Permeable Interlocking Concrete Pavements for Stormwater Management



- Contents
- Regulatory Requirements
- Sustainable Design
- Structural Design
- Construction
- Maintenance
- Costs and Comparisons

Challenges Facing Port Expansion

Regulatory Requirements

- Reduce Runoff
- Treatment
- Storing and Infiltrating

The Result! Loss of Land to Detention Facilities

Possible Solutions

- LID
- Infiltration with BMP's
- Design for Storage

The Result! Reducing or Eliminating Detention Ponds



Swank, W.T., and Crossley, D.A. 1988. Forest Hydrology and Ecology at Coweeta. New York, NY: Springer-Verlag.

Hydrology Comparison

Engineered System



Detention Under Pavement







1,000 trucks in 60 days





Water Quality

First Flush Pollutants

Hydrocarbons
Total Suspended Solids
Nitrates
Phosphates
Heavy Metals

Conventional Pavement Promotes

Sustainable Site Pavement Systems

LID Treatment Train Approach UCF Stormwater BMP Analysis Model

PERVIOUS PAVEMENT:					Blue Numbers = Red Numbers =	Input data Answers						
CONTRIBUTING WATERSHED AND PERVIOUS PAVEMENT CHARACTERISTICS:				GO TO STORMWATER TREATMENTANALYSIS								
Pervious Pavement Section Storage Calculator (S')			VIEW TYPICAL PERVIOUS PAVEMENT SYSTEM SCHEMATIC									
Layer	Thickness (in):	Void Space (%):	Storage (in):	Contributing watershed are	a:	4.000 ac						
Permeable Pavers	3.13	10.00	0.313	Required treatment efficien	cy <mark>(Nitrogen</mark>):	-135.726 %						
Other Perv. Pvmt. (see note below)		Ì		Required treatment efficien	cy (Phosphorus):	56.720 %						
#57 rock	4.00	21.00	0.840	Storage provided in specific	ed pervious pavement system:	3.573 in						
#89 pea rock	2.00	25.00	0.500	Area of the pervious paven	nent system:	4.000 ac						
#4 rock	8.00	24.00	1.920	Provided retention over the	e contributing watershed area:	3.573 in						
Recycled (crushed) concrete		21.00		Provided treatment efficient	cy (Nitrogen):	96.811 %						
Bold and Gold [™]		9.00		Provided treatment efficient	cy (Phosphorus):	96.811 %						
Other Sub Base (see note below)												
products in this in the BMP2A© does not represent an endorsement, approval or rejection by any regulatory agency.			Remaining treatment efficie Remaining treatment efficie Remaining retention depth	ency needed (Nitrogen) : ency needed (Phosphorus) : needed if retention:	0.000 % 0.000 % 0.000 in							
Note: For other pervious pavement sections and / or other sub-base sections, the user must have the appropriate certified "operational void space percentages" from a licensed geotechnical laboratory.				100 90 		Efficiency Curve						
	ERROR MESSAGE WINDOW FOR PERVIOUS PAVEMENT:											
				40 40 30								
NOTE FOR TREATEMENT	EFFICIENCY	GRAPH:				System Efficiency (N \$ P)						
The purpose of this graph is to help illustrate the treatment efficiency of the retention system as the function of retention depth. The graph illustrates that there is a point of diminished return as the retention depth is substantially increased. Therefore, to provide the most economical BMP treatment system, other alternatives such as "treatment trains" and compensatory treatment should be considered.			10 0.00 0.50 1.00 1 Rete	L.50 2.00 2.50 3.00 3.50 4.00								

Pervious Paven

Pinellas Park Success Story 1.25 Acre feet of storage

ASCE/ ASCE STANDARD

58-10

Structural Design of Interlocking **Concrete Pavement** for Municipal Streets

This document uses both the International System of Units (SI) and customary units

ASCE

Structural Design

Based on 1993 AASHTO – Guide for **Design of Pavement** Structures.

STRUCTURAL DESIGN for ICP: ASCE 58-10

PICP System **Design** in Florida

SUBGRADE EVALUATION - CBR

PICP System Design & Utilization

Climate	No Frost	No Frost	No Frost	o Frost No Frost Frost		Frost	Frost	Frost		
ESALs* (Traffic Index)	Soaked CBR Base Subbase (R-value)	> 5 (>24)	10-14 (18-23)	5 to 9 (11-17)	Gravelly Soils	Clayey Gravels, Plastic Sandy Clays	Silty Gravel, Sand, Sandy Clays	Silts, Silty Gravel, Silty Clays		
Pedestrian	No. 57	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)		
	No. 2	6 (150)	6 (150)	6 (150)	6 (150)	6 (150)	6 (150)	6 (150)		
50,000	No 57	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	**		
(6)	No. 2	8 (200)	8 (200)	8 (200)	8 (200)	8 (200)	8 (200)			
150,000	No. 57	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	4 (100)	**		
(7.2)	No. 2	8 (200)	8 (200)	8 (200)	8 (200)	8 (200)	10 (250)			
600,000 (8.5)	No. 57 No. 2	4 (100) 8 (200)	4 (100) 8 (200)	4 (100) 10 (250)	4 (100) 8 (200)	4 (100) 14 (350)	4 (100) 18 (450)	**		

ESAL (Estimated Standard Axle Load) / TI (Traffic Index)

Summation of the equivalent 18,000 Ibs-f single axle loads over the design life

ESALS / TI

$$TI = 9.0 \times \left(\frac{ESAL}{10^6}\right)^{0.119}$$

The second se	
ESALs	Traffic Index
10,000	5.2
20,000	5.7
50,000	6.3
100,000	6.8
200,000	7.4
500,000	8.3
1,000,000	9.0
2,000,000	9.8
5,000,000	10.9
10,000,000	11.8

PICP System Design in Florida

PICP systems serve as both a <u>Structural</u> and <u>Hydrological</u> Analyses - need to consider traffic, soil strength and infiltration, design storm, contributing area & storage volume.

SYSTEM DESIGN

PICP System Design & Utilization

Structural Number

Pavers Bedding 5-1/8" ai 0.3 = 1.538

Bas**e** 4" ai 0.09 = 0.36

Base 10 ai 0.06 = 0.60

SN = 2.498

SN = structural number of the pavement, calculated as $\Sigma a_i \times d_i$, where a_i = structural layer coefficient per layer *i*

 d_i = layer thickness per layer i

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Project: Example 2 US Customary	 Units Imperial 	•))• 🕒• 😭	ø 🗋 🖆							
Definition	Geometry					Report				₽
Pavement Structure	Pavement Geometry						1 of 1 🕨 🕅	- 🗧 🖪 🛃 🗐 🚽	100%	Ŧ
Pavement Geometry	Transformi					ICP	[ASA]	Permeable Interlocking Co	ncrete Pavements	^
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🕂 🏹 Resilient Modulus	and the first of the first of	Length 500	ft			Cite Information	•	Design Title: Example 2	US Customary	
🖃 🥐 Granular Layer		Width 50	ft			Site informati	ion	Povement Length	500 ft	
Configuration	Pa	avement Area 25,000	ft²					Pavement Width	50 ft	
Subbase								Pavement Area	25,000 ft	
Porosity								Catchment Area	25,000 ft (Avg CN=73.2)	
🖃 🔻 Base	Base Runoff from contributing area does not exist				Laver Informa	ation Desing Lever	Structural Coofficient	2		
Porosity	Contributing Area				Pavilig Layer		Structural Number	.5 1.5 in		
Paving Layer Structural Design	Description	Area of Contributing	Curve	Roughness Av	Average			Thickness	5.1 in	
Traffic	Soccer Field	Surrace (re)	Number	Loerricient Sid	pe (%)	I	Base Material	ASTM No 57 Stone		
Provide the second s	Asphalt Roadway	2,400	98	.011	2			Structural Coefficient	0.05	
 Precipitation 	*							Structural Number Thickness	0.2 m 4 0 in	
V Storm Pattern								Porosity	0.288	
Volume								Void Ratio	0.4	
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PERMEABLE DESIGN PRO SOFTWARE icpi.org

😵 Permeable Design Pro

PICP System Design in Florida

HS 20 Rated

8 acres Permeable Pavement

McCord Toyota

Sustainable Site Pavement Systems

Construction

- Interlocking Concrete Pavers
 - Min. 80 mm thick conform to ASTM C936
 - 45° or 90° herringbone pattern
 - ICPI Certified contractor
- Clean washed aggregate essential

TECH SPECH 18

 Construction of Permeable Interlocking Concrete Pavement Systems. Available at: icpi.org

Use stakes (except with liners) to hold the material in place.

CONSTRUCTION – Geotextile

PICP System Design & Utilization

Construction

Mechanical placement

Edges cut, placed then compacted

Construction

Filling the openings with No. 8 stone

Final Compaction

Immediately ready for use

Immediately ready for traffic

Action	Frequency
Maintain perimeter vegetation	Ongoing
Check outlets are clear of debris	Ongoing
Sweep surface debris	Twice a year
Vacuum and replenish jointing material	When surface ponding observed (2-10 years)
Repair ruts/deformations exceeding $\frac{1}{2}$ " (13mm)	As required
Reset pavers that are more than $\frac{1}{4}$ " (6mm) above adjacent	As required
Replace broken pavers	As required
Replenish jointing material if more than $\frac{1}{2}$ " (13mm) from chamfer bottom	As required

MAINTENANCE SCHEDULE

PICP System Design & Utilization

Estimated 15-20 year cycles

Vacuum Type Sweeper

Remedial Maintenance

Maintenance: Spot

Temporary plastic or metal edge spiked around opening perimeter

Repairs

Reinstate same pavers No curing time – ready for traffic **Minimal operations interruption**

Costs

Assumptions:
3 1/8 in. thick pavers
2 in. bedding layer
12 in. base with Geotextile

5,000 s/y \$55.00 s/y

Does *not* include concrete curbs

Cost Saving Opportunities

Eliminate Traditional Conveyance Systems Reduce or Eliminate Detention Ponds

TERMINOLOGY – FULL EXFILTRATION

PICP System Design & Utilization

TERMINOLOGY – PARTIAL EXFILTRATION

PICP System Design & Utilization

"Old School Stormwater

When BMP = Big Muddy Pond

www.bae.ncsu.edu/stormwater

Life Cycle Cost Analysis

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Port of Baltimore Seagirt & Dundalk Terminals

190,000 m² 1987-2005

120MM CONCRETE BLOCK PAVERS 1" SAND BEDDING 8" CONVENTIONAL ASPHALT CONCRETE 8" DENSE GRADED AGGREGATE

Seagirt wharf

120MM CONCRETE BLOCK PAVERS 2" SAND BEDDING 8 1/4" GRADED AGGREGATE MODIFIED ASPHALT SUBBASE

VARIABLE DEPTH, 6" MINIMUM

GRANULAR SUBBASE VARIABLE DEPTH

Dundalk wharf

ort and Industrial-36

Port of Oakland, CA

470,000 m² 2001-04

Berths 55-59 Pavement section: 100 mm thick concrete pavers 25 mm thick bedding sand 75 mm asphalt 450 mm aggregate base Soil subgrade 5% CBR

Container storage FLTs & RTGs

Conclusions

High quality wearing course Provides Stormwater Solutions

Design Proven methods & solutions

Construction Mechanized, QC protocols, experienced contractors

Ease of Maintenance & Management

www.Oldcastle.com

