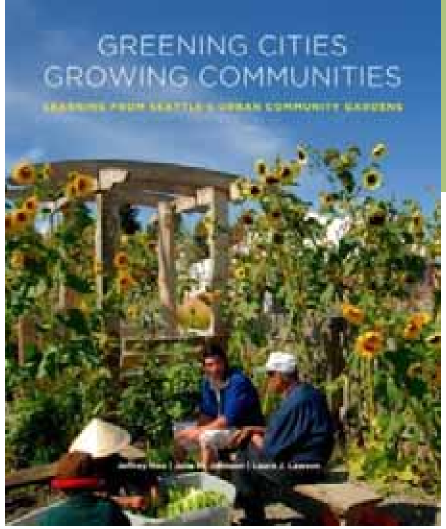
LANDSCAPE PERFORMANCE

Image credit: Unilock

Design for Performance: Segmental Concrete Pavements

February 27, 1-2pm EST
Professional Development Hours: 1.0 LA CES/HSW



LANDSCAPE ARCHITECTURE FOUNDATION

- 501(c)(3) nonprofit based in Washington, DC
- Founded in 1966 to preserve, improve and enhance the environment
- Increase our collective capacity to achieve sustainability:
  - Invested over $3 million in research
  - Awarded over $1.3 million in scholarships to over 550 students
  - Awarded $200,000 in leadership and innovation fellowships

LANDSCAPE PERFORMANCE SERIES

- Goal: Build capacity to achieve sustainability and transform the way landscape is considered in the design and development process
- Focuses on the measurable environmental, social, and economic impacts of landscapes:
  - Case studies and other online resources
  - Outreach and trainings
  - Resources for educators
  - Guide to evaluate performance
- Use it to find precedents, show value, and make the case for sustainable landscape solutions

Design for Performance: Segmental Concrete Pavements

LEARNING OBJECTIVES

- Explore the environmental, economic, and social benefits of segmental pavements.
- Understand inputs and assumptions used to conduct a life-cycle cost analysis for different types of pavements.
- Review design considerations and assembly options for segmental concrete pavement.
- Use the analysis tools and performance criteria from the SITES® rating system to estimate environmental performance.

Interlocking Concrete Pavement Institute®

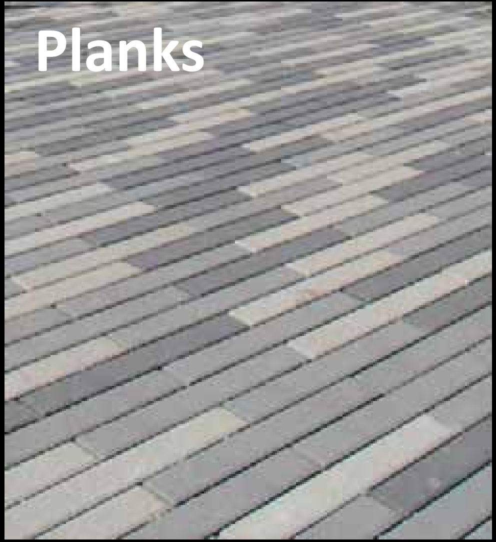
David R. Smith

Technical Director
Interlocking Concrete Pavement Institute

David Smith has worked on design, construction and maintenance of every kind of segmental concrete pavement application. He has published dozens of articles, peer-reviewed technical papers, guide specifications, technical bulletins, and contractor manuals, as well as authored three design idea books for residential, commercial and municipal applications.

Performance Potentials for Segmental Concrete Pavements

The Family



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Foundation for
Education and Research

Landscape Performance Process

Project design/performance objectives

Designed, planned & built landscapes

Performance measures the effectiveness by which landscape solutions fulfill their intended purpose & contribute to sustainability

LAF Landscape Performance Series supports the measurement process: What, how, when & where to measure, why measure

Content Tracks

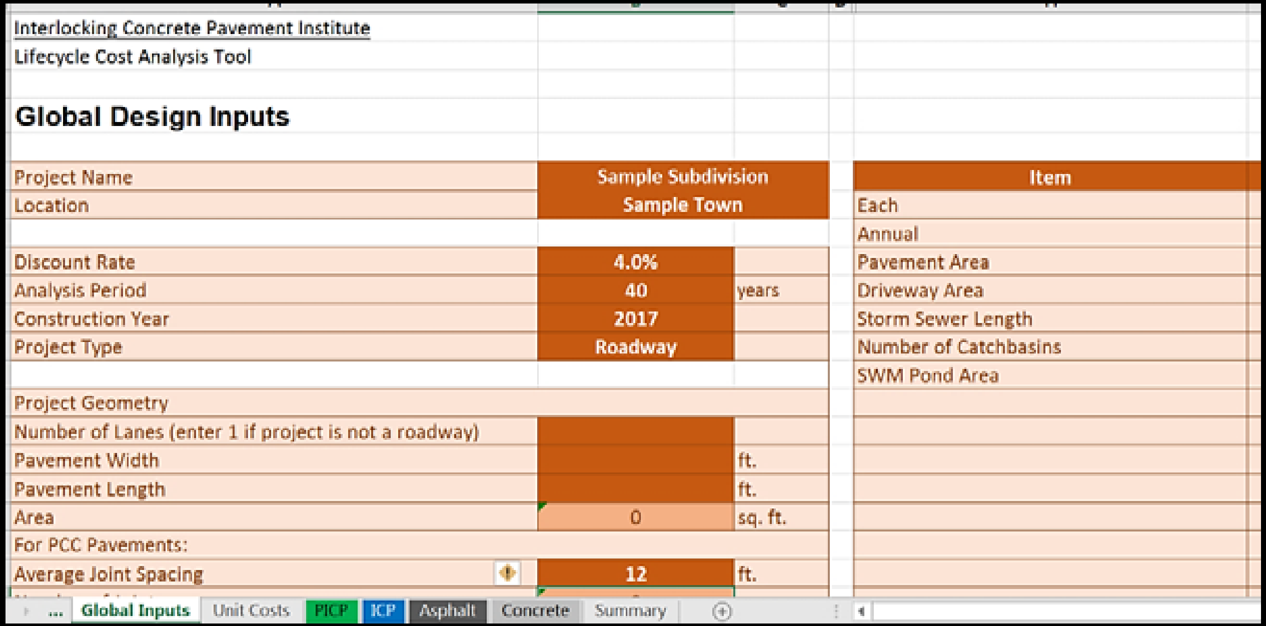
Economic, environmental & social benefits/ performance of segmental pavements

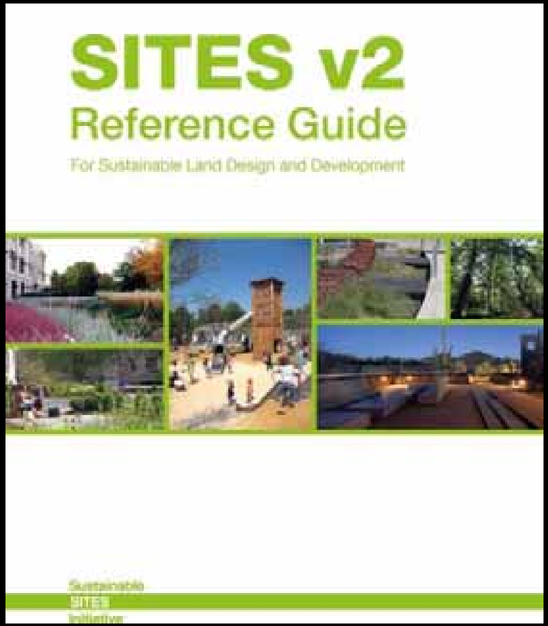
- Application guidelines from ICPI, past projects, peers, & industry to help maximize performance
- Ways to measure performance potentials while knowing/ respecting limitations
- ICPI resources on www.icpi.org to help translate performance into design schematics/development, specs, construction & maintenance

Source: Pavestone

Outline

- Understand the economic inputs & outputs for life-cycle cost analysis for pavements
- Use analysis tools & performance criteria from SITES v2 to evaluate environmental & social performance of segmental concrete pavements
- Underscore the growing importance of life cycle analysis of environmental impacts from pavements
- Review assembly options for segmental concrete pavement





Measuring Performance

- **Economic**

  Life cycle cost analysis - on & off-site costs & benefits

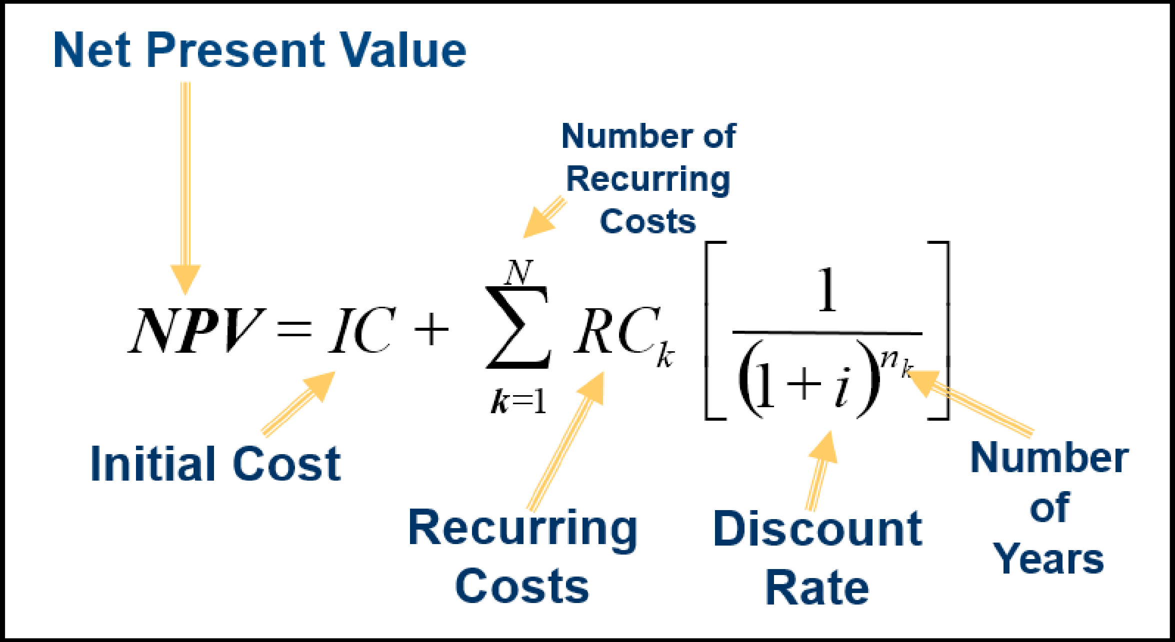
- **Environmental**

  Life cycle analysis from manufacturing, design decisions, construction, use & end-of-life

- **Social**

  Material language for increased human community, safety, education, comfort & beauty

Life-Cycle Cost Analysis (LCCA)



$$NPV = IC + \sum_{k=1}^{N} RC_k \left[\frac{1}{(1+i)^{n_k}} \right]$$

Inputs:

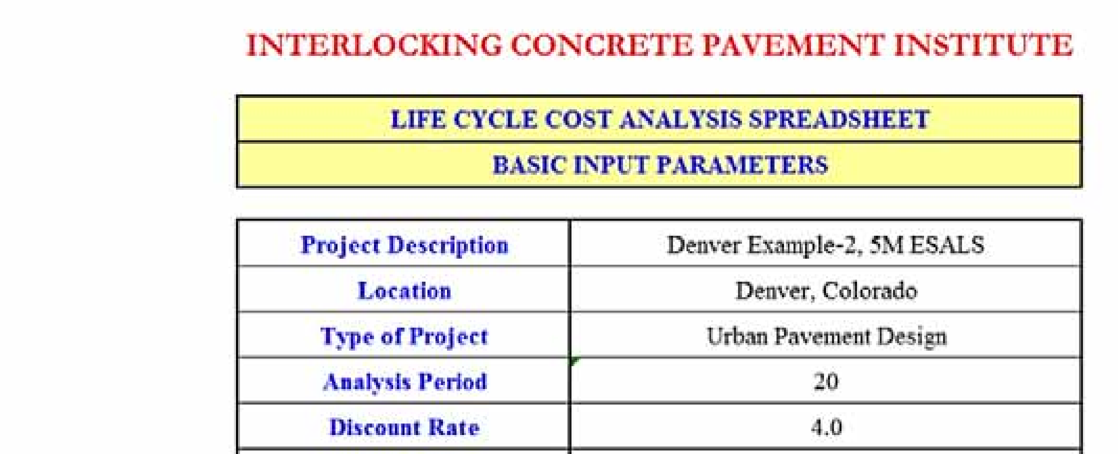
1. Analysis period in years
2. Construction costs
3. Off-site costs & compensating benefits
4. Future maintenance costs & schedules
5. Future costs *discounted* back to the present:

   Money spent in the future: worth *less* than today

   Future mntce costs discounted (reduced) to present value via a *discount rate* (interest rate - inflation rate)
6. End-of-life residual or salvage value

Output: Net present value of future costs + initial construction costs…compare to LCCAs of other pavement options

LCCA tool on www.icpi.org

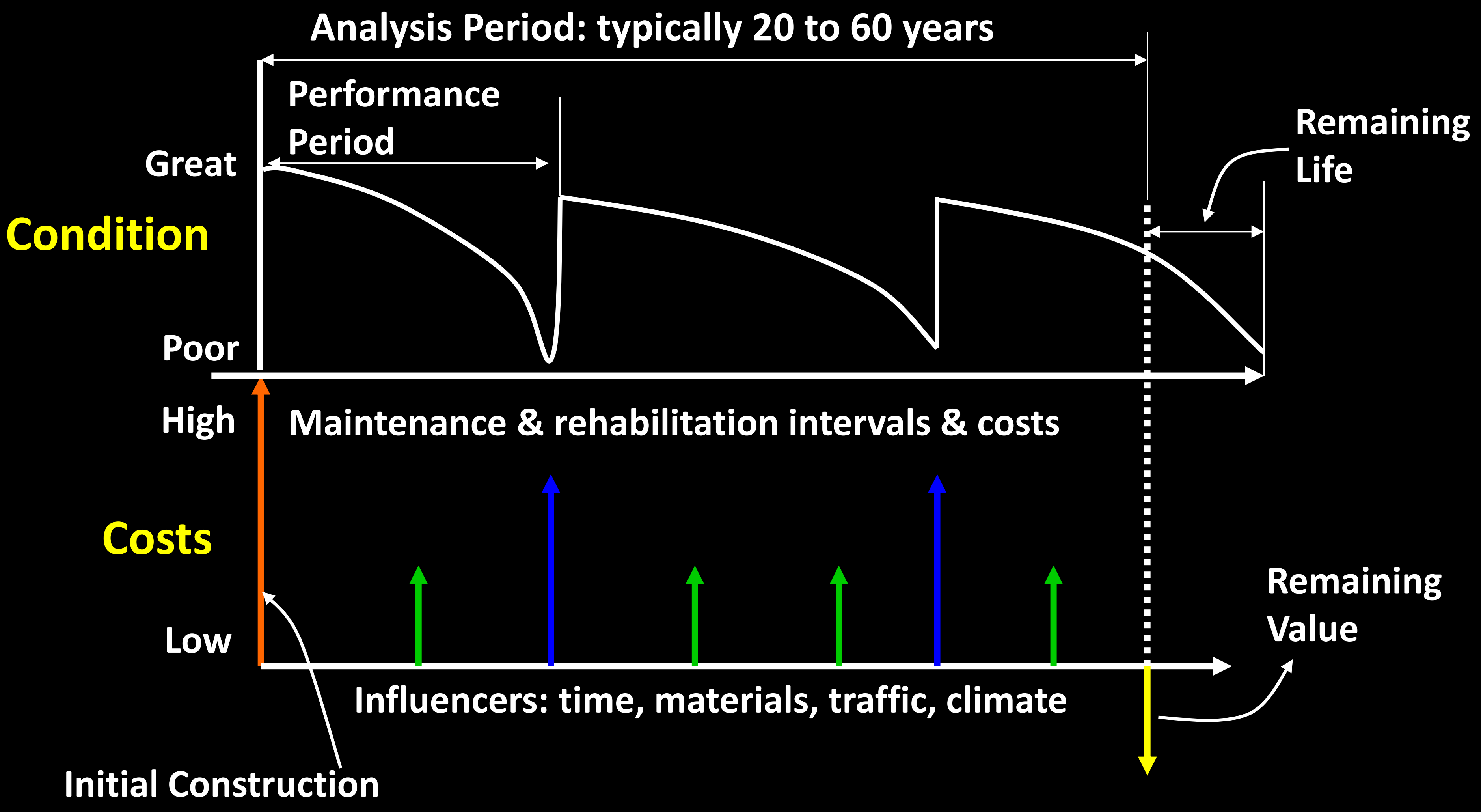


INTERLOCKING CONCRETE PAVEMENT INSTITUTE

LIFE CYCLE COST ANALYSIS SPREADSHEET
BASIC INPUT PARAMETERS

Project Description	Denver Example-2, 5M ESALS
Location	Denver, Colorado
Type of Project	Urban Pavement Design
Analysis Period	20
Discount Rate	4.0

Life-Cycle Cost Analysis Method



LCCA Case Study: North Bay, Ontario

Vacation city in northern Ontario

1984: 150,000 sf pavers in streets & walks

Roads: 14 in. aggregate base & subbase

Annual snow plowing & deicer use

8,000 vehicles per day, 5% trucks

1991: Structural testing study predicted 20+ years of performance

2003: LCCA performed, no maintenance yet

2017: After 33 years, City decides to refresh pavers in 2020

Interlocking Concrete Pavement			Asphalt Pavement		
Costs in $ per Kilometer of Each Lane (~36,000 sf / lane km): 40 year analysis, 4% discount rate					
Initial	Maintenance	Total	Initial	Maintenance	Total
$159,465	$9,072	**$168,537**	$94,256	$84,861	**$179,117**

Asphalt maintenance: Mill / overlay at 18 years (40 to 50 mm), 27 years (90 to 100 mm), & 36 years (40/50 mm). Periodic routing, sealing & patching included.

Concrete paver maintenance: $0.06/sf ($0.65/m^2) over ~40 years

LCCA Example: Off & On-site Economic Performance

LA Foundation Case Study: Canal Park, Washington, DC

Increases in:

Adjacent property values
Land/water conserved/used more efficiently
Income for landscape maintenance
Employment

Tools for Measuring Environmental & Social Performance

Sections relevant to performance measurement of segmental concrete pavement:

Site Design & Construction

Environmental Benefits

3 Water

4 Soil + Water

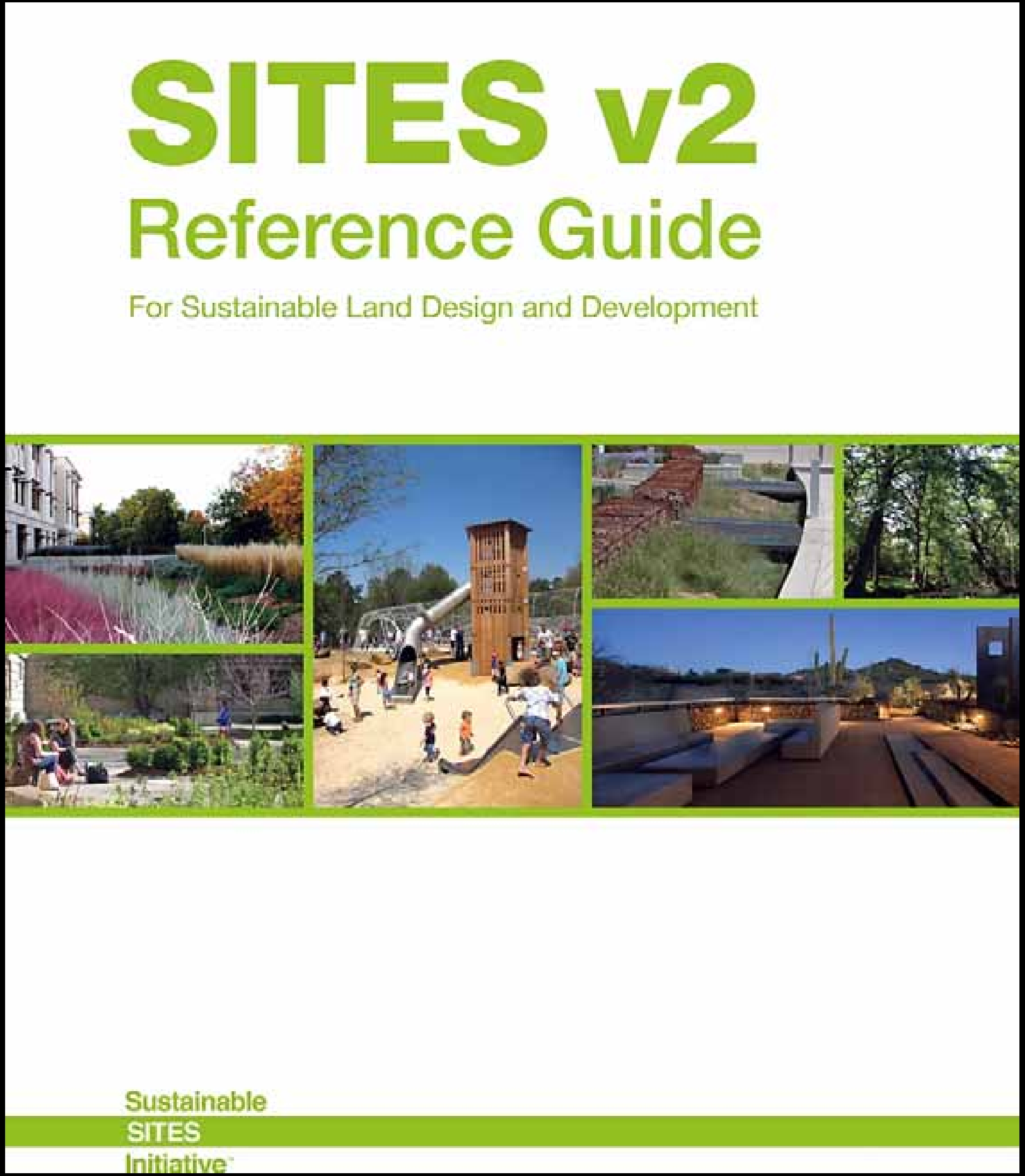
5 Materials Selection

7 Construction

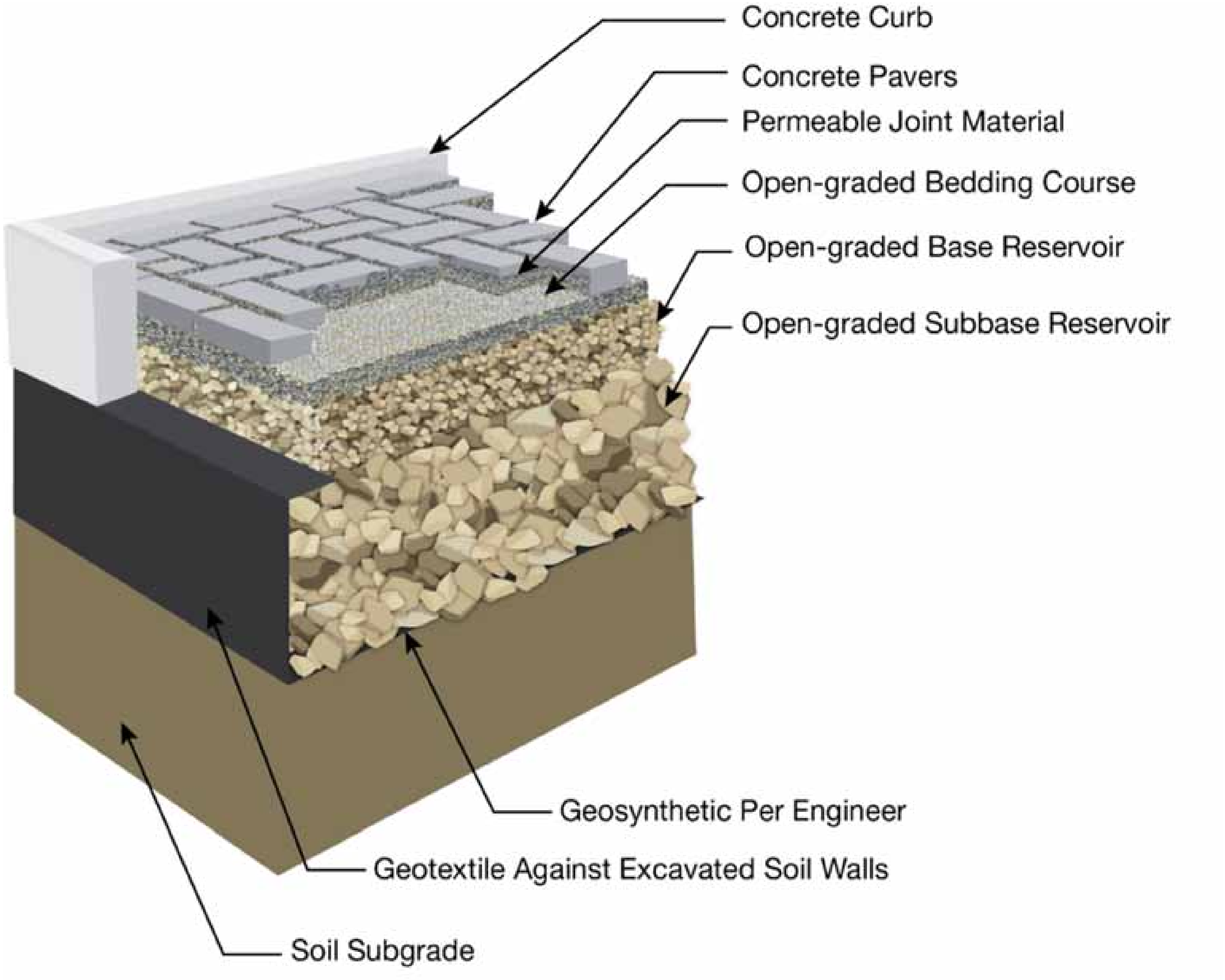
Social benefits

6 Human Health + Well-Being

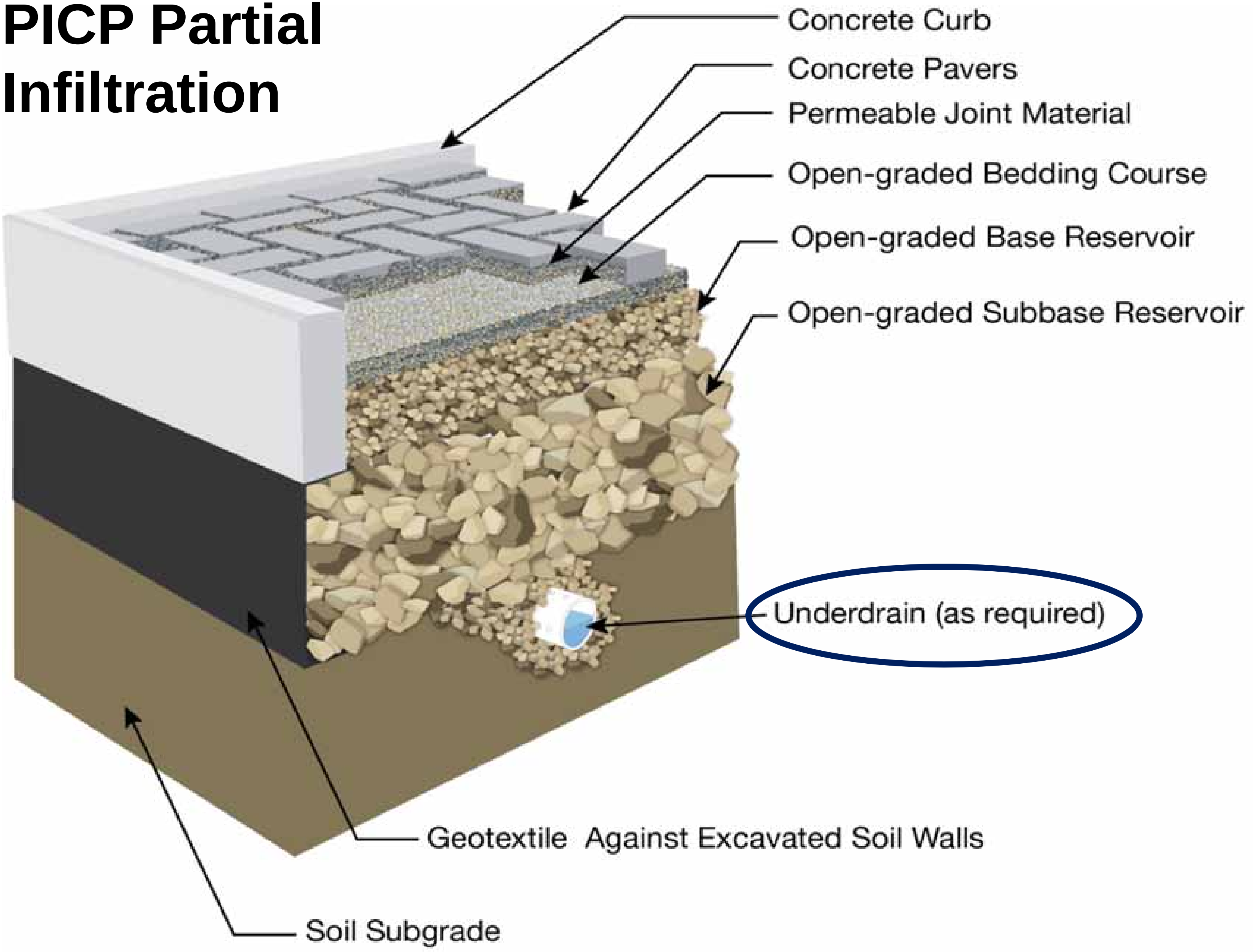
9 Education + Performance Monitoring

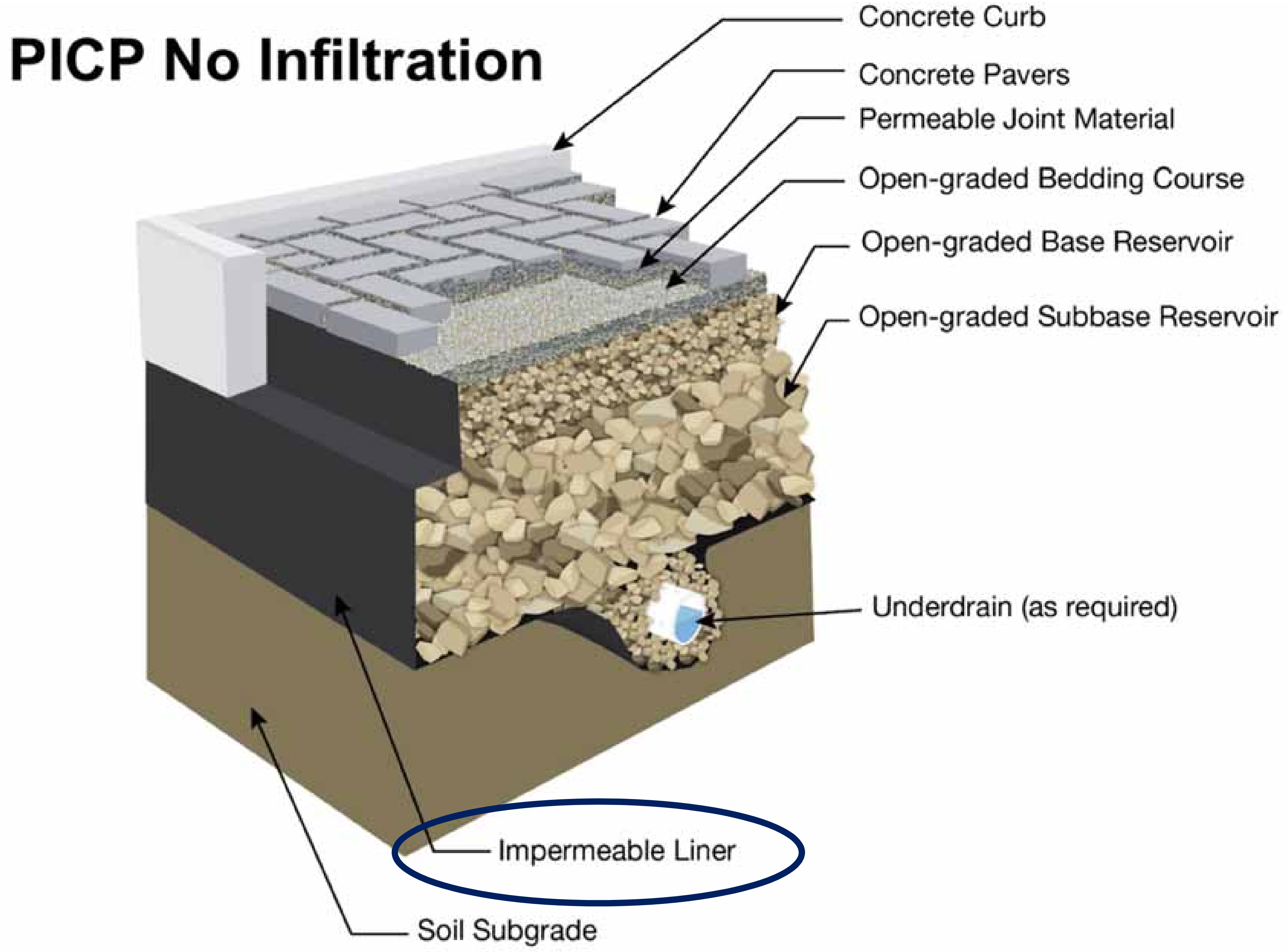


PICP Full Infiltration



PICP Partial Infiltration




PICP No Infiltration
Concrete Curb
Concrete Pavers
Permeable Joint Material
Open-graded Bedding Course
Open-graded Base Reservoir
Open-graded Subbase Reservoir
Underdrain (as required)
Impermeable Liner
Soil Subgrade

3: Site Design – Water

	PICP Infiltration Options		
Performance Criteria	**Full**	**Partial**	**No**
3.1 Required: Manage 60^{th} percentile storm event on site	■	■	■
3.2 Required: Reduce landscape irrigation by 50% or eliminate			■
3.3 Manage 80^{th}, 90^{th} or 95^{th} percentile storm event on site	■	■	■
3.4 Reduce irrigation water by 75% or no potable water use			■
3.5 Design stormwater features as amenities	■	■	■
3.6 Restore 30%, 60% or 90% of aquatic ecosystems	■	■	■

3.2 & 3.4
Water Harvesting for On-site Irrigation

Examples of no infiltration PICP

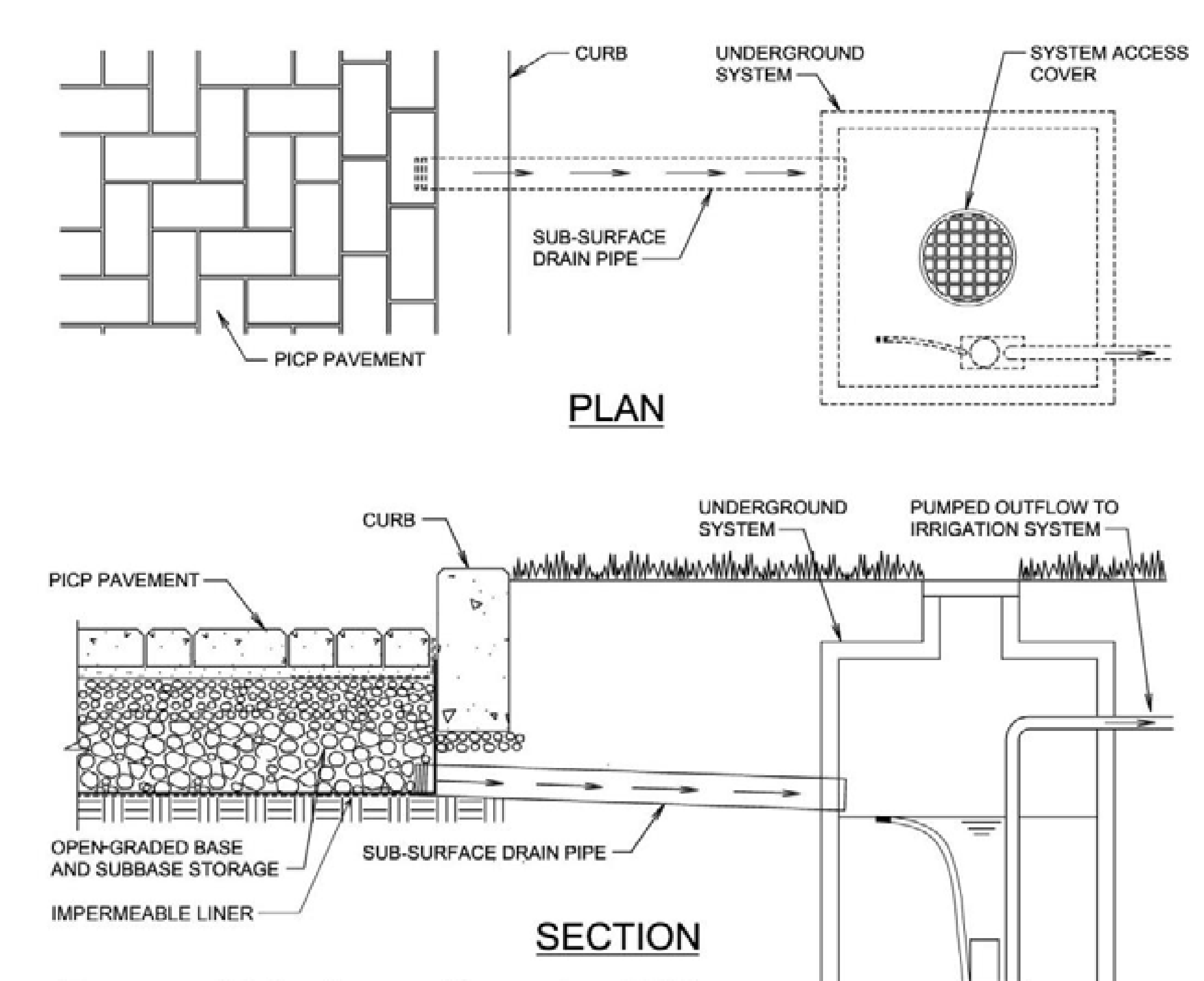
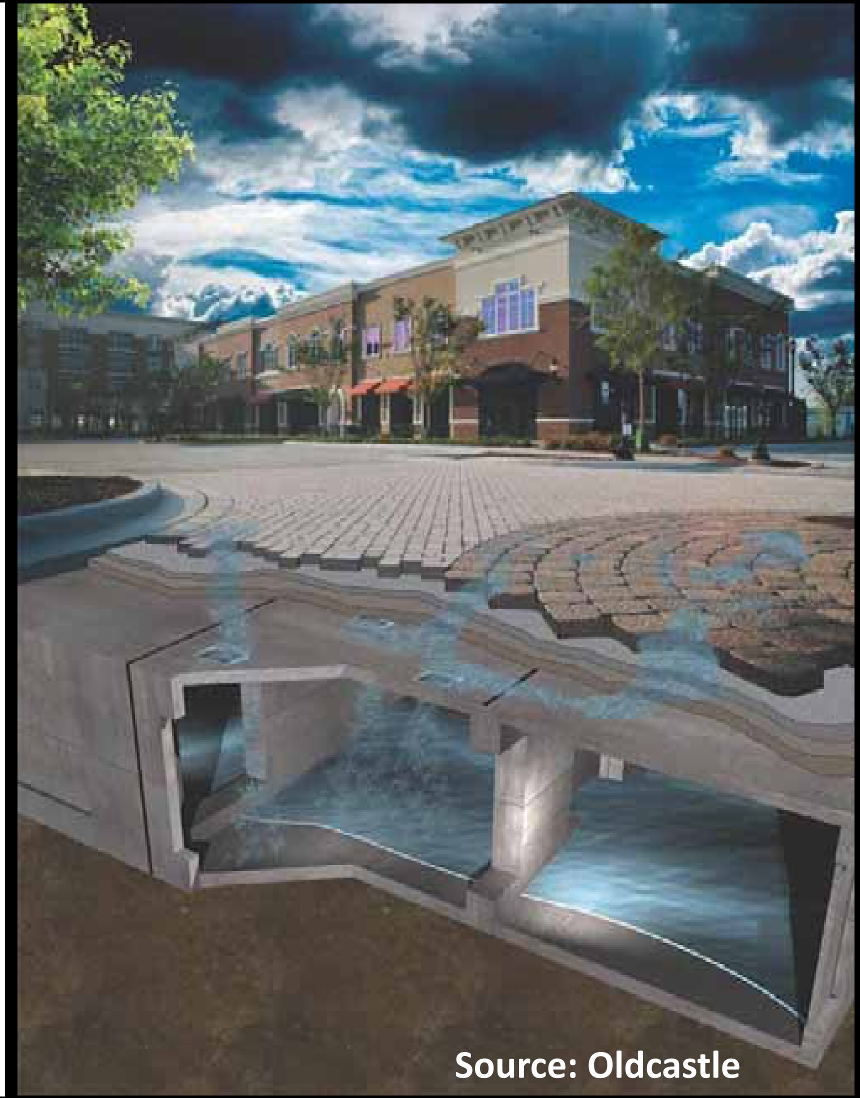


Figure 2. Water harvesting using PICP.



Source: Oldcastle

3.1 & 3.3 Manage 60th, 80th, 90th or 95th percentile storm event on site

Example: Allston Way, Berkeley, CA PICP street infiltrates the 85th percentile storm

3.5 Stormwater Amenity

50% to 100% of site stormwater features

Example:

Mary Bartelme Park

Chicago

3.6 Restore 30%, 60% or 90% of aquatic ecosystems

LA Foundation Case Study
Morton Arboretum
Lisle, IL 500-car PICP parking lot

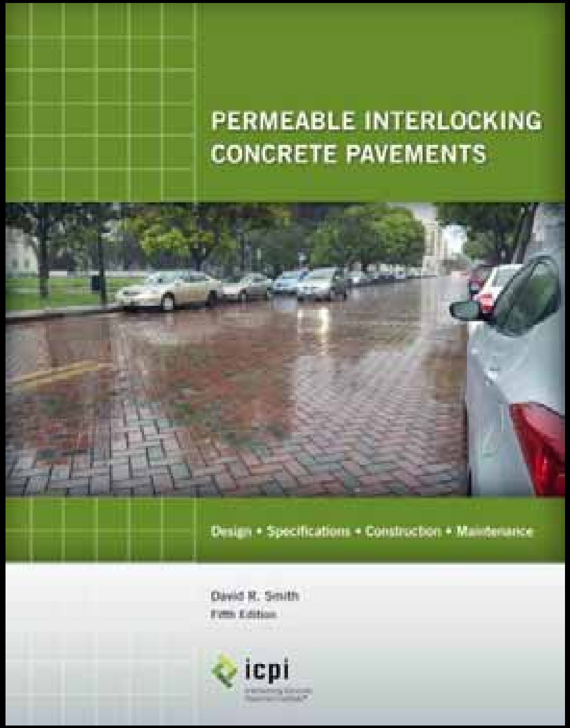
PICP reduced runoff & pollutants that helped restore the lake

Performance Tools for Measuring Stormwater Reduction

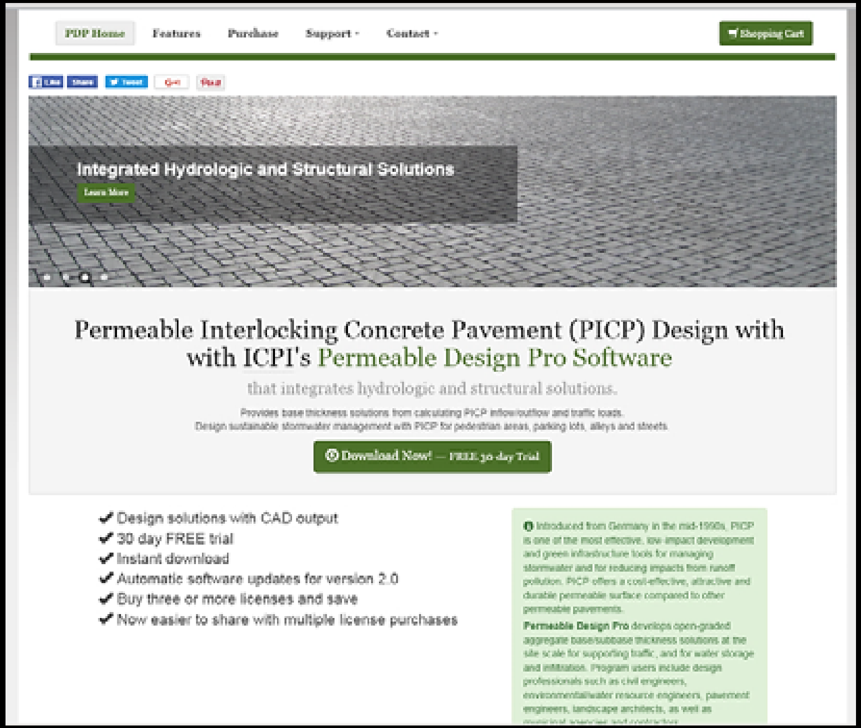
- EPA National Stormwater Calculator
- Regional EPA models
- State stormwater agency or DOT Excel sheets
- Technical Release 55: NRCS Curve Number & Nashville LID Manual

Tools:

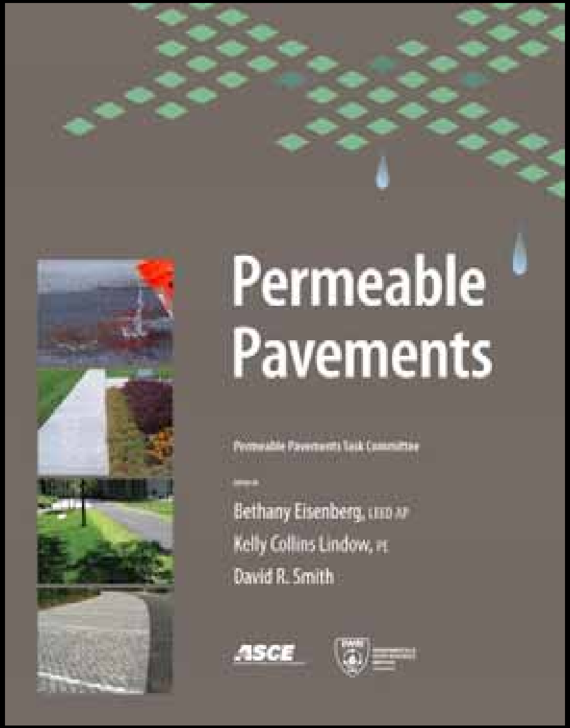
PICP Manual
www.icpi.org



www.permeabledesignpro.com

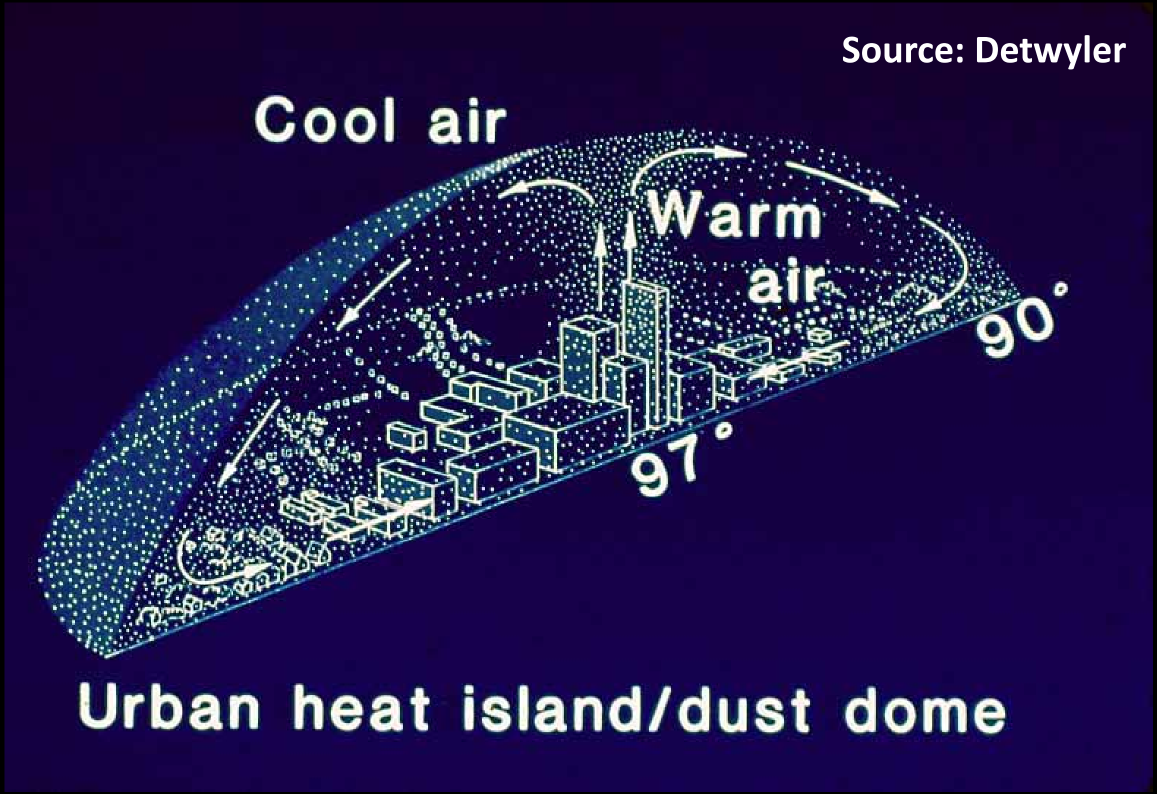


Guidebook



4: Site Design – Soil + Vegetation

4.9: Reduce Urban Heat Island Effects



Higher air pollution & summer electricity use

Biggest reductions from increasing…

- The urban forest
- Street trees
- Trees shading buildings

More reductions from increasing…

- Reflectivity (albedo) from light colored paving & roof surfaces

4.9: Non-Roof Applications

Measurement Method	Initial	3-yr aged
Solar Reflectance (Per ASTM C1549)	0.33	0.28

Concrete grids: min. 50% unbound materials – reduce microclimate temps by 3° F


Tech Spec 8

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Concrete Grid Pavements

Background

As cities grow, man-made surfaces contribute to urban heat and stormwater runoff. Heat is generated by the high concentration of pavements and buildings. It forms a dome of warm air, or an urban heat island, over cities that can be as much as 12° F (7°C) higher than outlying areas. The urban heat island also increases electricity consumption for air conditioning. This dome of heat traps dust and gases, increasing the concentrations of air pollution from automobile exhaust and industrial sources (1).

Globes. For more information on how grids can earn credits see ICPI Tech Spec 16–Achieving LEED® Credits with Segmental Concrete Pavement.

Properties of Concrete Grid Paving Units

The properties of concrete grid units are defined in ASTM C 1319, Standard

4.9: High Reflectance Roofs

Roof type	Slope	Initial SRI per ASTM E1980	3-yr aged SRI
Low-slope	≤ 2:12	82	64
Steep-slope	> 2:12	39	32

5: Materials Selection

5.3: Design for adaptability & disassembly




ICPI Resources on disassembly & adaptability

Tech Spec 6

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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.

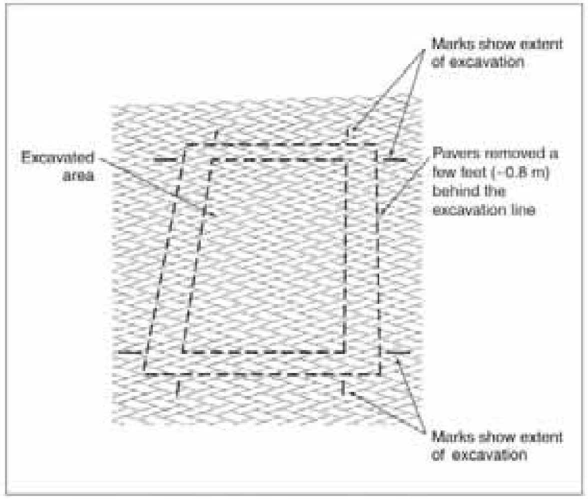

Figure 1. Pavement markings show the extent of paver removal and trench area.

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-

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Repair of Utility Cuts Using Interlocking Concrete Pavers

North American cities have thousands of utility cuts made in their streets each year. Figure 1 shows a daily occurrence in most cities: repairs to underground utility lines for water, sewer, gas, electric, steam, phone, fiber-optic, or cable services. A sample is given below of the number of annual utility cuts in a few cities.

Billings, Montana	650–730
Boston, Massachusetts	25–30,000
Chicago, Illinois	120,000
Cincinnati, Ohio	6,000
Oakland, California	5,000
San Francisco, California	10,000
Seattle, Washington	10–20,000
Toronto, Ontario	4,000

The Costs of Utility Cuts

The annual cost of utility cuts to cities is in the millions of dollars. These costs can be placed into three categories. First, there are the initial *pavement cut and repair costs*. These include labor, materials, equipment, and overhead for cutting, removing, replacing, and inspecting the pavement, plus repairs to the utility itself. Costs vary depending on the size and location of the cut, the materials used, waste disposal, hauling distances, and local labor rates.

Second, there are user costs incurred as a result of the repair. They include traffic delays, detours and denied access to streets by users, city service and emergency vehicles.

User costs depend on the location of the cut. A repair blocking traffic in a busy center city will impose higher costs and inconvenience from delays than a cut made in a suburban residential street. There are downstream costs to users from utility repairs such as lost productivity due to delays, and damage to vehicles from poor pavement riding quality. While these losses are difficult to quantify, they are very present.

The third cost is subtle and long term. It is the *cost of pavement damage* after the repair is made. Cuts damage the pavement. Damage can range from negligible to substantial, depending on the quality of the reinstated area and the condition of the surrounding pavement. The damage reduces pavement life and shortens the time to the next rehabilitation. The need to rehabilitate damaged pavements earlier rather than when normally required has costs associated with it.

Several studies have demonstrated a relationship between utility cuts and pavement damage. For example, streets in San Francisco, California, typically last 26 years prior to resurfacing. A study by the City of San Francisco Department of Public Works demonstrated that asphalt streets with three to nine utility cuts were expected to require resurfacing every 18 years (1). This represented a 30% reduction in service life

Figure 1. Repairs to utilities are a common sight in cities, incurring costs to cities and taxpayers.

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5.4: Reuse salvaged materials
10% to 20% of total project materials cost

5.5: Use recycled content materials

50% pre-consumer + post-consumer waste that constitutes
20% to 40% of all material costs

Pre-consumer content in concrete paving units:

Slag – Flyash – Silica Fume

Post consumer: recycled glass

5.6: Use regional materials from 30% to 90% of the total materials cost

Aggregates: within 50 miles of the job site

Paving units: within 500 miles

5.9: Support sustainability in materials manufacturing

Cradle-to-gate environmental impacts

A performance indicator:

Environmental Product Declarations (EPDs)

Global warming potential
Acidification
Eutrophication
Smog
Ozone
Energy use
Non-renewable material use
Renewable material use
Fresh water inputs
Non-hazardous waste
Hazardous waste

EPD “Nutrition” Label

Your Building Product

Amount per Unit

LCA IMACT MEASURES	TOTAL
Primary Energy (MJ)	12.4
Global Warming Potential (kg CO^2 eq)	0.96
Ozone Depletion (kg CFC^{-} 11 eq)	1.80E-08
Acidification Potential (mol H^{+} eq)	0.93
Eutrophication Potential (kg N^{-} eq)	6.43E-04
Photo-Oxidant Creation Potential (kg 03 eq)	0.121

Your Product's Ingredients: Listed Here

Example: Allston Way, Berkeley, CA

60 Year Pavement Greenhouse Gas (GHG) Emissions

Asphalt vs Concrete Pavers Source: 2012 UC Pavement Research Center Study

Asphalt Construction: 500k CO_2-e kg
Materials + Construction = 500k + 1,700k = 2,200k CO_2-e kg
Total installation = 3,672 metric tons CO_2
60-Year O & M = 1,836 metric tons CO_2 (mill at 10 yrs, repave at 30 yrs)
Life cycle total GHG emissions = 5,508 metric tons CO_2

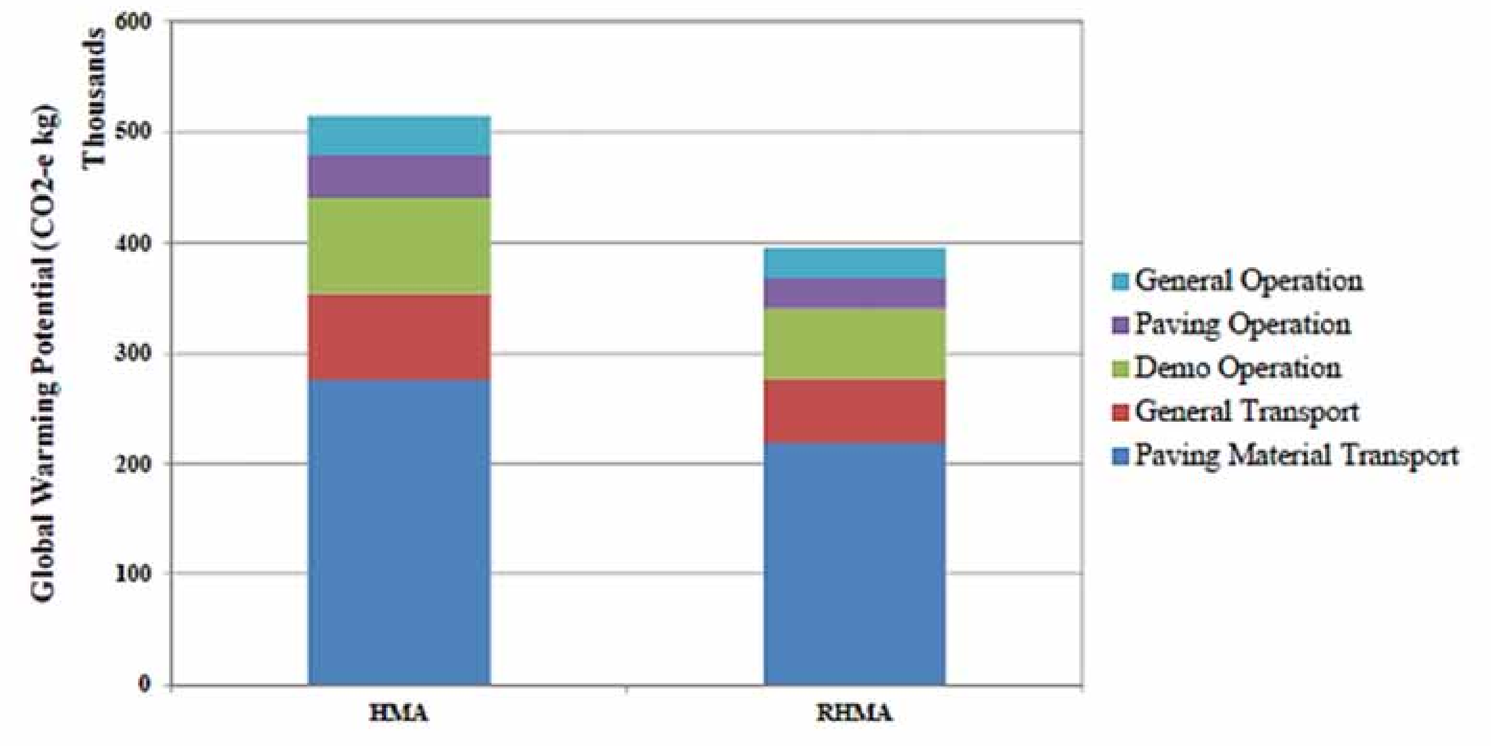

Figure 7.10: KER-5 Construction Phase: GHG emissions (metric tons).

Source: AECOM

Example: Allston Way, Berkeley, CA

60 Year Pavement Greenhouse Gas (GHG) Emissions

Concrete pavers: 350k CO2-e kg
Materials + Construction 350k + 700k = 1,050k CO2-e kg
Total installation = 447 metric tons CO2
60-Year O&M = 63 metric tons CO2 (2% pavers replaced every 8 yrs)
Life-Cycle total GHG emissions = 510 metric tons CO2

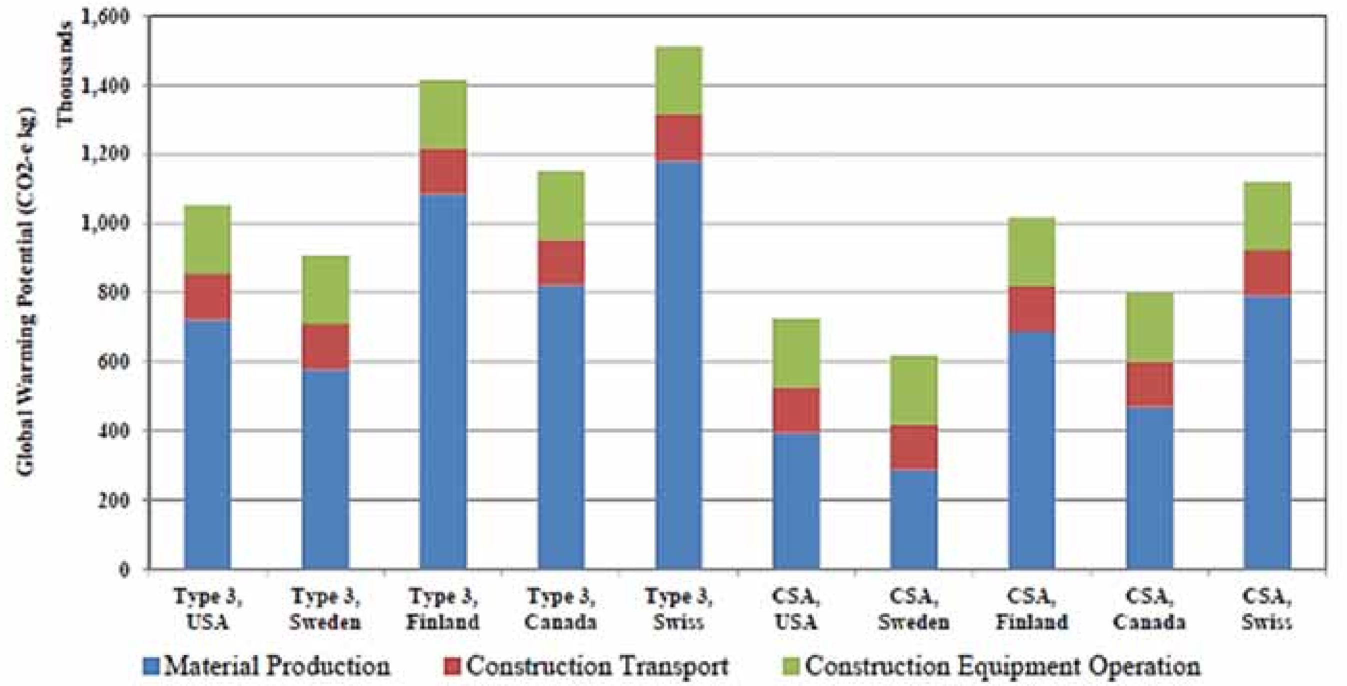

Figure 7.12: LA-5 Material Production Phase and Construction Phase: GHG emissions (metric tons) for the functional unit.
Note: These are based on LCIs from five different regions. However, each LCI was updated and recalculated to reflect California conditions (i.e., the California-specific electricity mix).

PICP produces 90% less GHG

Source: AECOM

Construction Environmental Performance

7.7 Protect air quality during construction

Limit unnecessary idling to no more than five minutes in any 60-minute period
Preventive maintenance plan for equipment
Use ultra-low sulfur diesel fuel 15 ppm for all non-road diesel equipment
50 percent of total run-time equipment hours has Tier 1 engines

Emerging: Bid tons of CO_2 emissions per pay item

Construction Environmental Performance

7.7 Protect air quality during construction

Mechanical Installation
Reduced emissions, tier 1 engines
5-8,000 sf/day per machine crew
PICP installed in rain

ICPI Resources on Mechanical Installation

Tech Spec 11

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Mechanical Installation of Interlocking Concrete Pavements

Mechanical installation originated in Germany and the Netherlands in the late 1970s. The growth of street, port, and airport projects required timely installation with fewer workers. Machines were developed to increase productivity while reducing fatigue and injury (1–4). Today, over 5,000 mechanical installation machines operate in Germany alone with thousands more in use throughout Europe. They are used for projects as small as 10,000 sf (1,000 m²) (5).

Mechanical equipment was first introduced in North America in the early 1980s. The first mechanically installed project was placed in 1981, a 1,000,000 sf (93,000 m²) container terminal in Calgary, Alberta. Since then, hundreds of commercial, municipal, port, and airport jobs have been installed mechanically in most states and provinces across North America. Some examples include city streets in Dayton, Ohio (the first mechanically installed street in the U.S.) (6); Cincinnati, Ohio; Toronto, Ontario; Northbrook, Illinois; Naples, Florida; and Palm Desert, California; container yards in Tampa, New Orleans, Baltimore, and Oakland; and an airfield at St. Augustine, Florida.

Mechanical installation must be viewed as a system of material handling from manufacture to on-site placement of the concrete pavers. This technical bulletin provides guidelines for the manufacturer, designer, and contractor of mechanically installed pavements in order to realize high efficiencies from this system of material handling. Successful mechanical installation relies on four factors that affect efficiency and costs. These include:

1. Equipment specifically designed to efficiently handle
   (a) transport of packaged concrete pavers onto/around the site,
   (b) screeding of bedding sand,
   (c) installation of the concrete pavers.

Figure 1. Mechanical installation equipment at Port of Tampa, Florida.

Figure 2. A cube of 90° herringbone pattern rectangular pavers ready for installation.

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Tech Spec 15

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A Guide for the Specification of Mechanically Installed Interlocking Concrete Pavements

Introduction

This guide assists design professionals in developing a construction specification for the mechanical installation of interlocking concrete pavement. The core is the Quality Control Plan that requires a high level of planning and detail for executing large-scale projects. When refined into a project specification, it should be a tool to obtain a commitment to its requirements by the General Contractor (GC), paver installation subcontractor, manufacturer, and facilitate coordination among them. The ultimate outcome is increased assurance for owners of large paved facilities.

The contractual relationships among the owner, engineer, GC, subcontractors, and manufacturers (suppliers) will vary with each project. This guide assumes that an engineer works for the owner who hires a GC to build the project. The GC subcontracts to a company specializing in interlocking concrete paving. The GC or subcontractor purchases pavers from a paver manufacturer. The engineer or other employees working for the owner inspect and accept the paving.

Construction specifications in North America follow various formats. A common one is by the Construction Specifications Institute (CSI) called MasterFormat (2004) and this guide is written to fit this format. Specifications using the CSI format sections have three parts; General, Products, and Execution. This guide is divided into these three parts to assist in writing each.

This Tech Spec does not include material or installation guidelines for permeable interlocking concrete pavement (PICP) installations. See the ICPI manual *Permeable Interlocking Concrete Pavements*, available at ICPI.org.

1.0 PART 1—GENERAL

This specification guide includes the installation of interlocking concrete pavers with mechanical equipment, bedding and joint sand and optional joint sand stabilization materials. *ICPI Tech Spec 11–Mechanical Installation of Interlocking Concrete Pavements* (ICPI 2004) should be consulted for additional

Figure 1. Mechanical installation of interlocking concrete pavements (left) and permeable units (right) is seeing increased use in industrial, port, and commercial paving projects to increase efficiency and safety.

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Designer decisions:

Paver pattern

Layout to reduce cutting

Social Performance

Pattern Language

Suggest direction & pace

Random

45° Herringbone

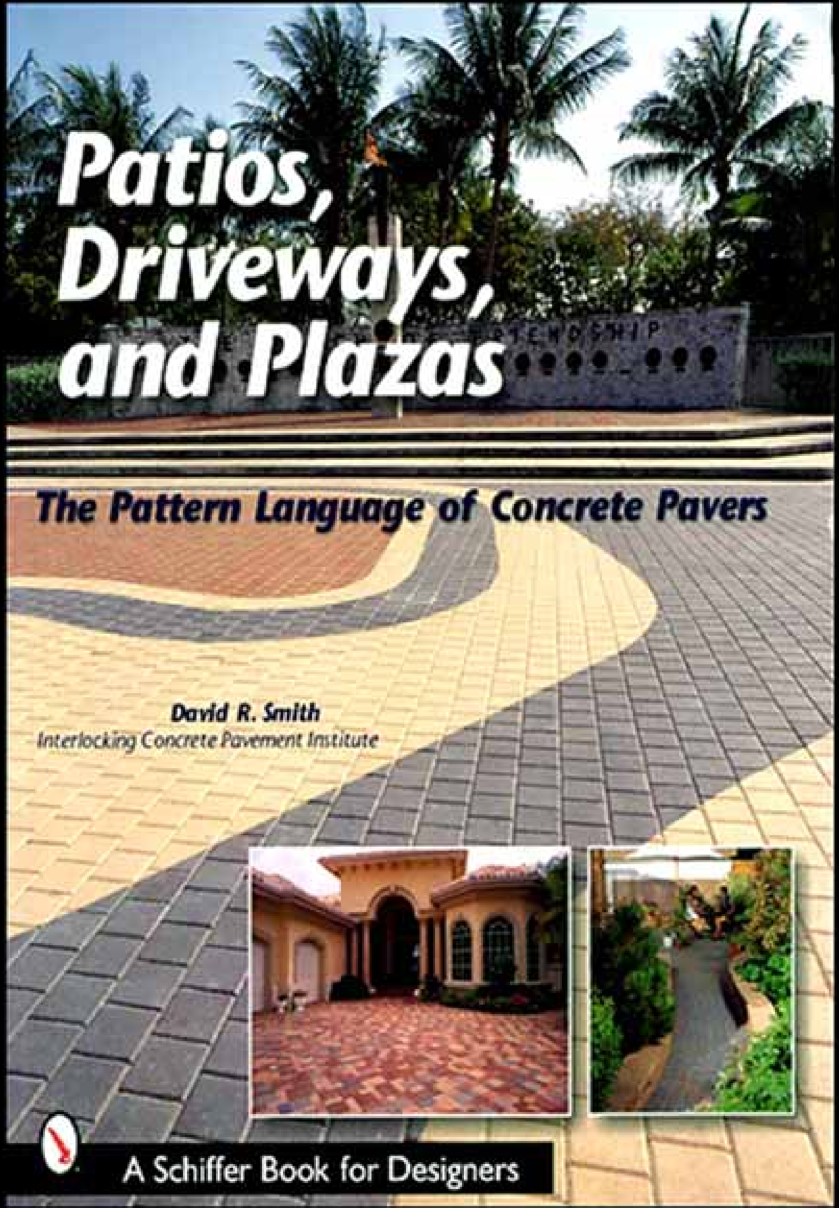
90° Herringbone

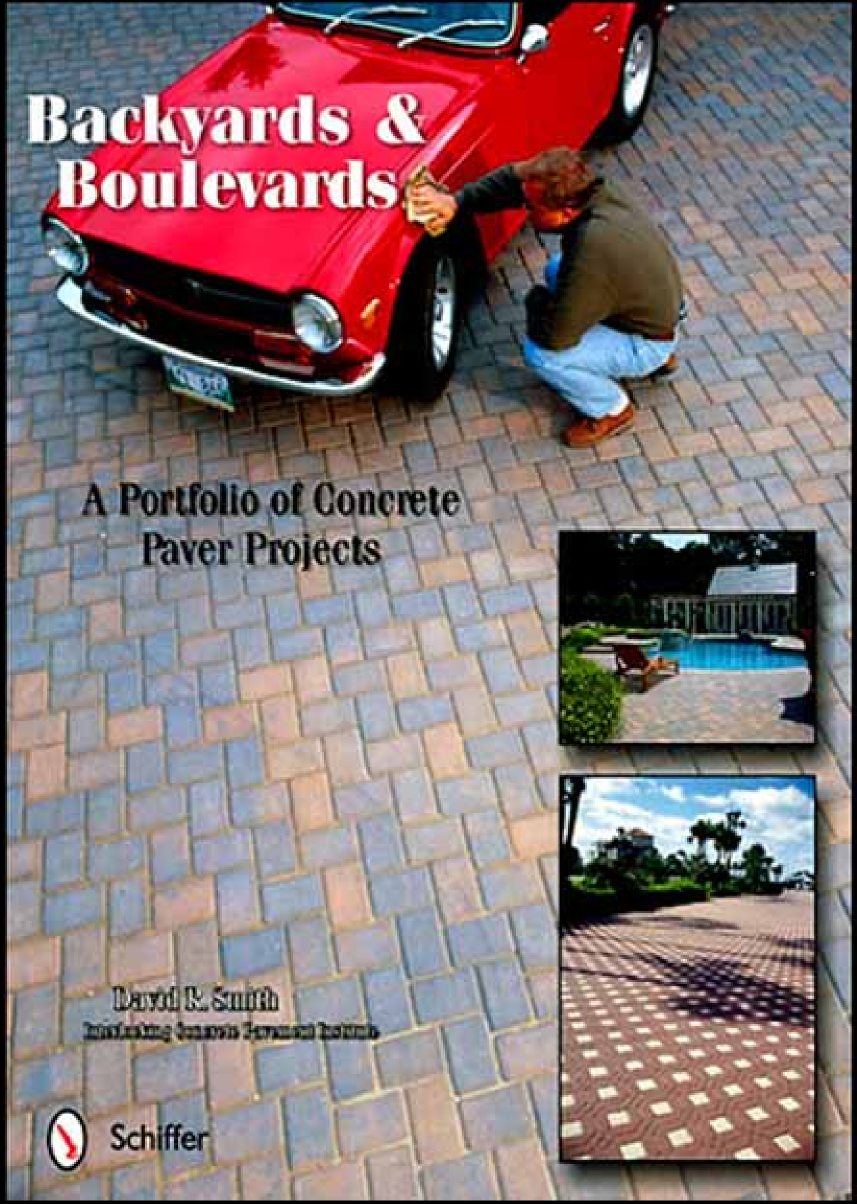
Running bond

Stack bond

ICPI Resources

Explores social language of segmental concrete paving





6.2: Provide optimum site accessibility, safety, & wayfinding

Wayfinding:

Clear entrances & gateways
Viewpoints & sight lines
Landmarks
Decision points or nodes
Hierarchy of ped & vehicular circulation
Distinct areas & regions
Orientation devices & systems
Maps & brochures


STOP VIOLA-TING HUMAN
RIGHTS IN TIBET
STOP THE KILLING IN TIBET

6.2: Provide optimum site accessibility, safety, & wayfinding

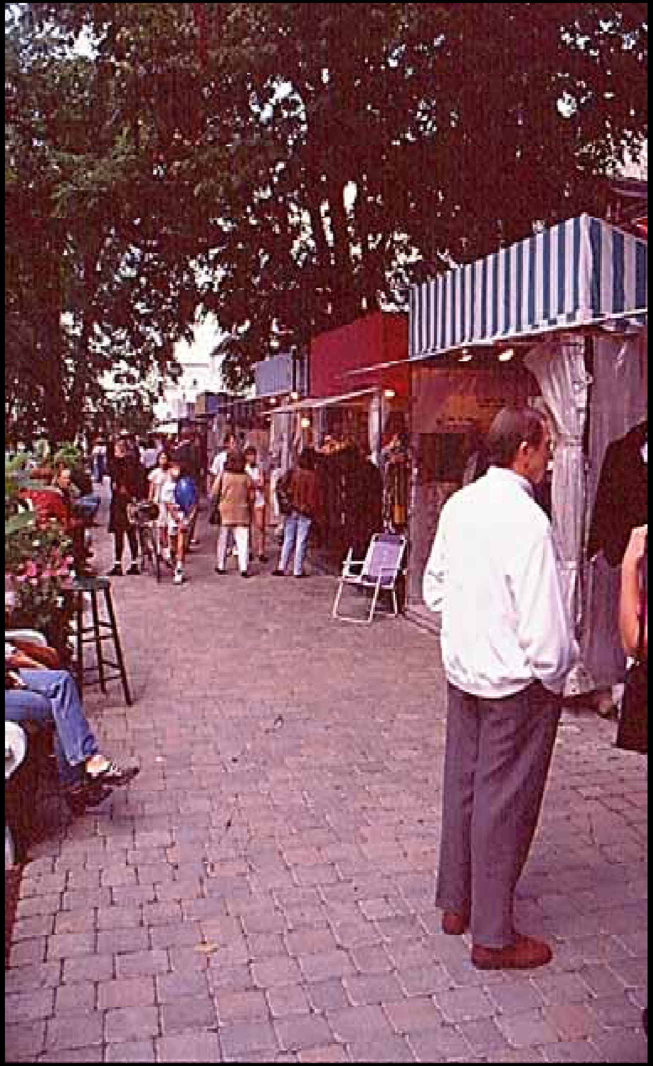
Safety via traffic calming




6.6: Support social connection

- Seating for min. 10% site users accommodating a variety of group sizes appropriate to the site
- Elements addressing microclimate and other site-specific conditions (e.g., sun, shade, wind)
- Amenities, services, or activity spaces (e.g., games, wireless access, food concessions, picnic or dining areas, outdoor auditoriums, playgrounds, farmers' markets)

6.6: Support social connection



Measuring Social Performance

User surveys - Pedestrian environmental quality index (PEQI)
Reduced / eliminated crime
Viewshed analysis / improvement
Increased amenities supporting site history
Increased recreation activities / participation
Self-guided educational activities

Case Study Example: Advocate Lutheran General Hospital Patient Tower
Reduced stress in 50% of patients

Assembly Selection Guide

Surface Bedding Options	Min. Unit Thickness Pedestrian, In. (mm)	Pedestrian Base Options	Min. Unit Thickness Vehicular, in. (mm)	Vehicular Base Options
Interlocking	2 3/8 (60)		3 1/8 (80)	
Sand 1 in. (25 mm)		DGA		DGA, cement or asphalt stabilized, asphalt or concrete
Sand-bitumen ¾ in. (15 mm)		Asphalt or concrete		Asphalt or concrete
Mortar		Concrete		N/A
Permeable Interlocking	2 3/8 (60)		3 1/8 (80)	
ASTM No. 8 stone 2 in. (50 mm) No. 8, 89 or 9 in joints		Open-graded aggregate		Open-graded aggregate, asphalt or cement treated permeable bases

DGA = Dense-graded aggregate

Assembly Selection Guide

Surface Bedding Options	Min. Unit Thickness Pedestrian, in. (mm)	Pedestrian Base Options	Min. Unit Thickness Vehicular, in. (mm)	Vehicular Base Options
Slabs	2 (50)		3 1/8 (80)	
Sand 1 in. (25 mm)		DGA or concrete		Concrete or asphalt
Sand-bitumen ¾ in. (15 mm)		Concrete or asphalt		Concrete or asphalt
Mortar		Concrete		N/A
Planks	3 1/8 (80)		4 (100)	
Sand 1 in. (25 mm)		DGA or concrete		Concrete or asphalt
Sand-bitumen ¾ in. (15 mm)		Concrete or asphalt		Concrete or asphalt
Mortar		Concrete		N/A
Grids	3 1/8 (80)		3 1/8 (80)	
Sand ½ - 1 in. (13-15 mm)		DGA		DGA

Structural Performance Limits

	Pedestrian	Automobiles	Lifetime ESALs*	Typical Vehicular Applications
Interlocking	Yes	Yes	< 10 million	Streets, parking lots, entries, crosswalks
Permeable Interlocking	Yes	Yes	< 1 million	Residential streets, on-street parking, alleys, parking lots
Slabs	Yes	Limited	< 75,000	Plazas
Planks	Yes	Limited	< 30,000	Plazas
Grids	Yes	Limited	< 7,500	Intermittent parking

*ESALs = 18,000 lb equivalent single axle loads


Tech Spec 4

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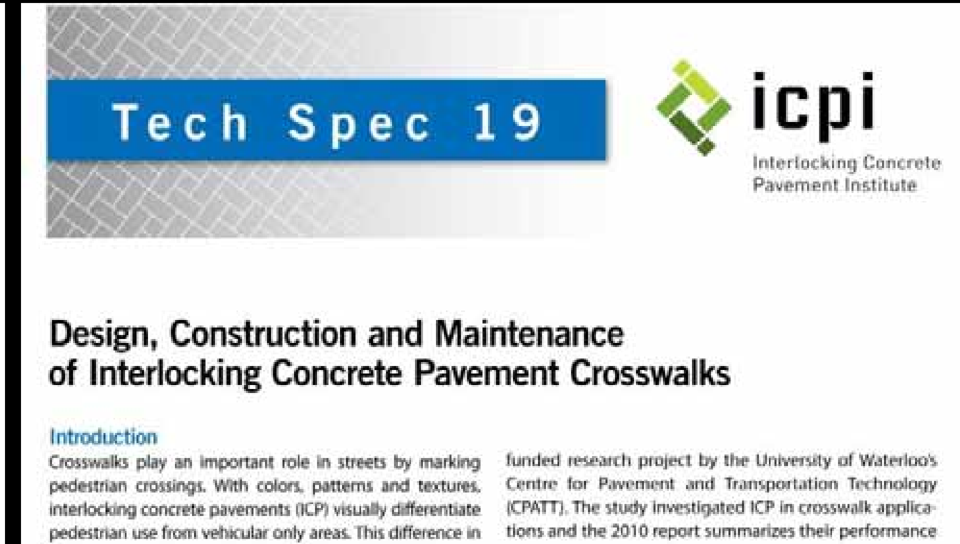
Structural Design of Interlocking Concrete Pavement for Roads and Parking Lots

History

The concept of interlocking concrete pavement dates back to the roads of the Roman Empire. See Figure 1. They were

from petroleum products or indentations from high temperatures. Once installed, there is no waiting time for curing. The pavement is immediately ready for traffic. Cracking and degradation of the surface is minimized because of the numerous joints (and sand in them) which act as a means for load transfer without damaging the pavement surface. Like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Design, Construction and Maintenance of Interlocking Concrete Pavement Crosswalks

Introduction

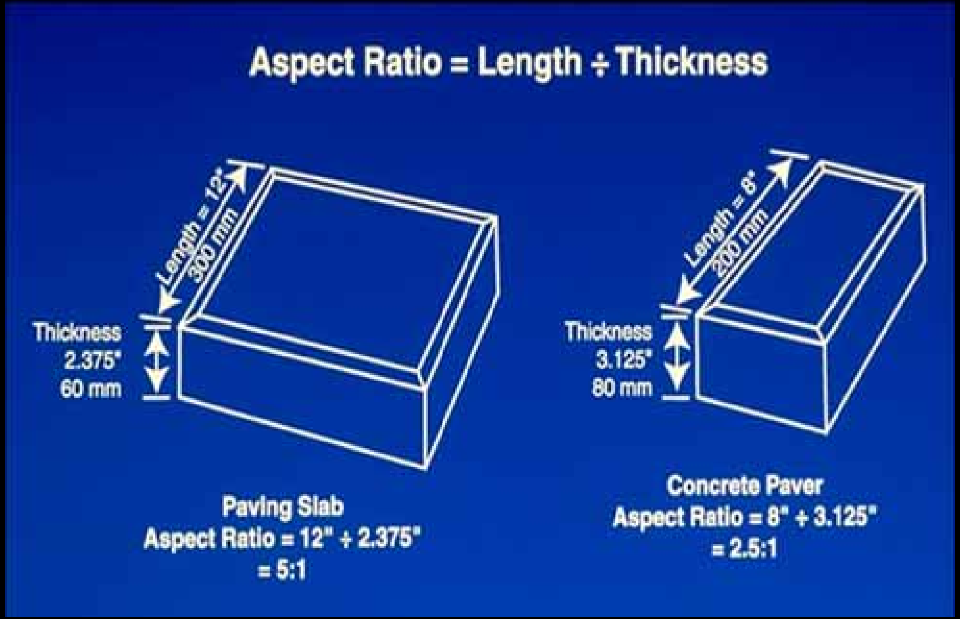
Crosswalks play an important role in streets by marking pedestrian crossings. With colors, patterns and textures, interlocking concrete pavements (ICP) visually differentiate pedestrian use from vehicular only areas. This difference in

funded research project by the University of Waterloo's Centre for Pavement and Transportation Technology (CPATT). The study investigated ICP in crosswalk applications and the 2010 report summarizes their performance

Slab, Plank & Grid Structural Performance in Vehicular Traffic

Best Practice
Aspect ratio =
length ÷ thickness
Vehicular: 3 max
Residential drives: 3 to 4
Pedestrian: > 4

	Pedestrian	Automobiles	Lifetime ESALs*	Typical Vehicular Applications
Slabs	Yes	Limited	< 75,000	Plazas
Planks	Yes	Limited	< 30,000	Plazas
Grids	Yes	Limited	< 7,500	Intermittent parking



Hotel entrance: 4 x 18 x 3 1/8 in. thick planks, base unknown, 7 months old

Some Wisdom on Measuring Performance

"Every tool carries with it the spirit by which it has been created."

**"Since the measuring device has been constructed by the observer…
we have to remember that what we observe is not nature in itself but nature exposed to our method of questioning."**

- Werner Karl Heisenberg
Physics and Philosophy **1958**

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