Session 40

Marty Wanielista

University of Central Florida

Performance of Pervious Pavement

Topic Description

Pervious concrete performance from existing florida sites have been examined to document their hydraulic performance. Construction and maintenance will also be discussed.

Speaker Biography

Marty Wanielista is the director of the Stormwater Management Academy, Professor of Engineering and Professor Emeritus at the University of Central Florida. He has been at UCF for over 36 years. He has a Civil Engineering degree from the University of Detroit, Masters from Manhattan College, and a PhD in Environmental Systems from Cornell. He has completed over 60 research projects in the areas of Hydrology and Stormwater, and is currently working on 12 projects for the Stormwater Management Academy. He has over 200 publications including 7 textbooks.

Session 40

Manoj Chopra

University of Central Florida

Performance of Pervious Pavement

Topic Description

Pervious concrete pavements have shown some potential to allow replenishment of the groundwater by allowing most of the surface waters to infiltrate the surface. This paper investigates the hydraulic properties and field performance of such pavements. It also looks at the proper construction practice and the rejuvenation of the pavement. Lastly, the impact on water quality is discussed.

Speaker Biography

Associate Professor of Civil Engineering specializing in Geotechnical Engineering. Thirteen years at UCF in the Civil and Environmental Engineering Department after receiving his PhD from SUNY at Buffalo. He is a member of the Stormwater Management Academy and has several publications in the areas of soils, geo-environmental engineering and pervious pavements.

2006
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Designing For More Than Bridges and Roads

Performance of Pervious Pavement

Presentation by Marty Wanielista and Manoj Chopra
August 2nd 2006

Stormwater Management Academy
"Managed stormwater is good water."

UCF

Team Members are:

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* Stormwater Management Academy, UCF
** FDOT, Deland
*** Rinker Materials

Acknowledgements

- Rick Renna, Florida Department of Transportation
- Eric Livingston, Florida Department of Environmental Protection
- Ready Mixed Concrete Research Foundation
- Florida Concrete Products Association
- Rinker Materials

Outline of Presentation

- Overview
- Background and Current State
- Objectives of this On-going Project
- Issues -
  - UCF Laboratory Test Site
  - Field Performance Tests
  - Clogging Rehabilitation and Prevention
  - Stormwater Management Credit
  - Construction Specifications
- Discussion

Overview

- Pervious or no-fines Concrete – mixture of coarse aggregate, Portland Cement, admixtures and water
- Increased Porosity due to limited fines and 15-20% air voids
- Strong need for Current and Updated Assessment of Pervious Pavements

Background and Current State

- Replacement of Impervious Areas with Properly Designed and Constructed Pervious Paving Surfaces is Desirable
- Treating Pervious Concrete as a System with Pavement and Subsoil
- ACI Committee 522 (chaired by Matt Offenberg) has been formed to develop Guidelines for the use of Portland Cement Pervious Concrete

Historical and Literature Review

- PC Pervious Pavements have been used for past 20+ years in Areas of Lower Traffic Loads (parking lots, shoulders, airport taxiways, some state and local roads).
- Must have suitable
  - Subsoil Conditions
  - Groundwater Locations

Advantages and Disadvantages (EPA Fact Sheet, 1999)

- Advantages -
  - Recharge to Local Aquifer
  - Water budget retention and pollution removal
  - Less need for Storm Sewers
- Disadvantages –
  - Lack of Construction Experience and Expertise
  - Clogging
  - Cold Weather Problems

DOT/WMD Issues and Interests

- Need for Credit (partial or total) for substituting pervious surfaces
- Based on Volume of water that can be Stored and allowed to Replenish the Aquifer
- Issues under investigation –
  - What are design issues– materials, dimensions, GWT?
  - What are proper construction methods?
  - What is the infiltration rate for the system?
  - What is effect on water quality?
  - Can vacuum sweeping or other operations be used to rejuvenate the pavements?

Objectives

- Issues being addressed –
  - Design Section
  - Construction Methods
  - Acceptance Criteria
  - Infiltration Rate Performance
  - Credit for Replacement of Impervious Area
  - Maintenance and Rehabilitation

Field Testing Objectives

- Develop New Embedded Single Ring Test Method to Measure Infiltration rates
- Laboratory Testing – Built Two Test Cells at the UCF Stormwater Laboratory Site
- Field Testing Sites –
  - Four located in Central Florida
  - One located in Tallahassee
  - One located in Greenville, South Carolina
  - Two located in Georgia

Preparation of Test Cells

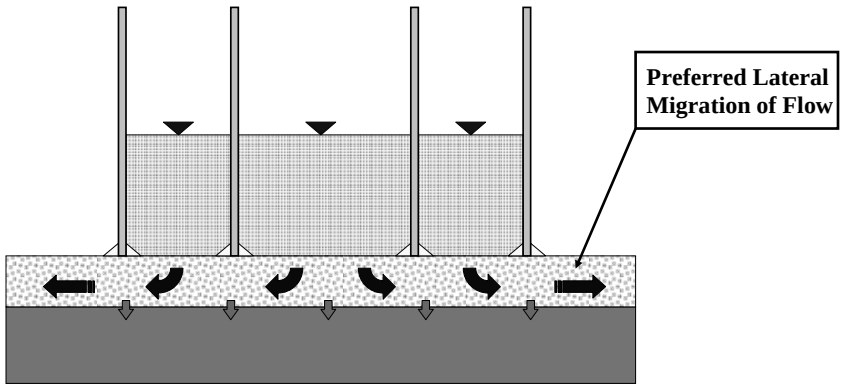
- Stormwater Laboratory Field Sites
- Two 6 ft x 6ft x 4 ft deep Chambers
- 5 inch thick pervious concrete pavement
- One cell has a “reservoir” of 3/8 inch coarse aggregate to increase storage
- Soils were Sandy (Type A hydrological) compacted in 8 inch lifts to 92% Standard Proctor to about 104 lb/ft^3

Results at Test Cells

- Using ASTM D3385-03 (Double Ring) procedure was adapted to an embedded Single Ring
- Initial Double Ring Tests on Bare Subsoil before Concrete Placement have yielded an average infiltration rate of 2.6 in/hr
- Without compaction, the rate for the soil was 12-20 in/hr

Initial Experimentation

- Double Ring Infiltrometer on the Surface of PC

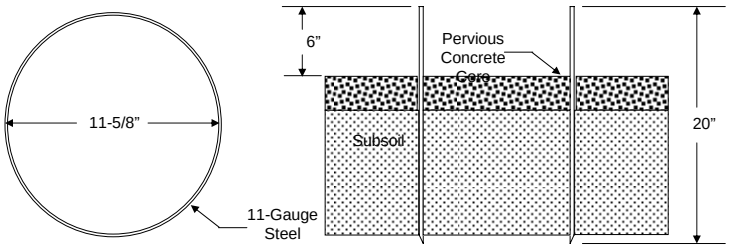


Infiltration rates exceeded 200 inches per hour, but how can that be if the soil infiltration rates were only 2-4 inches per hour? Answer… lateral flow.

Development of Embedded Single Ring Infiltrometer

- Double Ring Infiltrometer on the surface of Pervious Pavement not Suitable due to Preferred Lateral Migration of Water
- Led to Concept of Single Embedded Infiltrometer
- Depth of Embedment is an Important Parameter (Initial Assumption = 14 inches including the 6 inches of pavement)
- 12 inch Diameter (11-5/8” ID) with 11-Gauge Steel

Embedded Single Ring Infiltrometer



1. One dimensional flow (no horizontal flow between pavement and soil).
2. Representative of site existing conditions.

Choice of 14 inches was based on a soil, concrete storage volume of 4 inches of rainfall. Four (4) inches of rainfall is greater than the average of the maximum daily rainfall in one year for Florida. Thus flow is maintained in a vertical direction within the ring. The depth of ring penetration can be greater if there is expected greater depth of infiltrate such as a combination of building runoff water plus rainfall.

Results of UCF Embedded Ring Tests

Test Location	Test Date	Volume of Rainfall (in)	Infiltration Rate (in/hr)
Core A	1/19/05	1.94	2.40
Core A	1/20/05	0.85	1.16
Core A	1/21/05	0.93	1.03
Core A	1/25/05	1.37	1.48
Core B	1/19/05	1.49	2.41
Core B	1/20/05	0.89	1.21
Core B	1/21/05	1.03	1.45
Core B	1/25/05	1.21	1.45

Preliminary Observations from UCF Test Chambers

- Pervious Concrete Pavement and Subsoil System displays Infiltration Rates nearly equal to Subsoil Alone
- Infiltration rates of the system are greater than the minimum rates of 1 in/hr commonly used for the design of FDOT retention areas.

Field Site Reconnaissance

- Field Sites in Florida
  - Vet Office in Sanford
  - FCPA Office in Orlando
  - Sunray StoreAway – Lake Mary
  - Strang Communications – Lake Mary
  - FDEP Office – Tallahassee
- Field Sites outside Florida
  - Cleveland Park - Greenville, South Carolina
  - SOUTHFACE Office - Atlanta, Georgia
  - Effingham County Landfill - Guyton, Georgia

Watershed Data

Site	Site Name	Description	Number of Cores	Age (years)
1	Sunray Storaway	Paved Areas at Storage Facility	6	14
2	Strang Communication	Paved Parking Area	3	13
3	Murphy Vet Clinic	Paved Parking Area	3	18
4	Florida Department of Env. Protection	Paved Loading Area	6	16
5	Florida Concrete & Products Assoc.	Paved Parking Area	3	6
6*	Southface Institute	Paved Parking Area/Driveway	3	--
7*	Cleveland Park	Paved Parking Area	3	--
8*	Effingham County Landfill	Paved Dumpster Pad	3	--

* Site not in Florida

-- Data not available

Personnel at each site indicated that little or no runoff occurs during a storm, frequent traffic, and at the land fill (site #8), there was heavy equipment use.

Testing Program

- 12-in diameter cores using UCF Coring M/C
- Perform Field Tests
  - Determination of Field Unit Weight
  - Embedded Single Ring Infiltrometer Test
- Collect Soil Samples
- Laboratory tests on soil samples
  - Sieve Analysis
  - Liquid & Plastic Limits
  - Permeability Tests
- Laboratory test on Cores for infiltration rates

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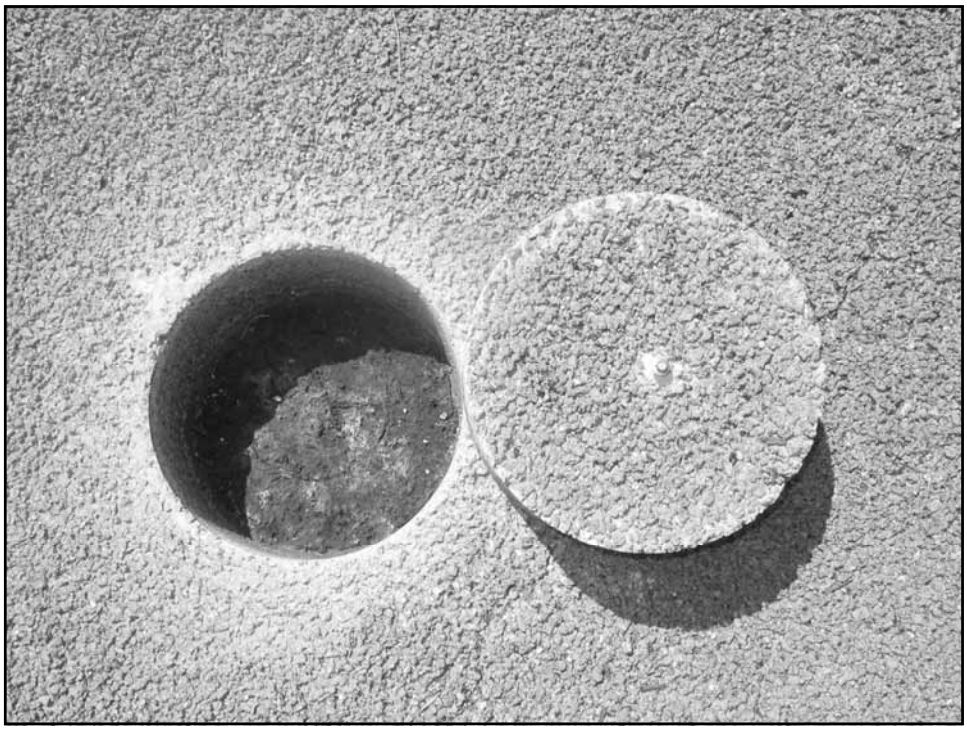
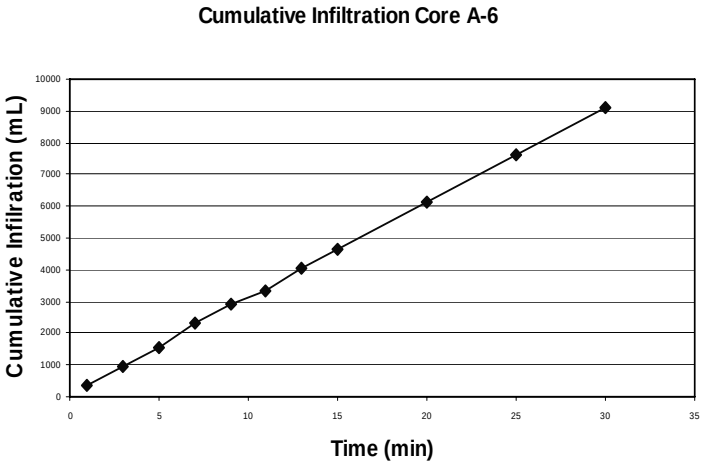


Typical Field Test Results



Field Testing Progress

- Florida: Six cores at Sunray Storeaway and Tallahassee, Three at Strang Communications, FCPA, and at Murphy Vet Clinic.
- Out of State: Three cores at each of the three sites.
- Field infiltration tests completed at all locations in Florida. No field tests possible at sites outside Florida due to Gravel Layer.
- Laboratory tests on all the 30 cores using Control Chamber

Field Test Results

Test Location	Avg. Concrete Rate [in/hr] (Range)	Avg. Soil Rate [in/hr]	Limiting Factor
Sunray StoreAway – Area 1	25.7 (19 – 32.4)	34.5	Concrete
Sunray StoreAway – Area 2	3.6 (2.8 – 4.5)	14.8	Concrete
Strang Communications	5.9 (5.3 – 6.6)	5.4	Soil
Vet Clinic	14.4 (2.1 – 22.5)	21.5	Concrete
Tallahassee – Area 1	2.1 (0.7 – 4.5)	15.6	Concrete
Tallahassee – Area 2	2.9 (0.9 – 4.9)	15.6	Concrete
FCPA Office	3.7 (1.7 – 5.4)	8.8	Concrete

***Age of concrete varies from 10 to 20 years (except for Site 4 – Area 1).**
***Field Tests were not conducted out of state due to the presence of storage reservoirs**

Observations from Field Tests

- System rates are nearly the same as the subsoil
- Design rates of 2 in/hr for stormwater retention ponds are exceeded in all cases above
- Some of the cores were found to have very low rates potentially due to improper design or construction

Rehabilitation of Clogged Pavements

- Determine the effectiveness of various rehabilitation techniques on clogged previous concrete including:
  - Vacuum Sweeper
  - Pressure Cleaning
  - Combination of both of the above
- Develop a standardized inspection and maintenance schedule

Laboratory Testing Process

- Determined initial infiltration rates of cores obtained in the field using SRI.
- One core was subjected to one of the following rehabilitation techniques:
  - Pressure Washer (3000 psi Gas Pressure)
  - Vacuum Sweeper (6.5 hp Wet/Dry Vaccum Sweeper)
  - Both Pressure Washer & Vacuum Sweeper
- Determined the rehabilitated infiltration rates of cores using SRI.

Test Setup

Clogging Rehabilitation Results

Pressure Washed
Vacuum Sweep
Both

Site A: SunRay
Site B: Strang
Site C: Murphy Vet

Core No.	Initial Infiltration Rate (in/hr)	Rehabilitated Infiltration Rate (in/hr)	Percent Increase in Infiltration(%)
A-1	627	1200	191
A-2	34.5	66.6	193
A-3	20.2	84.3	417
A-4	3.7	96.2	2600
A-5	4.8	30.1	627
A-6	3	187	6233
B-1	1.4	4.1	292
B-2	5.6	28.5	509
B-3	7.1	180	2535
C-1	2.3	720	31304
C-2	19.7	164	832
C-3	24	655	2729

Effectiveness of Rehab-Observations

- Both methods resulted in significant increase in the infiltration rates.
- The rates at the completion of the cleaning are higher than the soil rates measured at these sites.
- Cores tested were anywhere between 10 and 30 years in service without any maintenance performed.

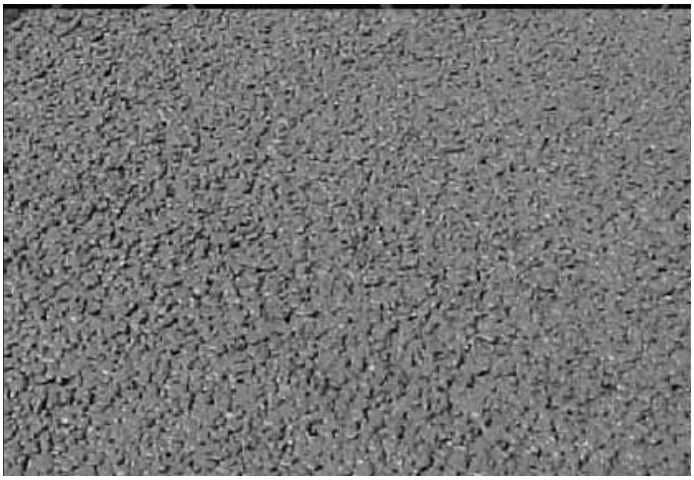
Construction Specifications

- Placement and finishing techniques for pervious concrete are different from plain concrete
- Pervious concrete must be placed with specialty equipment and the water content of the fresh concrete must be carefully controlled
- NRMCA has implemented a Contractor Certification Program as of September, 2005

Construction Specifications

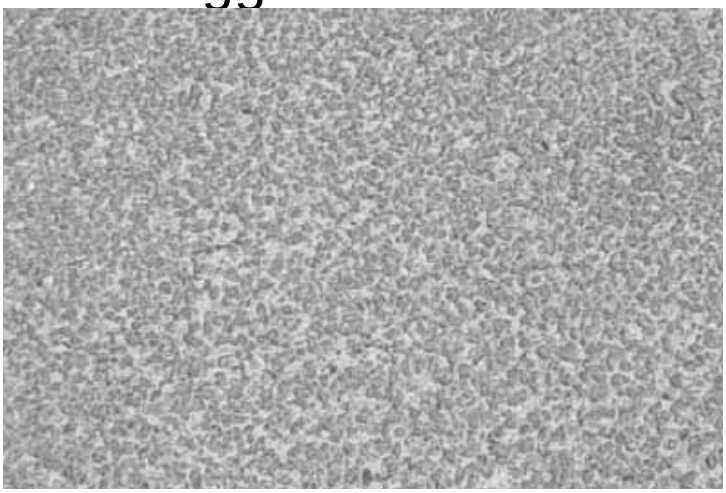
- Appropriate mix proportions
- +/- 5 lbs/CF of design unit weight
- Discrepancies are generally related to water content
- Too much water – must reject load

Surface Texture



Excess Water in Mix

Clogged Pavement



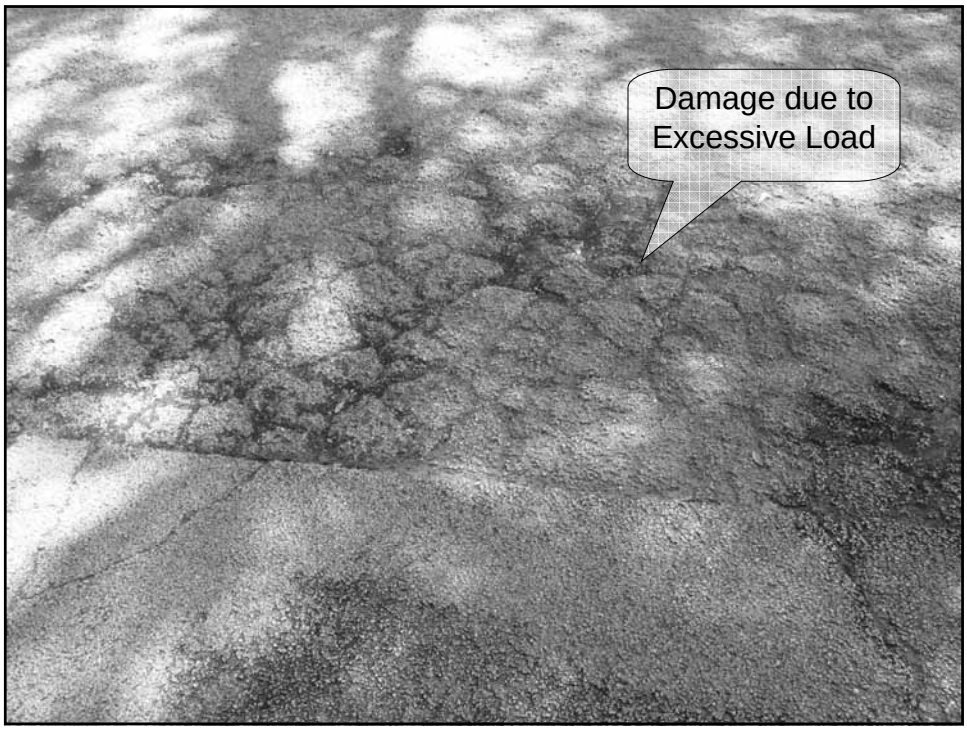
Construction Specifications

- Concrete should be stricken off ¼ to ½ of an inch about the form boards and compacted to level
- Compaction – roll with a 10-inch schedule 40 steel pipe
- Curing Time – pavement should be covered a minimum of 7 days
- Curbing should be used to direct infiltrating water downward and to prevent erosion at the edges of pervious concrete slabs

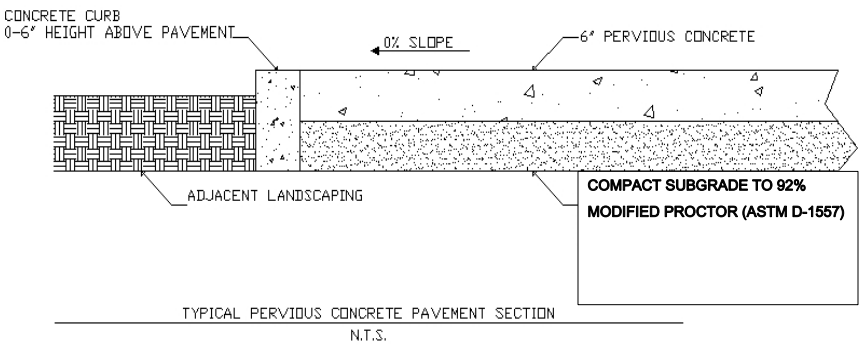
Insufficient Curing

Operational Specifications

- Limit frequency of heavy traffic – e.g. construction vehicles, garbage trucks, etc.
- Remove or Limit sources of Sediments
- Signage such as “ADOPT A LOT”
- Adopt a Standard Maintenance Schedule



Proposed Design Section



Simulation Model

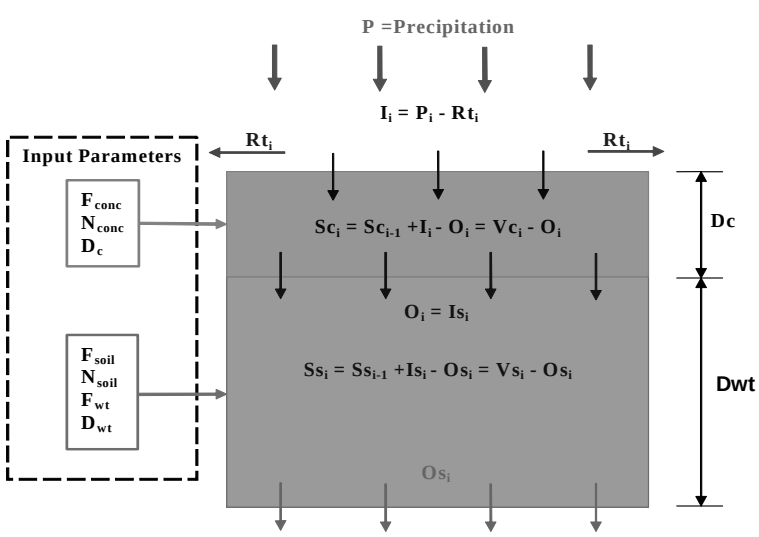
How can the credit (% of rainfall infiltrated or kept on site) be determined?

- Determine Rainfall Excess and Recharge
- Simulate over a period of time (1 year)
- One Dimensional

Mass Balance Model

- Three Controlling Infiltration Rates – Concrete, Soil, Water Table
- Other Parameters – Concrete & Soil Porosity, Depth of Concrete, and Depth of Soil to WT
- One year of Rainfall Data (2003)
- Variable Time Step (one minute - one day)

Mass Balance Modeling

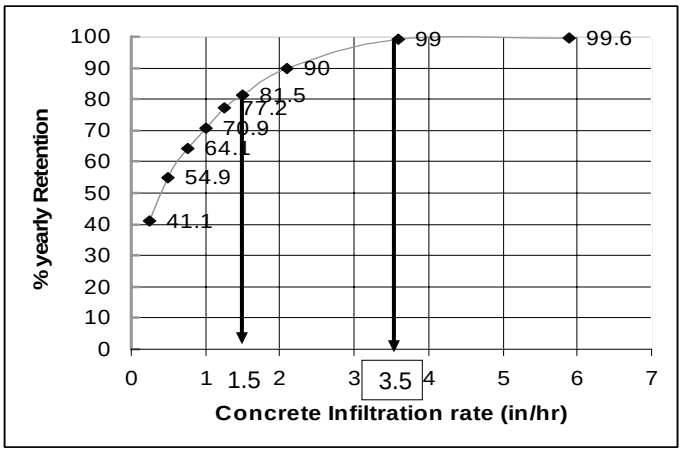


Field Results & % Yearly Retention

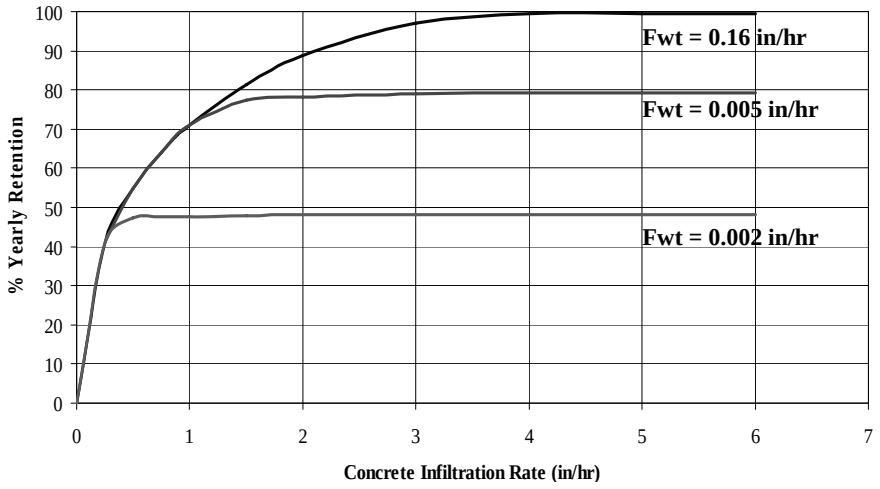
Location	F_{conc} (in/hr)	F_{soil} (in/hr)	F_{aq} (in/hr)	D_c (in)	D_{wt} (in)	% Retained
Site 1.1	25.7	34.5	0.16	10	120	99.9
Site 1.2	3.6	14.8	0.16	10	120	99.5
Site 2	5.9	5.4	0.16	8	120	99.6
Site 3	14.4	21.5	0.16	7	72	99.9
Site 4.1	2.1	15.6	0.002	10	12	40.9
Site 4.2	2.9	15.6	0.002	8	12	40.2
Site 5	3.7	8.8	0.16	8	72	99.5

% Yearly Retention as a function of Pervious Concrete infiltration rate (in/hr)

From model using "real" field data, Rain = 52.49 in/year, F_{soil} = 5.4 in/hr, F_{aq} = 0.16 in/hr, D_c = 8 in, & D_{wt}= 24 in



Percent Yearly Retention as a function of concrete infiltration rate for groundwater movement



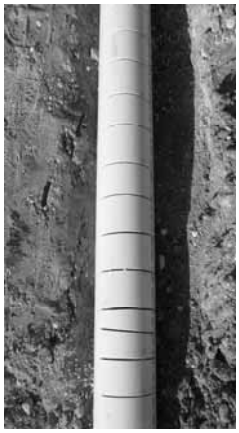
I-4 Shoulder and Watershed Area (equivalent to 6 lanes of traffic)

Test shoulder site is 90 feet long by 10 feet wide

Under Drains and Separation Fabric to Collect Water Quality Samples

Adjacent to existing pave
And 7 feet from edge of pave

Separation
Fabric



Slotted pipe to collect
Infiltrated water

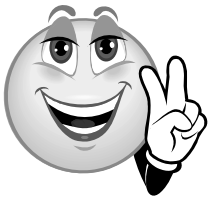
Filter Media, Pervious Concrete and Testing

Black and Gold Nuggets ™

Pervious Concrete

Placement, Striking, Pizza Cutter and 7 day Curing

Preliminary Water Quality Results



- Based on seepage water under the I-4 rest area shoulder with a 12 inch depth of pervious concrete and 12 inches of water quality media.
  - OP4 averages about .1 to .2 mg/l
  - NO3-N averages about .3 to .4 mg/l
- Rainfall in the area has about
  - OP4 of 0.2 mg/L
  - NO3-N of 0.4 mg/L

Conclusions

- Proper Construction (Placement, Water, and Curing) is Important. Certification is required!
- Specifications needed for Design and Operational Practices (Curbing, Pavement Thickness, Signage).
- New construction: place single ring infiltrometers embedded within the PC, then testing is easier.
- Infiltration rates are Comparable to Stormwater Retention Ponds.

Conclusions

- Water Quality in the filtrate is about equal to rainfall in terms of nitrate nitrogen and orthophosphate
- Site infiltration tests can be done. Rates less than 1.5 inches/hr indicates a need for rehabilitation.
- Pressure Washing and Vacuum Sweeping are Effective Rehabilitation Techniques.
- Water Retention is directly proportional to the infiltration rates of the pervious concrete. Modeling efforts indicate pervious concrete should be given credit in a stormwater management plan.

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Thank you,
Questions?

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H2O4U

Stormwater Management Academy

"Managed stormwater is good water."