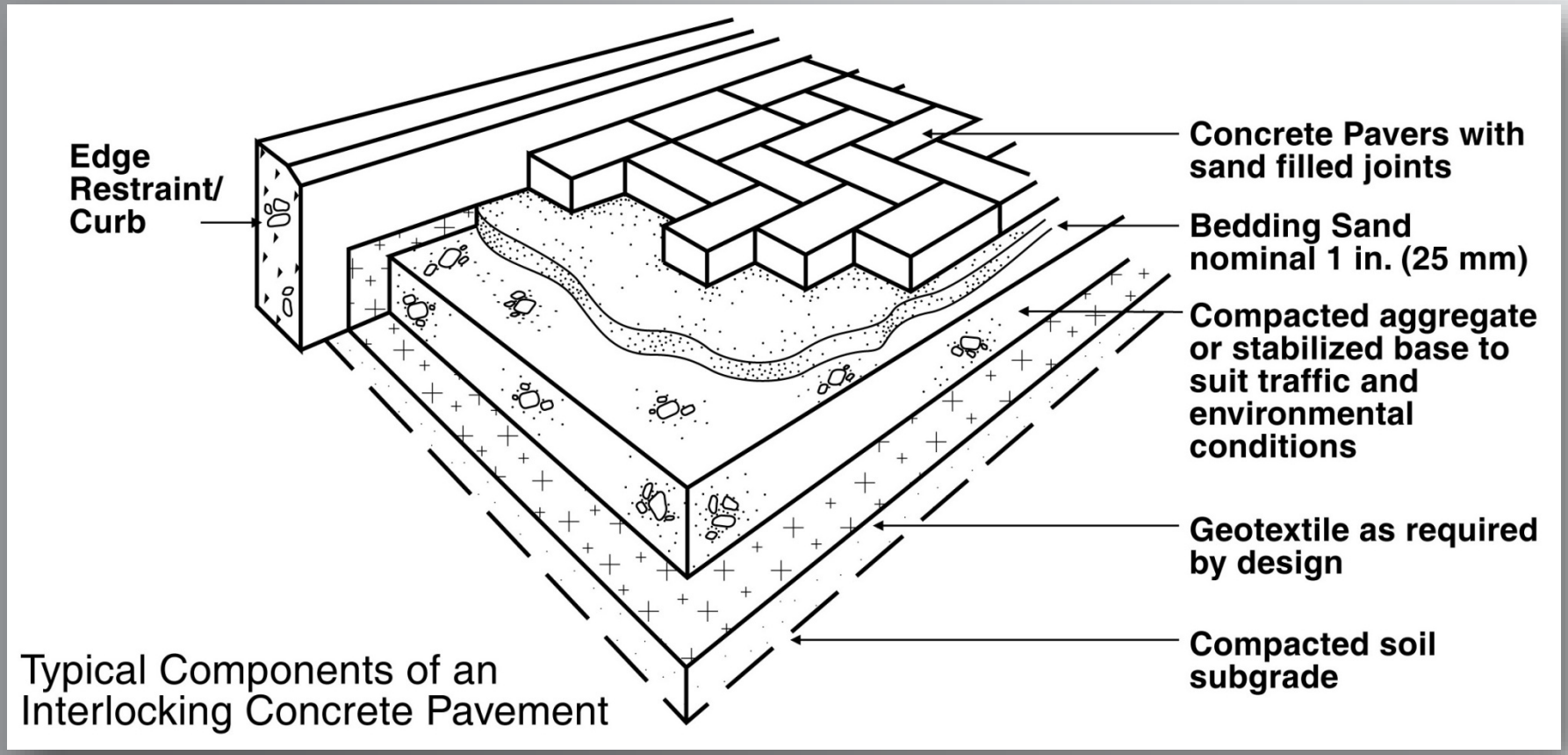
Our Mission

To deliver education and technical guidance leading to awareness, acceptance and use of segmental concrete pavement systems in the United States and Canada.

Advancing the Urban Surface Evolution

Interlocking Concrete Pavement

ICP System Components



Typical Components of an Interlocking Concrete Pavement

Product Standards

- Canadian Standards Association (CSA)
  - CSA-A231.2 Precast Concrete Pavers
- Test requirements:
  - Compressive strength (Production or Field)
  - Freeze-thaw durability in deicing salt solution
  - Dimensional tolerances

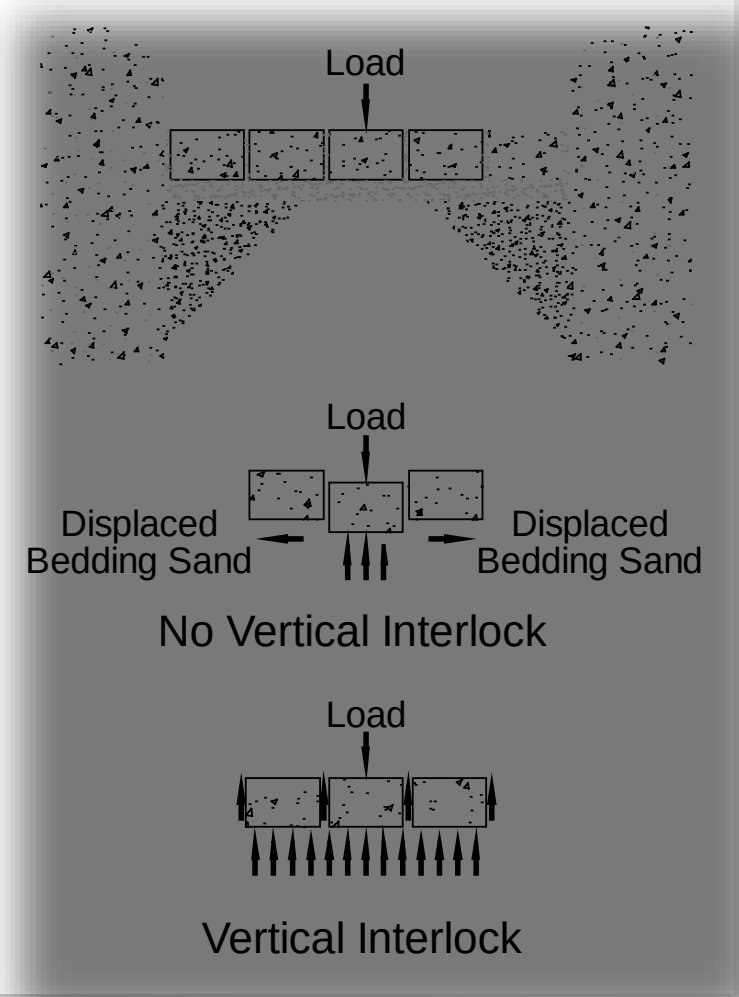
CSA Group

How do pavers work?

- Flexible behavior with concrete surface
- Minimized stress cracking on surface
- **Interlock:** inability of a paver to move independently of its neighbours

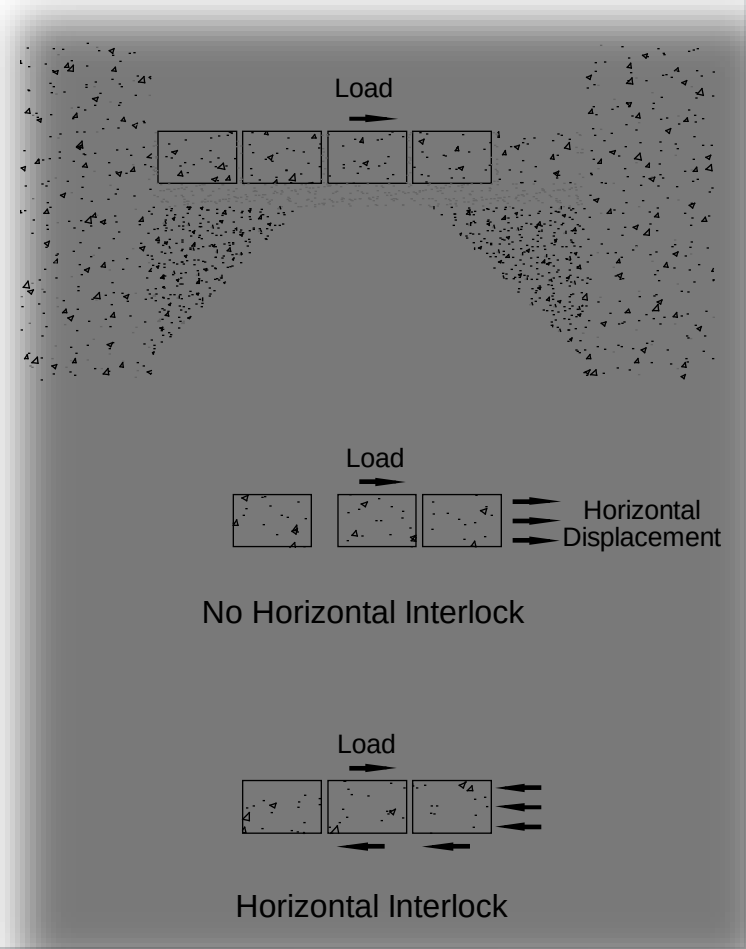
Vertical Interlock

- Achieved by shear transfer of loads to surrounding units through sand in the joints

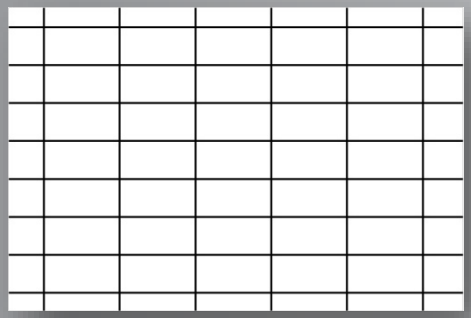


Horizontal Interlock

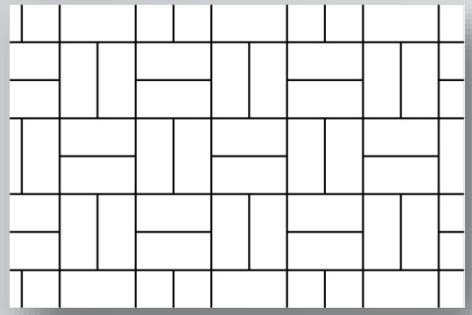
- Achieved with laying patterns that disperse forces from braking, turning and accelerating tires



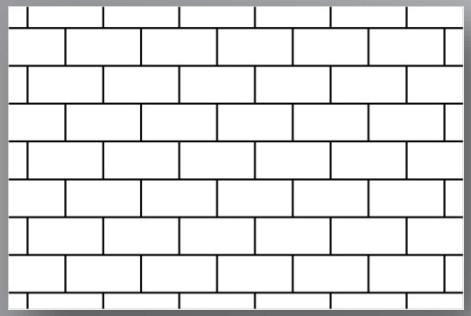
Basic Patterns



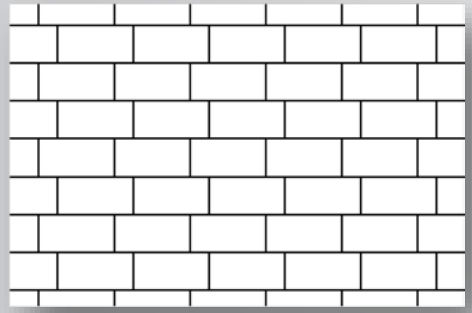
Stack Bond



Parquet

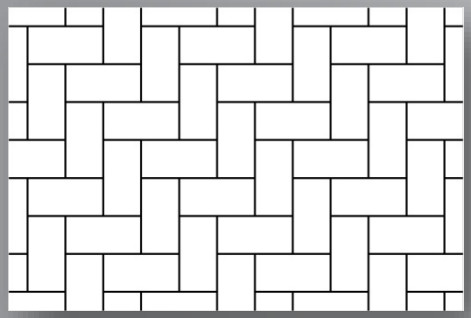


Running Bond

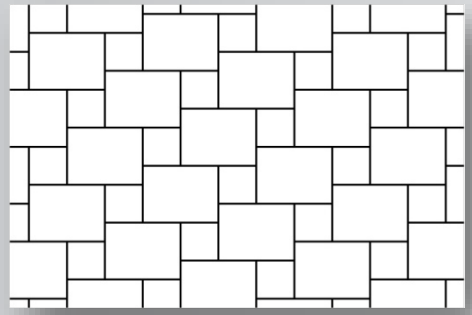


Mod.Running Bond

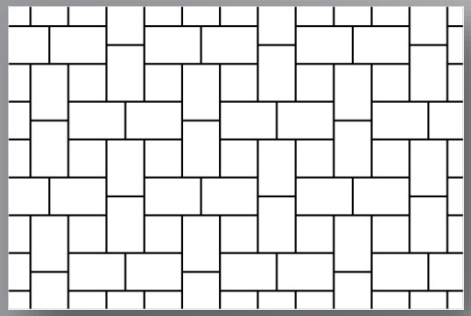
Basic Patterns



Herringbone



Mod. Herringbone

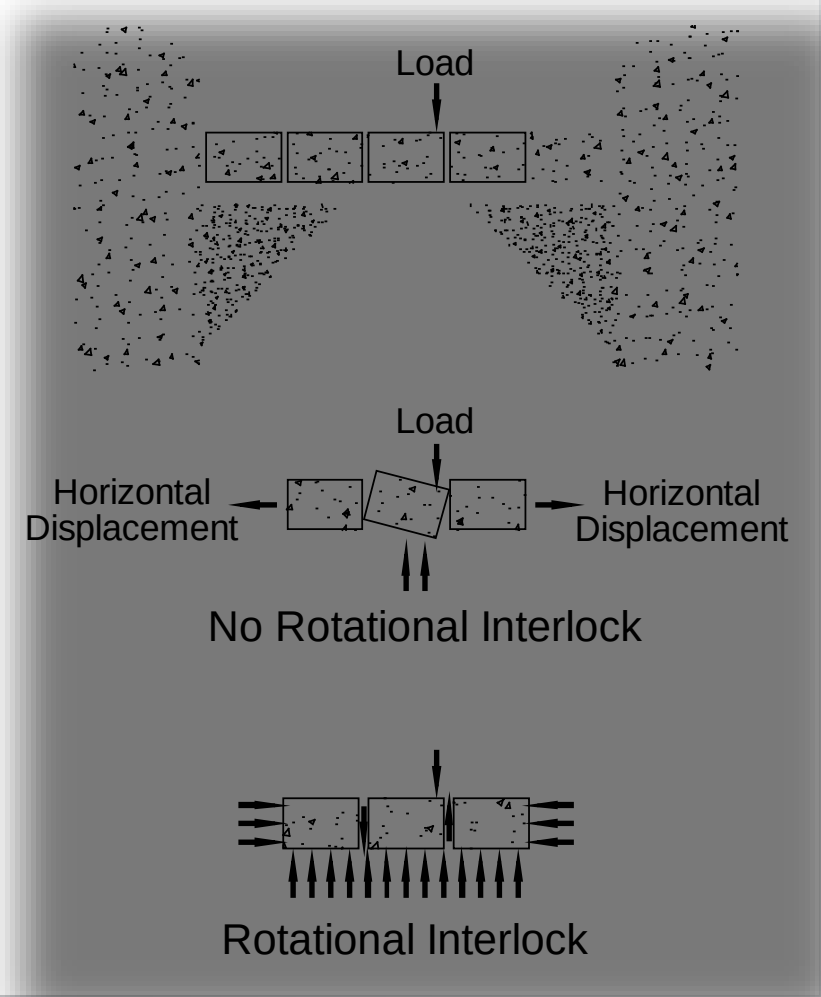


K Pattern

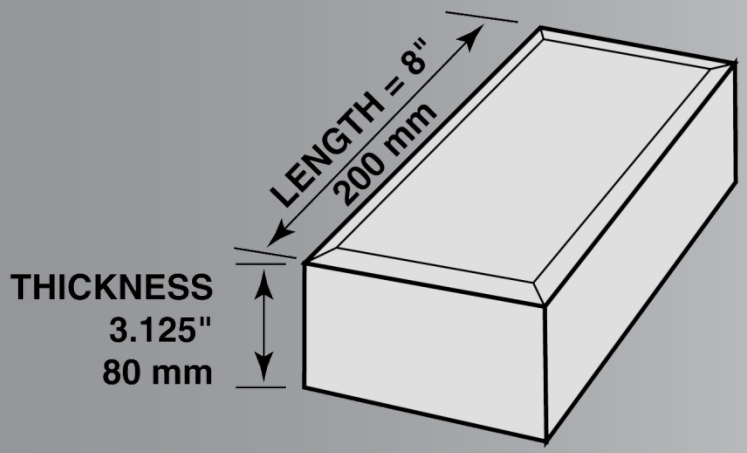
- Shorter, discontinuous bond lines, not aligned with traffic provide the greatest strength

Rotational Interlock

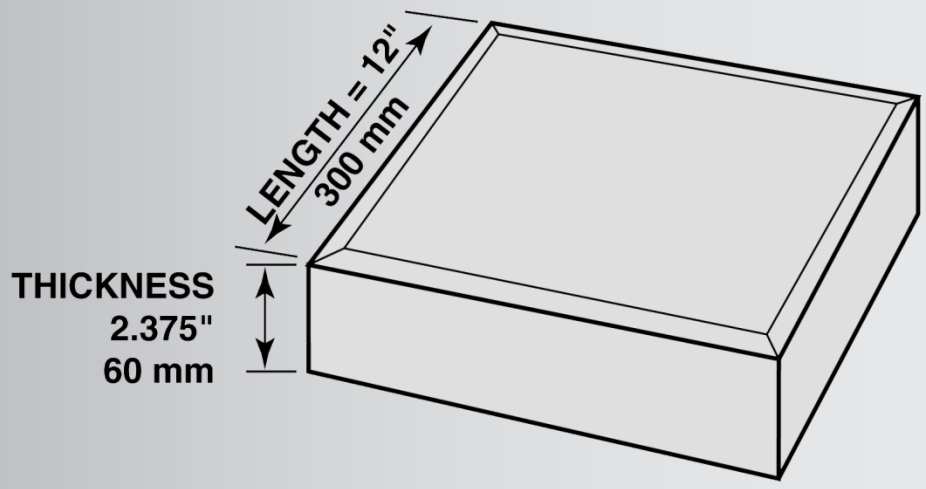
- Achieved by thickness of paver and confinement due to edge restraint.



Aspect Ratio for Different Applications



CONCRETE PAVER
ASPECT RATIO = 8" ÷ 3.125"
= 2.5 : 1



PAVING SLAB
ASPECT RATIO = 12" ÷ 2.375"
= 5 : 1

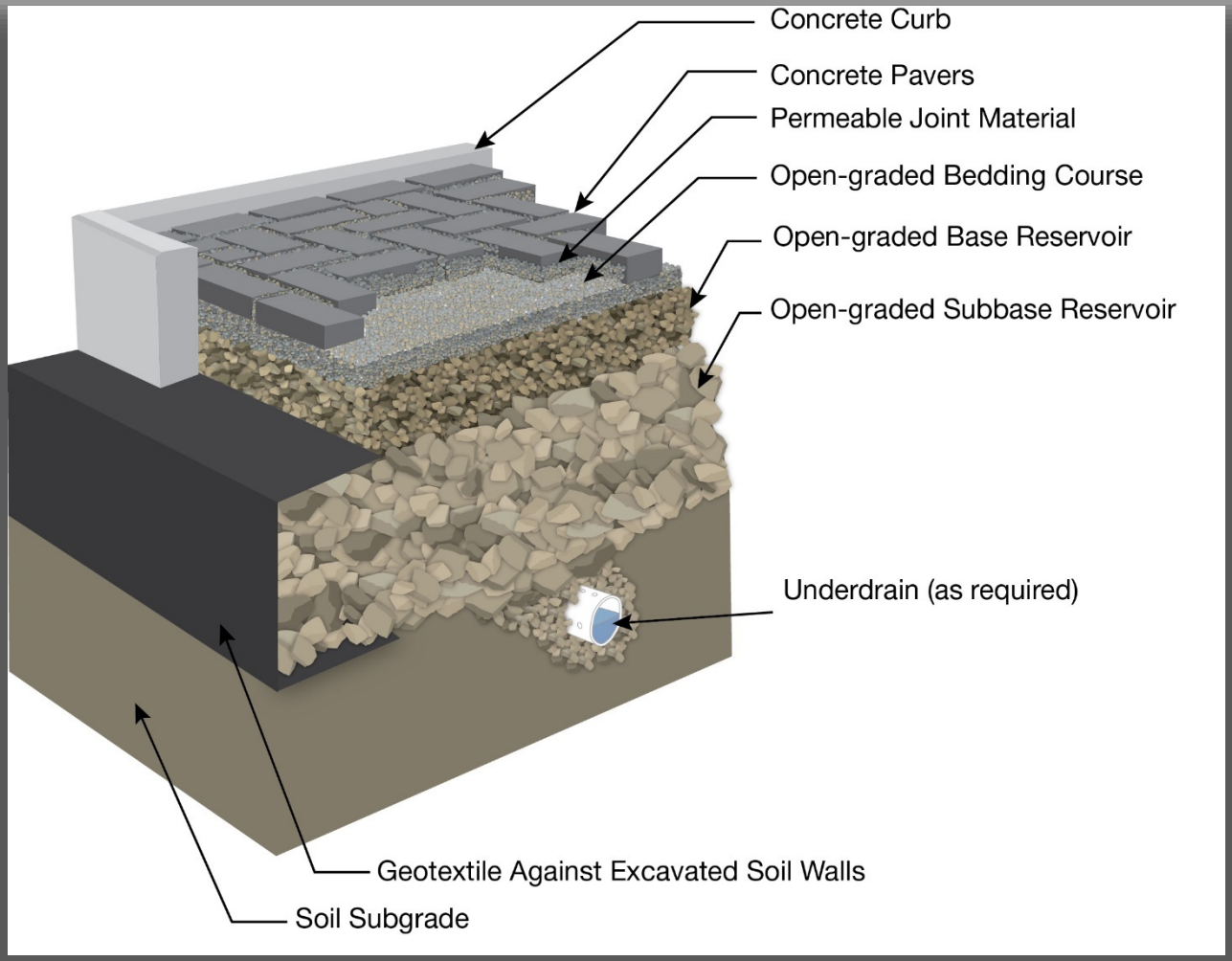
Aspect Ratio for Different Applications

		Pedestrian	Residential Driveways	Parking Lots and Streets
3:1 or less	Higher rotational and vertical interlock	•	•	•
Between 3:1 and 4:1	Moderate rotational and vertical interlock	•	•	
4:1 or more	Reduced rotational and vertical interlock	•		

Advancing the Urban Surface Evolution

Permeable Interlocking Concrete Pavement

PICP System Components



Subbase Aggregate

- ASTM No. 2 crushed aggregate
  - Min. porosity (volume of voids/ total volume of base) > 0.32
  - Water storage capacity in void spaces = 30% to 40%
  - Minimum 6 in. (150 mm) thick layer
  - Adds stability during subbase/base spreading & compaction
  - Can eliminate geotextile over subgrade

ASTM No. 2	
Sieve Size	**Percent Passing**
75 mm (3 in.)	100
63 mm (2½ in.)	90 to 100
50 mm (2 in.)	35 to 70
37.5 mm (1½ in.)	0 to 15
19 mm (3/4 in.	0 to 5

Base Aggregate

- ASTM No. 57 crushed aggregate or similar
  - Min. porosity (volume of voids/ total volume of base) > 0.32
  - Storage capacity in its void spaces = 30% to 40%
  - Min. 4 in. (100 mm) thick layer
  - Compacted No. 57 layer above “chokes” into No. 2 layer

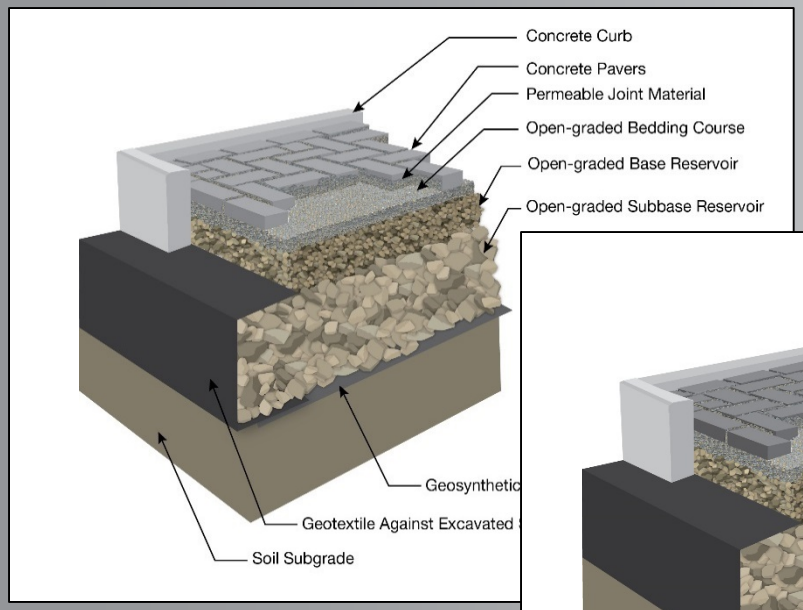
ASTM No. 57	
Sieve Size	**Percent Passing**
37.5 mm (1½ in.)	100
25 mm (1 in.)	95 to 100
12.5 mm (1/2 in.)	25 to 60
4.75 mm (No. 4)	0 to 10
2.36 mm (No. 8)	0 to 5

Bedding and Joint Aggregate

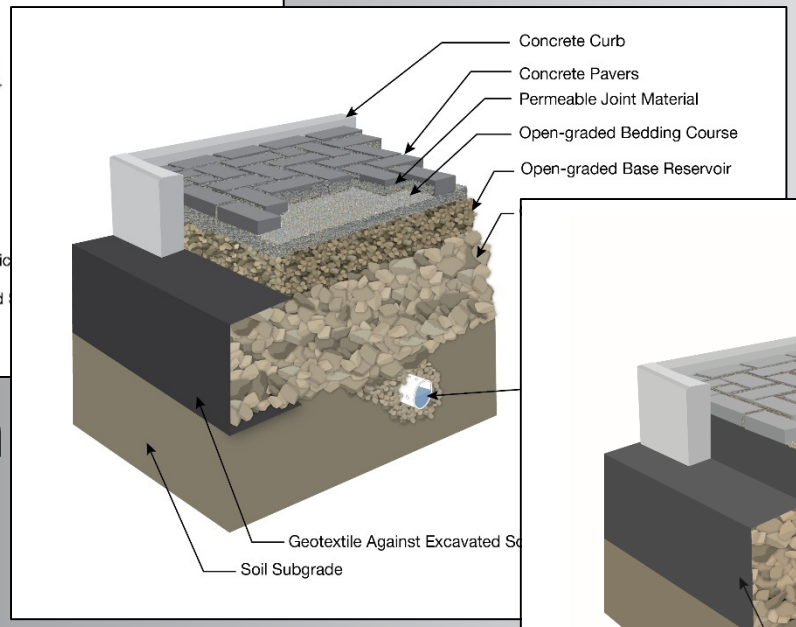
- ASTM No. 8 crushed stone
  - Max. thickness 2 in. (50 mm) prior to compaction
  - Filtration rate ~500 to 1,000 in./hr
  - Stores water, but not included in storage calculations - buffer
  - Beds or "chokes" into No. 57 stone layer underneath
  - Smaller washed stone may be used to fill narrow joints

ASTM No. 8	
Sieve Size	**Percent Passing**
12.5 mm (1/2 in.)	100
9.5 mm (3/8 in.)	85 to 100
4.75 mm (No. 4)	10 to 30
2.36 mm (No. 8)	0 to 10
1.16 mm (No. 16)	0 to 5

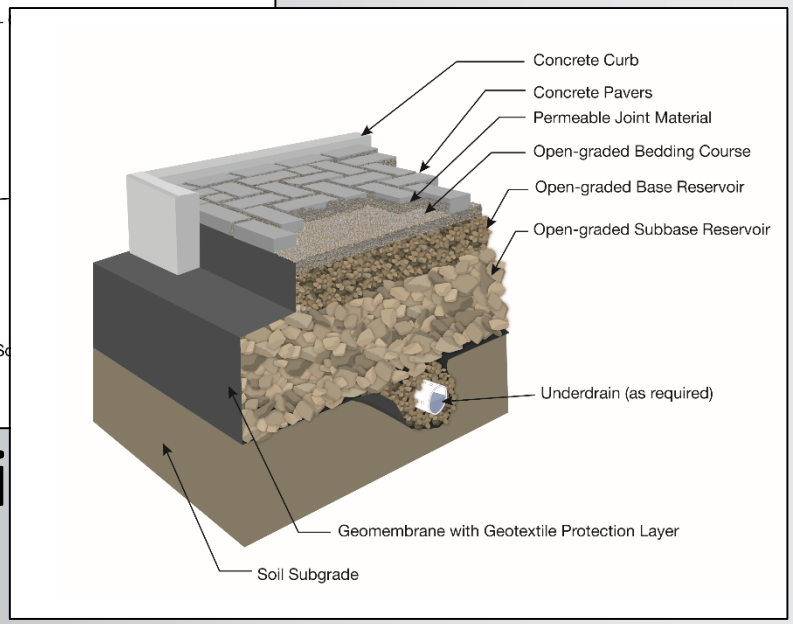
Different assemblies for different objectives



Full Infiltration



Partial Infiltrati



No Infiltration

Advancing the Urban Surface Evolution

Education

ICPI Certified Installer

Phase 1: Earn the CPI Record of Completion

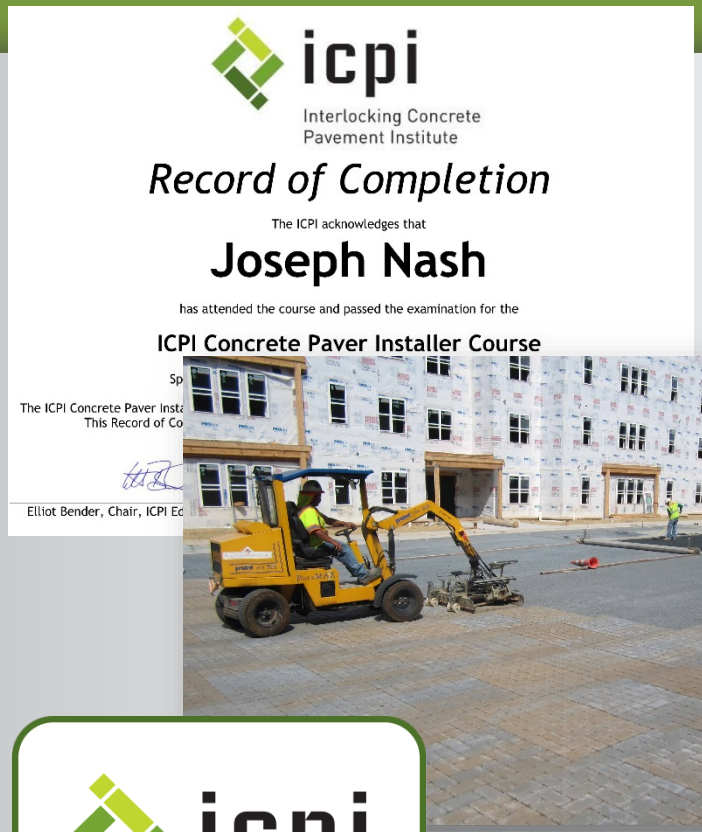
- Complete 2-day Concrete Paver Installer course and pass the exam
- Does not expire

Phase 2: Become an ICPI Certified Installer

- Hold a ICP Record of Completion
- Document ICP experience of 5 projects & 10,000 SF

Phase 3: Maintain ICPI Certified Installer

- Earn continuing education credits: minimum of 8 hours over 2 years
- Renew certification biennially



icpi
CERTIFIED INSTALLER

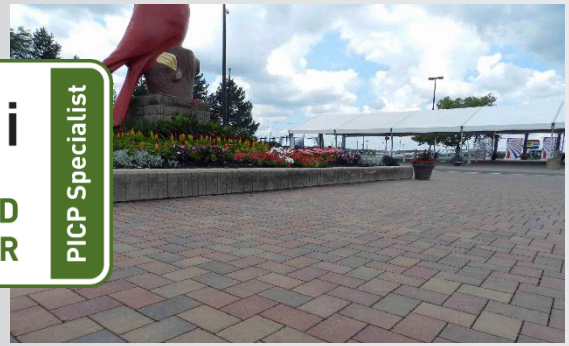
ICPI Installer Specialist Designations

Commercial

- Take Commercial Paver Technical Course & pass the exam
- Document installation of min. 50,000 sf of commercial projects
- Maintain certification to maintain designation with continuing education

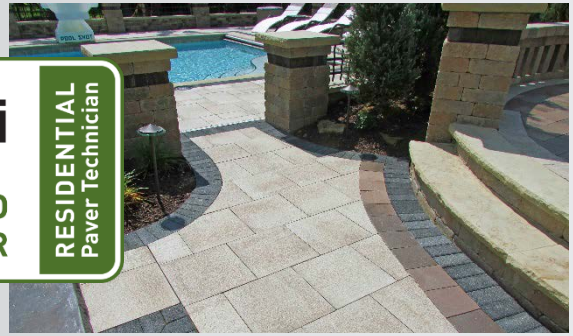
Permeable Interlocking Concrete Pavement

- Take PICP course & pass the exam
- Document installation of min. 10 projects & 50,000 sf of PICP projects
- Maintain certification to maintain designation with continuing education



Advanced Residential

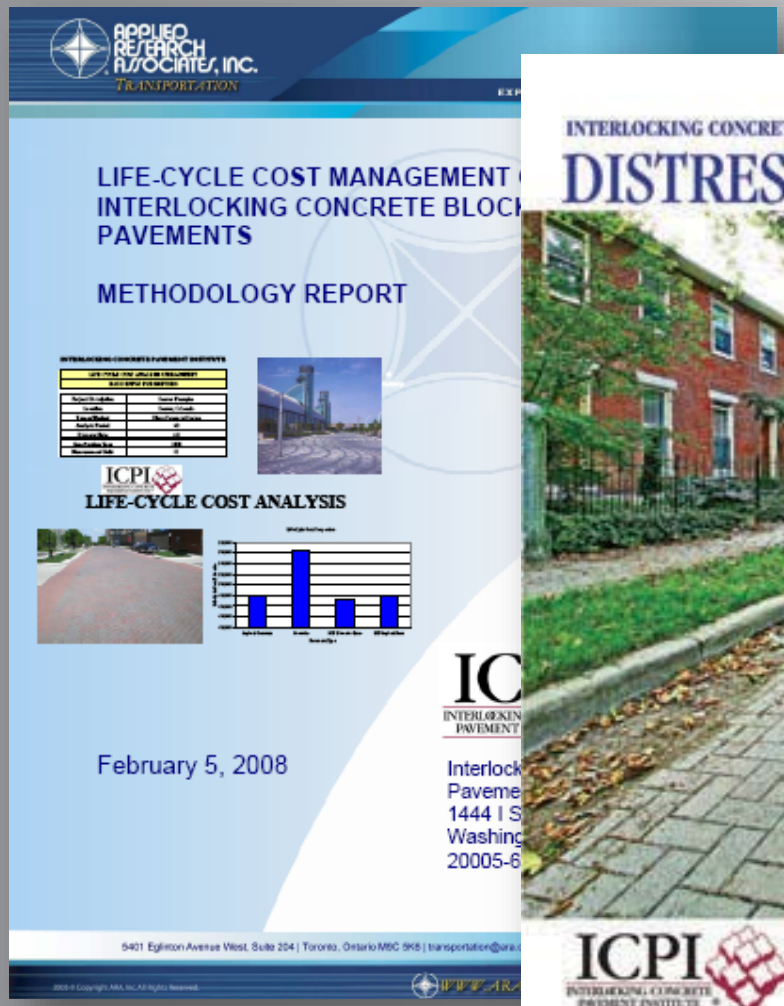
- Take Advanced Residential course & pass the exam
- Document installation of min. 50,000 sf of residential projects
- Maintain certification to maintain designation with continuing education

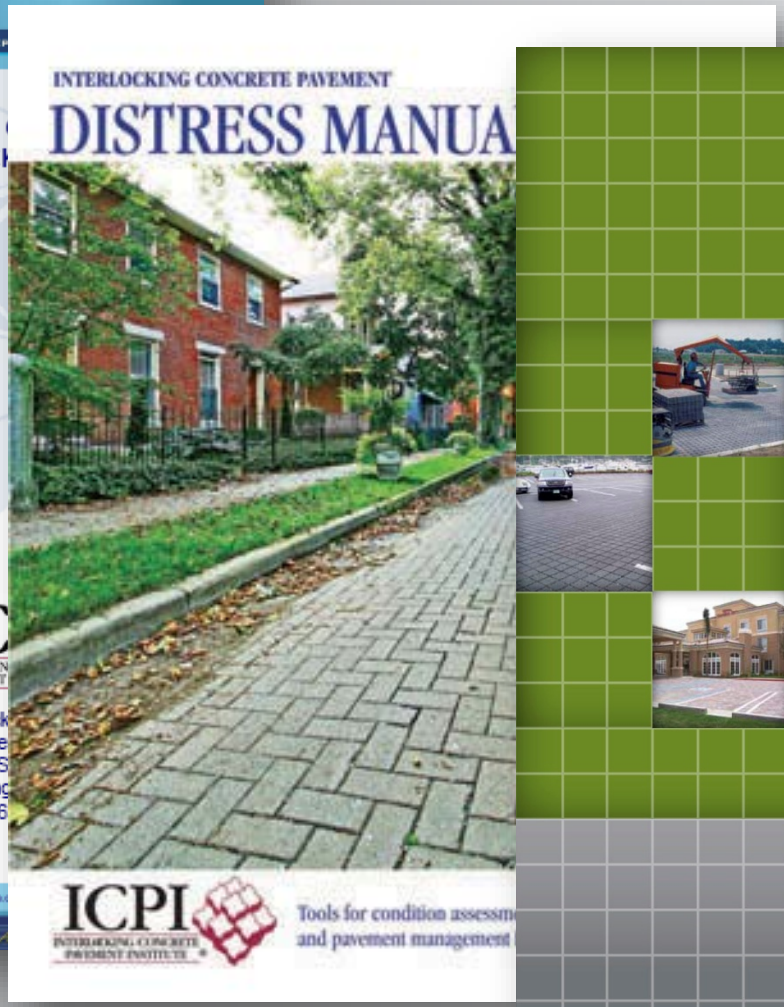


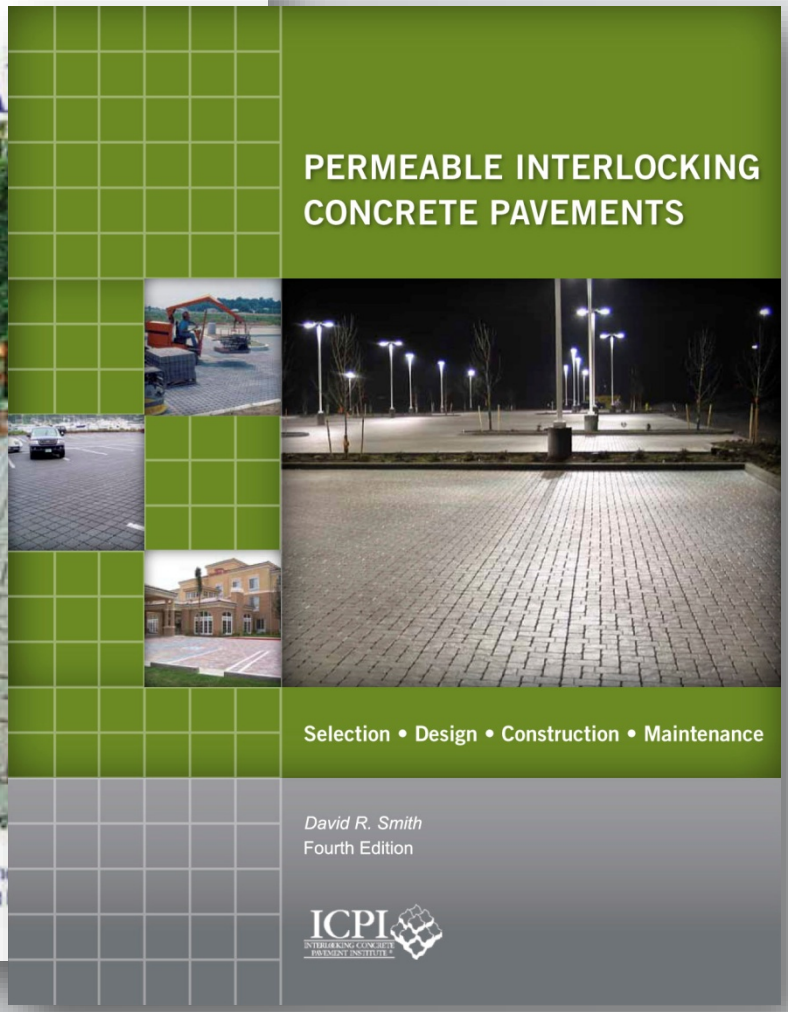
Advancing the Urban Surface Evolution

Resources

ICPI Manuals







ICPI Tech Specs

Tech Spe

Construction of Interlo

Purpose

This technical bulletin gives construction guidelines for design professionals and contractors of interlocking concrete pavements. The bulletin reviews the steps in construction of the aggregate base, bedding sand and concrete pavers. Pavement structure is commonly used for pedestrian and vehicular applications. Pedestrian areas, driveways, and areas subjected to limited vehicular use are paved with units 2 3/8 in. thick. Streets and industrial pavements should be paved with units at least 3 1/8 in. (80 mm) thick.

It is recommended that ICPI Certified Installers be used for the construction of interlocking concrete pavements. These individuals have attended training and have demonstrated their knowledge of the guidelines, materials and techniques specific to interlocking concrete pavement. ICPI maintains a list of Certified Installers on www.icpi.org .

Aggregate bases stabilized with asphalt or cement are recommended under very heavy loads, and over poorly saturated soil subgrades. These are sometimes used when adequate aggregates are not available or when a stabilized base is more economical than unstabilized aggregate. Refer to *Tech Spec 4–Structural Design of Interlocking Concrete Pavements for Roads and Parking Lots* when looking for additional information regarding the structural design of the base and pavement. *Tech Spec 4* is based on the design methods detailed in 58-10 *Structural Design of Interlocking Concrete Pavements for Municipal Streets and Roadways*.

Concrete pavers made in the U.S. should meet the requirements established in the American Society for Testing and Materials (ASTM) C 936, *Standard Specification for Interlocking Concrete Paving Units*. Requirements of this specification include a minimum average compressive strength of 8,000 psi (55 MPa), average absorption no greater than 5%, and resistance to at least 50 freeze-thaw cycles with average mater

© 1995 ICPI Tech Spec No. 2 Interlocking Concrete Pavement

Tech Spec 4

Structural Design of Interlocki for Roads and Parking Lots

History

The concept of interlocking concrete pavement dates back to the roads of the Roman Empire. See Figure 1. They were constructed with tightly-fitted stone paving units set on a compacted aggregate base. The modern version, concrete pavers, is manufactured with close tolerances to help ensure interlock. Concrete pavers were developed in the Netherlands in the late 1940s as a replacement for clay brick streets. A strong, millennia-old tradition of segmental paving in Europe enabled interlocking concrete pavement to spread quickly. It is now established as a conventional means of paving there with some four billion ft² (400 million m²) installed annually. Concrete pavers came to North America in the 1970s. They have been used successfully in numerous residential, commercial, municipal, port and airport applications. This *Tech Spec* covers the structural design of interlocking concrete pavement over an aggregate base as well as asphalt and cement stabilized bases, asphalt concrete and Portland cement concrete bases.

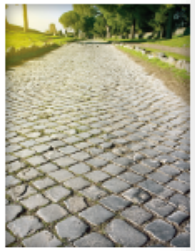


Figure 1. The Roman Appian Way: early interlocking pavement

Advantages

The paving system offers the advantages of concrete materials and flexible asphalt pavement. As high-strength concrete, the units have high resistance to freeze-thaw cycles and deicing salts, high abrasion and skid resistance, no damage

© 1995 ICPI Tech Spec No. 4 Interlocking Concrete Pavement Institute • All rights reserved—Revised May 2011

Tech Spe

Cleaning, Sealing and of Interlocking Concre

When properly installed, interlocking concrete pave very low maintenance and provide an attractive sur cades. Under foot and vehicular traffic, they can bec to dirt, stains and wear. This is common to all paver technical bulletin addresses various steps to ensure of interlocking concrete pavements and to help res original appearance. These steps include removing cleaning, plus joint stabilization or sealing if require

Stains on specific areas should be removed first should be used next to remove any efflorescence a the entire pavement. A newly cleaned pavement ca portune time to apply joint sand stabilizers or seal it achieve maximum results, use stain removers, clean stabilizers, and sealers specifically for concrete pave be purchased from a manufacturer, contractor, deal member of the Interlocking Concrete Pavement Ins

Removing Stains

Commercial stain removers available specifically for ers provide a high degree of certainty in removing s kinds of stains can be removed while minimizing th oring or damaging the pavers. The container label c a list of sta be remove questions, should be help with the effecti chemical i specific sta

Identif prior to ap cleaner. A tion shouk in a small, i stained are ing effecti

Figure 1. Many sealers enhance the appearance of concrete pavers and protect against staining.

© 1995 ICPI Tech Spec No. 5 • Interlocking Concrete Pav

and accelerating vehicles. Herringbone patterns are th most effective laying patterns for maintaining interlock (se Figure 3). Testing has shown that these patterns offer greate structural capacity and resistance to lateral movement the

Tech Spec 6

icpi Interlocking Concrete Pavement Institute

Reinstatement of Interlocking Concrete Pavements

Introduction

Concrete pavers can act as a zipper in the pavement. When the need arises to make underground repairs, interlocking concrete pavements can be removed and replaced using the same material. Unlike asphalt or poured-in-place concrete, segmental pavement can be opened and closed without using jack hammers on the surface and with less construction equipment. This results in no ugly patches and no reduction in pavement service life. In addition, no curing means fast repairs with reduced user delays and related costs.

The process of reusing the same paving units is called reinstatement. This Tech Spec covers how to reinstate or "unzip and zip" interlocking concrete pavement. The following step-by-step procedure applies to any interlocking concrete pavement, including pedestrian areas, parking lots, driveways, streets, industrial, port and airport pavements.

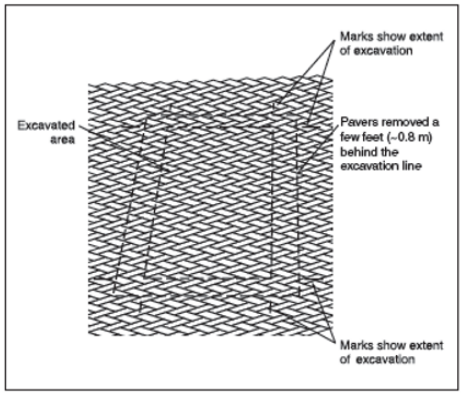


Figure 1. Pavement markings show the extent of paver removal and trench area.

Step 1—Locate Underground Utilities in the Area to be Excavated

The location and depth of existing utilities should be established prior to excavating. Many localities have one telephone number to call for obtaining marked utility locations. Set cones, traffic signs, or barricades around the area to be excavated according to local and state or provincial standards.

Determine and mark the area of pavers to be removed. Remove pavers a few feet (~0.8 m) wider on each side of the trench open-

© 1996 ICPI Tech Spec No. 6 • Interlocking Concrete Pavement Institute—Revised August 2011

ICPI Tech Spes

Tech Spec

Bedding Sand Selection f
Pavements in Vehicular A

Bedding sands are a critical component of all sand-set
mental concrete paving systems. Especially for vehi
applications, specifiers and contractors need to con
bedding sand selection. While gradation is an impo
consideration, other characteristics should be assess
order to ensure long-term pavement performance.
technical bulletin examines these characteristics and
vides guidance to specifiers and contractors.

Background

Bedding sand provides four main functions. It beds the
ers during installation; helps initialize interlock amon
pavers; provides a structural component for the syste
described in *ICPI Tech Spec 4 Structural Design of Interlo*
Concrete Pavement for Roads and Parking Lots) and facili
drainage of water that infiltrates through the joints. T
specifications require bedding sands to conform to AS

ASTM C33	
Sieve Size	Percent Passing
3/8 in.(9.5 mm)	100
No. 4 (4.75 mm)	95 to 100
No. 8 (2.36 mm)	80 to 100
No. 16 (1.18 mm)	50 to 85
No. 30 (0.6 mm)	25 to 60
No. 50 (0.3 mm)	5 to 30
No. 100 (0.15 mm)	0 to 10
No. 200 (0.075 mm)	0 to 1[1]

Note 1: Bedding sands should conform to ASTM C33 or CSA A2
additional limitations on the No. 200 (0.075 mm) sieve
passing the 80 µm sieve from 3% to 1%.

Table 1. Gradation for Bedding Sand

*Although the ASTM equivalent for the No. 200 sieve size
French (AFNOR) standard equivalent sieve size of 80 micr*

Tech Spec 18

Construction of Permeable Interlocki
Concrete Pavement Systems

INTRODUCTION

Permeable interlocking concrete pavement (PICP) is recognized by federal and state stormwater and transportation agencies as a Best Management Practice (BMP) and Low Impact Development (LID) tool to reduce runoff and water pollution. In addition, PICP offers unique design opportunities for addressing combined sewer overflows with green alleys and streets, as well as use in parking lot and pedestrian surfaces. Traditional stormwater management solutions focus on collecting, concentrating and centralizing the disposal of stormwater. As a key BMP and LID tool, PICP helps disconnect, decentralize and more widely distribute runoff through infiltration, detention, filtering and treatment.

The Interlocking Concrete Pavement Institute (ICPI) provides a comprehensive, 92-page manual entitled *Permeable Interlocking Concrete Pavements*, which covers design, specifications, construction and maintenance. This manual is available on www.icpi.org and provides extensive information from academic research and practical field experience. This

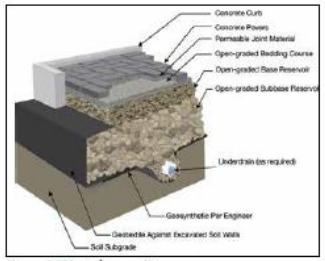


Figure 1. PICP typical cross section.

Tech Spec bu
techniques c
ance on best
for contracto

Figure 1
individual co

Concret
joints and/or
pavement su
C 936 (ASTM
Canada. Pav
thick for veh
in. (60 mm) t
shapes and
openings all
through the
configuratio

Permea
consists of a
able joints al
pavement su

Open-g
is typically 2
the pavers. I
aggregate, t
rial.

Open-g
layer that is t
cations see e
material is m
in. (25 mm d
base layer is
may be omi
ity in the sp

material also serves as a choking layer between the bedding and subbase layers. The stone size is typically ASTM No. 57 or similar sized material.

Tech Spec 23

icpi
Interlocking Concrete Pavement Institute®

Maintenance Guide for Permeable Interlocking Concrete Pavements

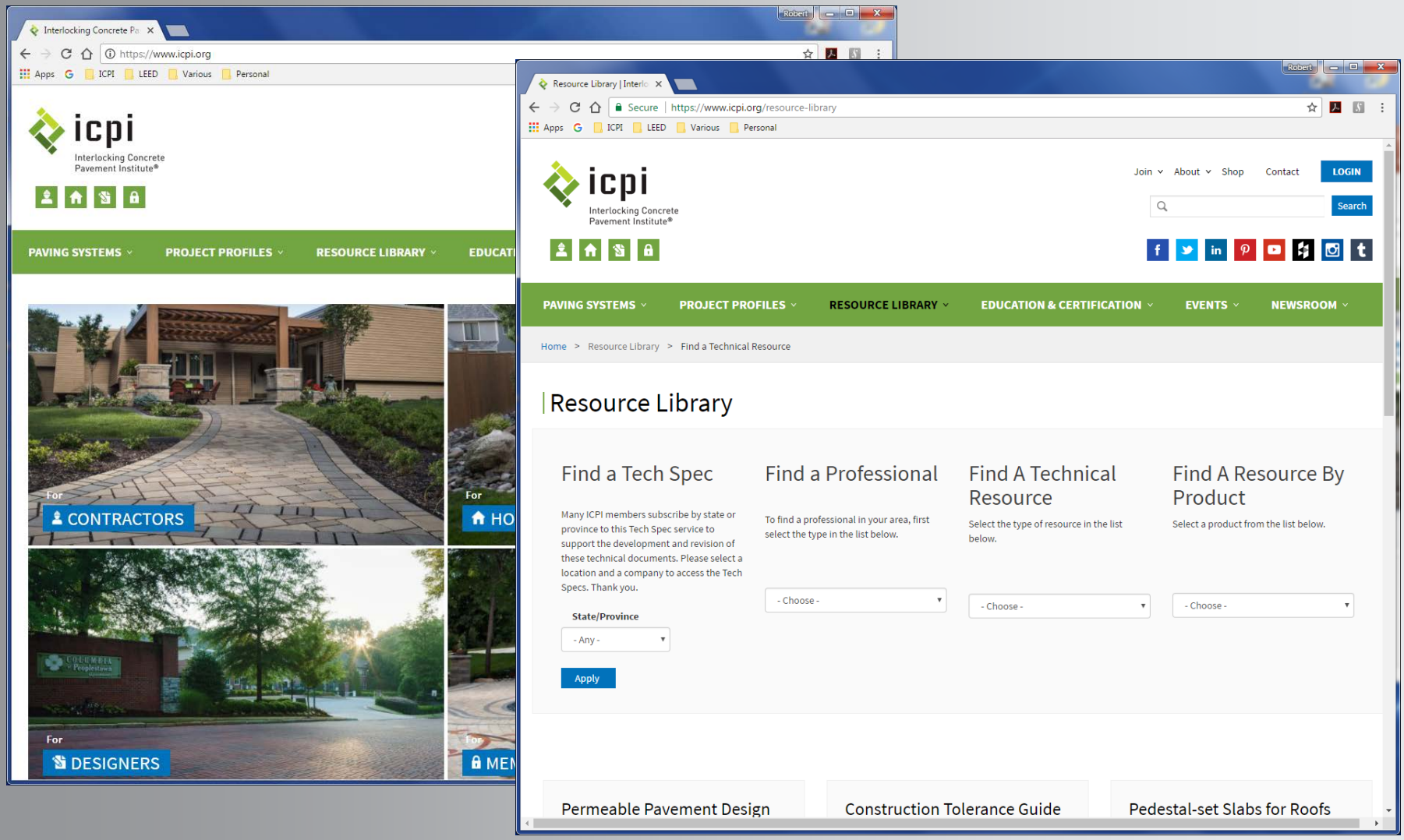
Introduction

Permeable interlocking concrete pavements (PICP) are a proven method for reducing stormwater runoff and pollutants while supporting pedestrian and vehicular traffic. Many laboratory and in-situ research projects over the past two decades by universities, government stormwater agencies, and industry have demonstrated significant runoff and pollutant reductions with cost-saving benefits. The U.S. Federal Highway Administration **www.fhwa.dot.gov/pavement/concrete/pubs/hif15006.pdf** has published information supporting PICP use in walkways, plazas, driveways, parking lots, alleys and streets.

Like all stormwater control measures, PICP requires maintenance as it traps sediment on its surface not unlike an air conditioning filter. Larger particles are initially trapped while allowing water to pass. Some enter the jointing stone and are trapped there. The jointing stone with larger particles eventually captures smaller particles and this decreases the infiltration rate over time. While still infiltrating water, many smaller particles are trapped within the surface and interior joints. Smaller particles are trapped and eventually decrease infiltration which results in surface ponding.

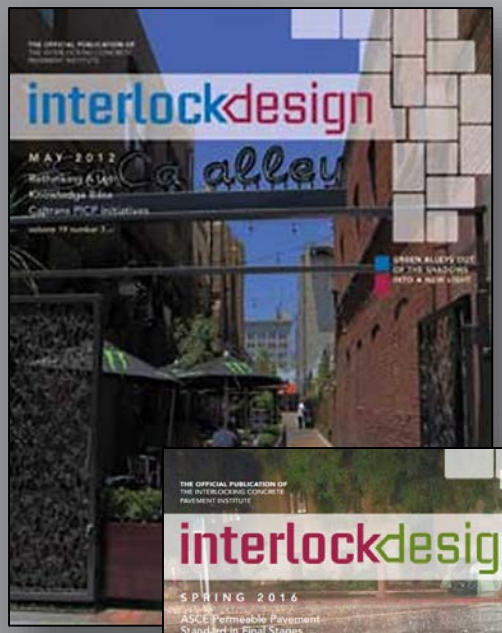
Figure 1. PICP is seeing increased use in municipal streets to reduce stormwater runoff, local flooding, storm pipe upsizing, and combined sewer overflows. These streets are in Atlanta, GA.

www.ICPI.org


https://www.icpi.org
icpi
Interlocking Concrete Pavement Institute®
PAVING SYSTEMS
PROJECT PROFILES
RESOURCE LIBRARY
For
CONTRACTORS
For
DESIGNERS
Resource Library | Interlo
Secure | https://www.icpi.org/resource-library
Join
About
Shop
Contact
LOGIN
Search
EDUCATION & CERTIFICATION
EVENTS
NEWSROOM
Home > Resource Library > Find a Technical Resource
Resource Library
Find a Tech Spec
Many ICPI members subscribe by state or province to this Tech Spec service to support the development and revision of these technical documents. Please select a location and a company to access the Tech Specs. Thank you.
State/Province
- Any -
Apply
Find a Professional
To find a professional in your area, first select the type in the list below.
- Choose -
Find A Technical Resource
Select the type of resource in the list below.
- Choose -
Find A Resource By Product
Select a product from the list below.
- Choose -
Permeable Pavement Design
Construction Tolerance Guide
Pedestal-set Slabs for Roofs

Municipal Applications Brochure

Interlock Design Magazine

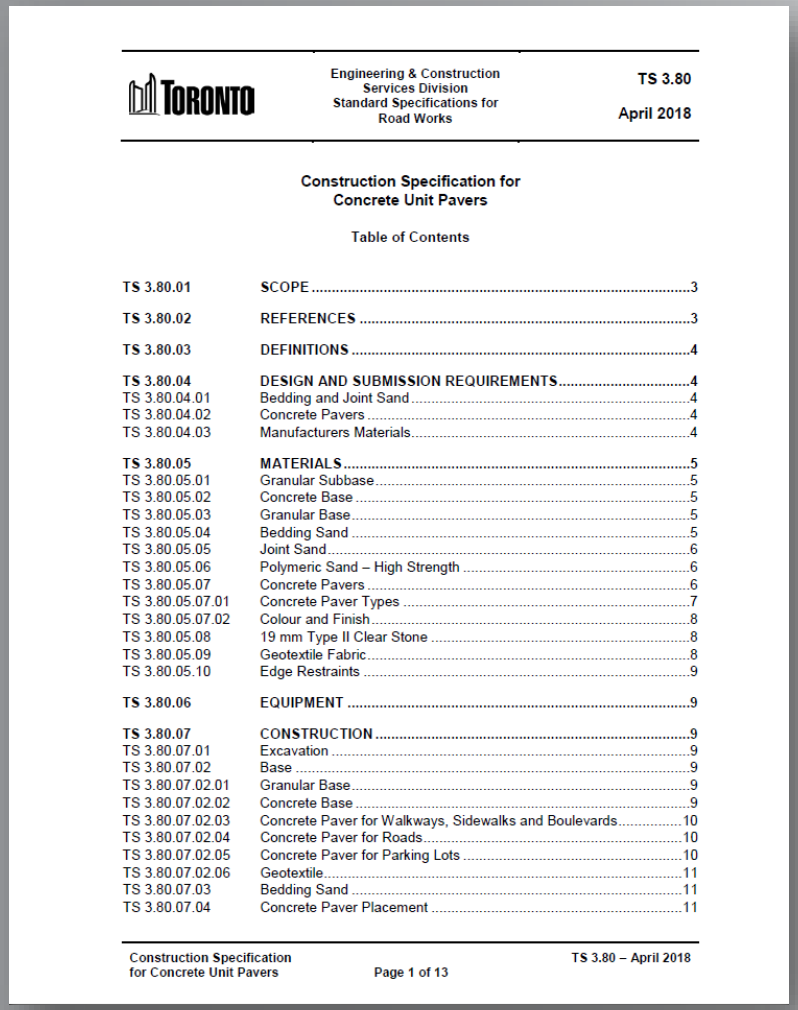


Resources Working for You

North Bay, ON

Interlocking Concrete Pavement Costs			Asphalt Pavement Costs		
Initial $/ lane-km	Maintanance $/ lane-km	Total $/ lane-km	Initial $/ lane-km	Maintanance $/ lane-km	Total $/ lane-km
159,465	**9,072**	**168,537**	**92,256**	**84,861**	**179,117**

Toronto, ON



TORONTO

Engineering & Construction Services Division
Standard Specifications for Road Works

TS 3.80
April 2018

Construction Specification for Concrete Unit Pavers

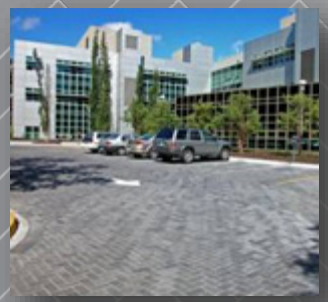
Table of Contents

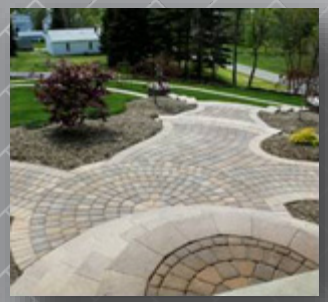
Construction Specification for Concrete Unit Pavers
Page 1 of 13
TS 3.80 – April 2018

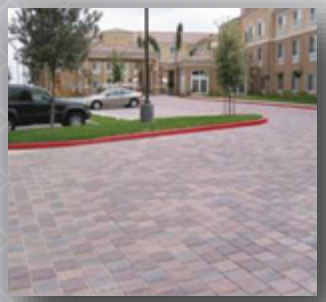
- References ICPI Tech Specs
- Standardized palette based on 8cm pavers
- Tighter specification for bedding sand

Kitchener, ON

- Design and constructed based on ICPI guidance







14801 Murdock Street
Suite 230
Chantilly, VA 20151
703.657.6900
www.ICPI.org

icpi

Interlocking Concrete
Pavement Institute

Visit us at booth B604