Porous Pavement

EcoVative Conference and Trade Show

Thursday, April 22, 2010

POROUS PAVEMENT 101

Presented by: Matt Rogers, PE

CENTURY WEST
ENGINEERING CORPORATION

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What is porous pavement?

- METRO Definition: Surface to walk, drive or park on that reduces stormwater runoff by allowing water to soak into the ground.

- Examples include permeable pavers, pervious concrete, porous asphalt, and gravel.

Why use porous pavement?

- Infiltration of stormwater onsite mimics the predevelopment condition
- Does not require dedication of additional land for stormwater facilities
- Provides improved treatment because stormwater is not concentrated into a point source discharge
- Reduces storm surge by

  slowly infiltrating stormwater

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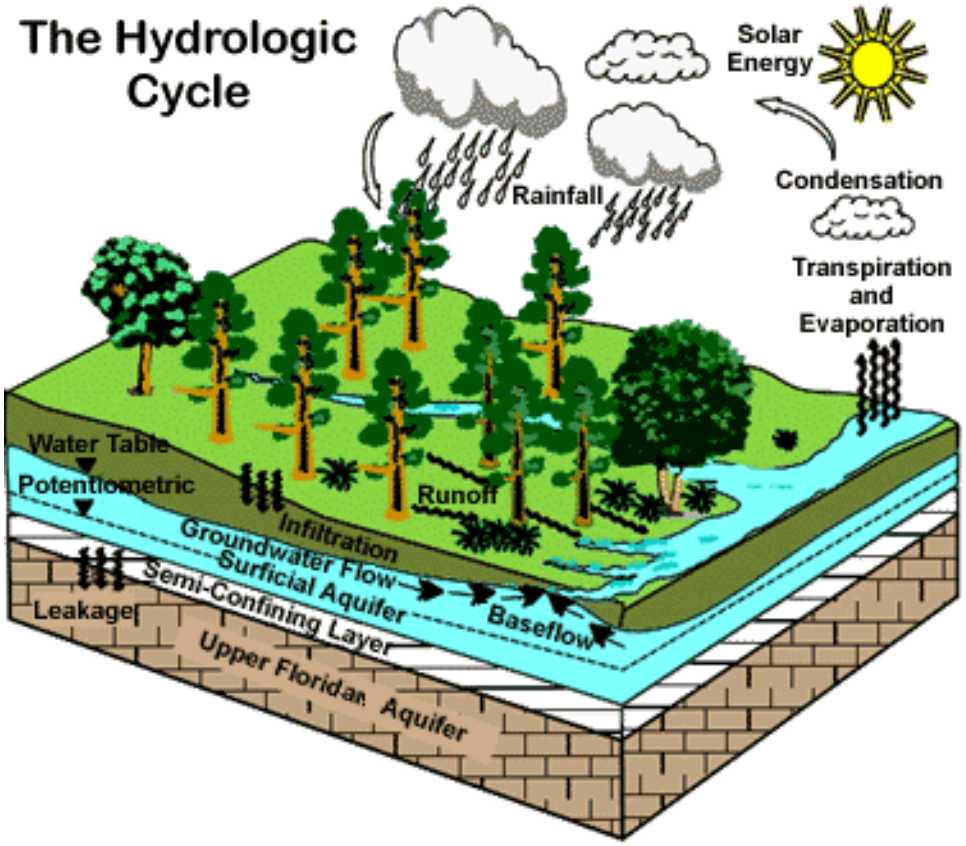

Source: US EPA

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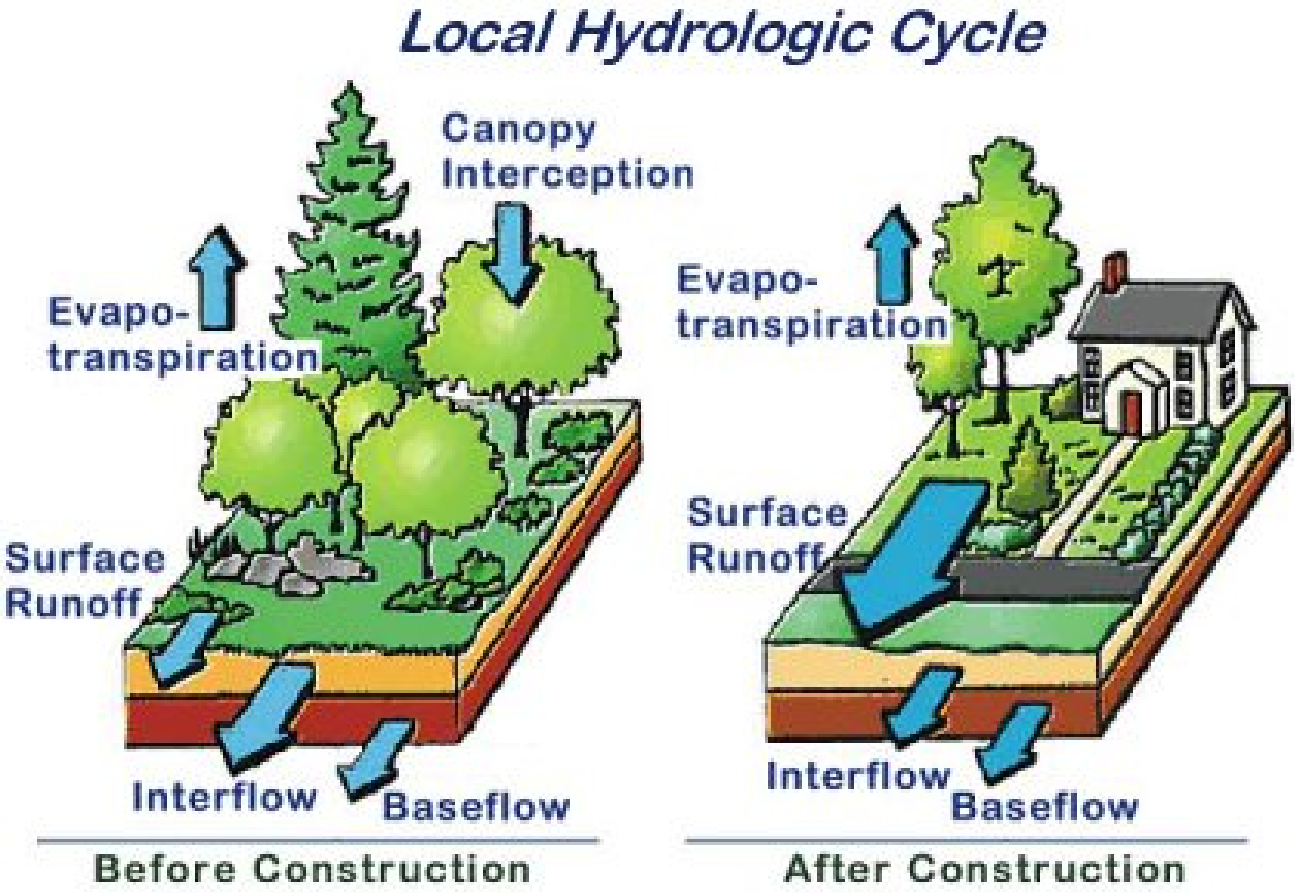

Source: US EPA

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Stormwater Treatment

- More efficient than conventional materials at degrading or retaining pollutants
- Treatment through filtration, absorption, and microbial degradation
- Shown to remove metals, nutrients and hydrocarbons

Source: University of Rhode Island “Porous Pavement and Groundwater Quality Technical Bulletin”

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Is Porous Pavement right for my application?

- What is the site topography?
  - Are there steep slopes?
  - Can runoff onto the site be controlled?
- How will my site be used?
  - What is the anticipated loading?
  - Is there a potential for spills/contamination?
- What are the subsurface soil conditions?
  - How permeable is the soil?
  - Where is the groundwater table?

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EPA Recommendations

…The Slope of the Area	Not more than 5%
…The Infiltration Rate	1.3 cm (0.5 in) per hour at a depth of 0.9 m (3 ft) below the bottom of the stone reservoir
…The Minimum Depth to Bedrock	At least 1.2 m (4 ft) below the stone reservoir
…The Seasonally-High Water Table	At least 1.2 m (4 ft) below the stone reservoir
…The Minimum Setback from Water Supply Wells	At least 30 m (100 ft)
…The Minimum Setback from Building Foundations	At least 3 m (10 ft) down gradient At least 30 m (100ft) up gradient
…The Drainage Area	Not more than 6.1 hectares (15 acres)
…The Use of Porous Pavement	Not to be used in areas where wind erosion supplies significant amounts of windblown sediment

Types of Porous Pavement

- Porous Asphalt
- Pervious Concrete
- Permeable Pavers
- GrassPave
- GravelPave

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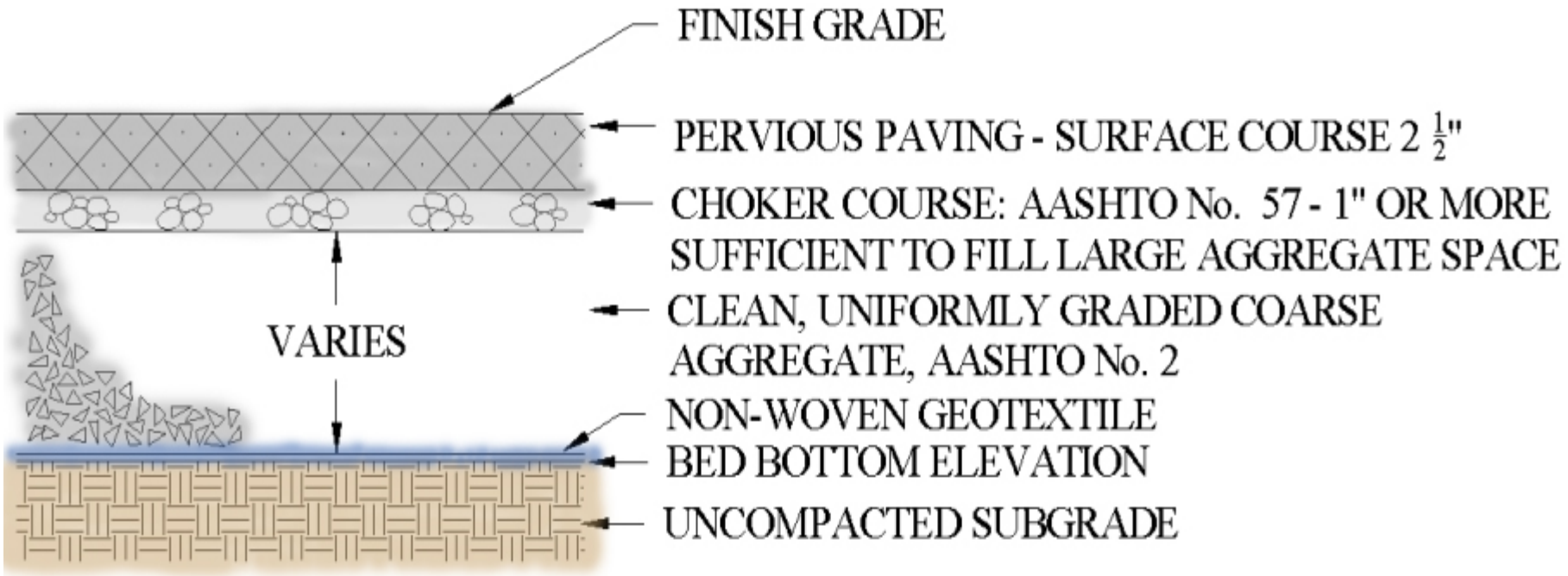
Porous Pavement Section



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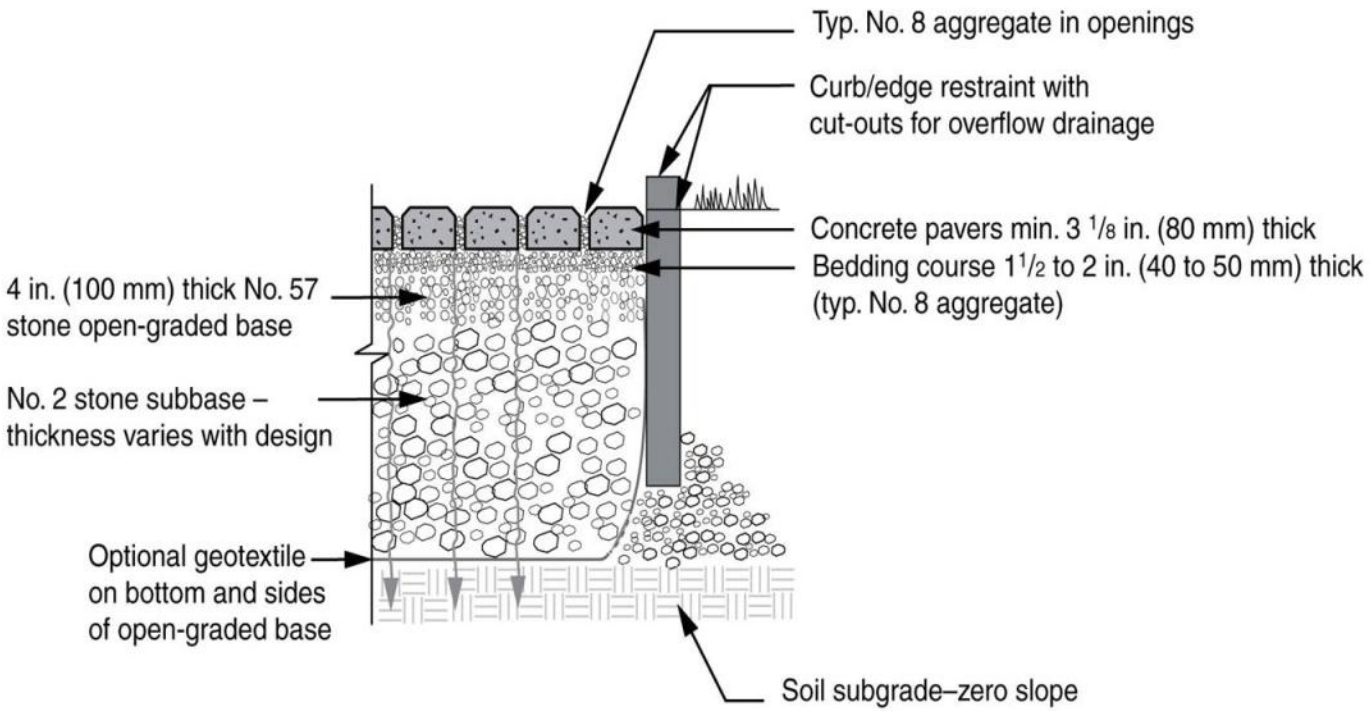
Porous Paver Section



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Site Preparation

- Excavate to subgrade elevation
- Protect the subgrade from compaction during construction
- Do not allow construction traffic on subgrade
- Verify design infiltration rates prior to placing coarse aggregate base

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Subgrade & Base Preparation

- Place geotextile fabric on uncompacted subgrade
- Verify that material meets specifications
- Place coarse aggregate base similar to wet weather construction
- Avoid traffic on subgrade!

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Stone Base Grading

Course	Square-Sieve Opening	Percent Passing (by weight)
Top and Bottom Filter Courses	1/2 inch	100
	3/8 inch	0-5
Reservoir Course	3 inch	100
	2 ½ inch	90-100
	2 inch	35-70
	1 ½ inch	0-15
	3/4 inch	0-5
Additional requirement, if needed	100	0-2

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Standard Pavement
Porous Pavement

Denver, CO – After Major Snowfall

Sites Directly Across The Street – Photos Less Than 5 mins. Apart

Pervious Concrete (Left)

Conventional Asphalt (Right)

Photo Source: Dan Huffman - National Ready Mixed Concrete Association

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Critical Considerations

- Porous pavement is a stormwater facility - to function properly it must be designed and constructed properly
- Constructed on uncompacted subgrade
- Coarse aggregate must be clean with no fines
- Surface Course must be installed per engineer or manufacturer specs
- Specifications and construction practices must be strictly observed for proper function
- Adjacent site drainage must be controlled

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Maintenance

- Inspect several times first few months during storm events
- Inspect semi-annually thereafter
- Pavement surface may be flushed or jet washed
- Pavement surface should be cleaned with a Vac Truck at least twice a year

Costs

- Typically more expensive than traditional surfacing due to increased aggregate section
- Costs may be offset by lack of other stormwater infrastructure (piping, manholes, catch basins, ponds, etc.)
- Cost may be offset by lower stormwater fees, reduced timelines, accelerated permitting

Costs

- METRO conducted alternatives cost analysis for different surfacing options
- Purpose was to develop an “apples to apples” cost comparison
- Used three types of installations for the cost comparison

Costs - Design Alternatives

- Six pavement sections were considered for the three scenarios considered:
  - Porous Asphalt Pavement
  - Pervious Concrete Pavement
  - Permeable Interlocking Concrete Pavers
  - Porous Gravel with a Geo-cellular grid
  - Conventional Asphalt plus Drainage Structures
  - Conventional Concrete plus Drainage Structures

Costs - Design Scenarios

- **Neighborhood Roadway** – A roadway roughly consistent with a 200’ city block. Assuming 50’ lots, the street would access eight homes. The width would be sufficient to accommodate two 12’ travel lanes with 10’ for parking on one side of the street. Based on these requirements the street’s paved area would total 6,800 SF. It is assumed that the street will be curbed; however, sidewalks were not considered for this study.

- **Parking Lot** – A parking lot for a small business. The lot would include ten 10’x20’ stalls and a 50’x24’ drive aisle. The total area would be 3,200 SF. Curbs, but no sidewalks, are assumed.

- • **Driveway** – A driveway large enough for three cars with room for some maneuvering. 800 SF of pavement is assumed.

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Costs - Driveway

Driveway				
	Surface	Base		
Material	inches	inches	Size	Cost
Porous Concrete	8	9	1"-0"	$7,220
Porous Asphalt	3	9	1"-0"	$3,880
Interlocking Pavers	Paver	9	1"-0"	$11,600
Plastic Grid Reinforced Gravel	Geocell	9	¾"-0"	$3,680
Conventional Concrete	4.5	4	1"-0"	$5,330
Conventional Asphalt	3	8	1"-0"	$3,440

Photo Source: www.paverpro.com

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Costs – Parking Lot

Parking Lot				
	Surface	Base		
Material	inches	inches	Size	Cost
Porous Concrete	8	9	1"-0"	$37,630
Porous Asphalt	3	12	1"-0"	$19,660
Interlocking Pavers	Paver	12	1"-0"	$50,450
Plastic Grid Reinforced Gravel	Geocell	9	¾"-0"	$11,900
Conventional Concrete	5	6	1"-0"	$31,870
Conventional Asphalt	3	12	1"-0"	$24,570

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Costs – Neighborhood Road

Neighborhood Road				
	Surface	Base		
Material	inches	inches	Size	Cost
Porous Concrete	8	9	1"-0"	$73,040
Porous Asphalt	4	12	1"-0"	$38,590
Interlocking Pavers	Paver	12	1"-0"	$100,460
Plastic Grid Reinforced Gravel	Not Applicable			
Conventional Concrete	5	6	1"-0"	$70,340
Conventional Asphalt	4	12	1"-0"	$58,020

Photo Source: Jim Huddleston Asphalt Pavement Association of Oregon

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Pervious Concrete

Dan Huffman

Vice President, National Resources

National Ready Mixed Concrete Association

Portland

ecovative

HBA Home Builders Association of Metropolitan Portland

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Pervious Concrete

AGENDA

- Brief description/definition
- Benefits and limitations
- Cost
- Applicability - appropriate situations and site conditions for use
- Design – How to
- Install – How to
- Maintain – How to
- Features- what does it do and how is it UNIQUE from other materials?

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OVERVIEW

Pervious Concrete

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Pervious Concrete Pavement

General Description:

- Structural pavement: 500-4000 psi
- Components:
  - Coarse aggregate
  - Portland cement
    - Supplemental mtrls.
      - Fly Ash / Slag
      - Fibers, Integral Color, etc.
  - Water
  - Admixtures
- Void content range of 15-30%
- Designed to allow stormwater drainage to the sub-grade for filtration, ground water recharge & reduction in over-all runoff

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BENEFITS & LIMITATIONS

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Conventional vs Pervious

Asphalt Pavement **(Left)** (Same Site) Pervious Concrete **(Right)**

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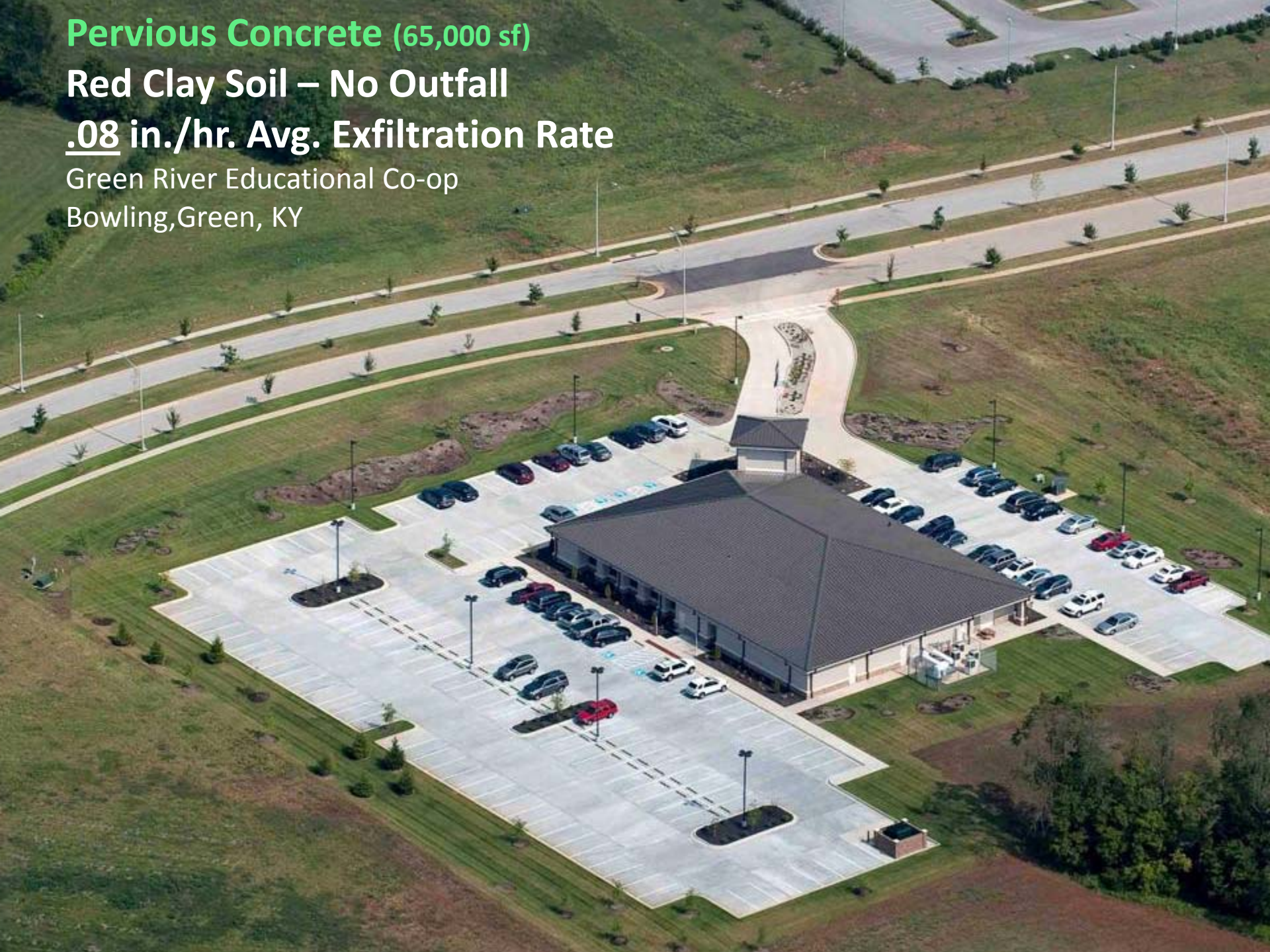
Conventional Pavement – Asphalt (Background)

Pervious Concrete (Foreground) - Raining


Pervious Concrete (65,000 sf)
Red Clay Soil – No Outfall
.08 in./hr. Avg. Exfiltration Rate
Green River Educational Co-op
Bowling,Green, KY

COST

Pervious Concrete

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Pervious Concrete

COSTS

See Exhibiting Vendors

&

Better Ready-Mixed Concrete Producers

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Cost Savings / Site Optimization

CMI Homebuilders Inc. – Snohomish, WA

20 Home Subdivision (near Seattle)

Traditional Const.

- $175 K – Cost of traditional Detention Vault, Catch Basins, & Pipes
- $48 K – Asphalt Road Const. – 1st cost
- $37 K – Traditional Raised Curbs

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CMI Homebuilders Inc. – Snohomish, WA

20 Home Subdivision (near Seattle)

Pervious Concrete Technology

- Eliminated All Catch Basins Within Plat
- Eliminated Piping To Detention Areas (Cleaning!)
- Eliminated Detention Vault
- Eliminated Street Curbing
- **Reclaimed 2 Lots worth $100 K each**

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CMI Homebuilders Inc. – Snohomish, WA

20 Home Subdivision (near Seattle)

Pervious Concrete Technology

- $ 260 K – 1st Cost Differential Favorable to Pervious Concrete ($200 K vs $ 460 K)
- Site Optimization – Increased Revenue Opportunity – ROI / ROE dynamics

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APPLICABILITY

Pervious Concrete

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Pervious Concrete Apps.

- Parking Areas
- Driveways
- Sidewalks
- Roadways
- Pedestrian Plazas
- Swales & Ditches
- Erosion Control
- Slope Protection
- Load-bearing Walls
- ETC.

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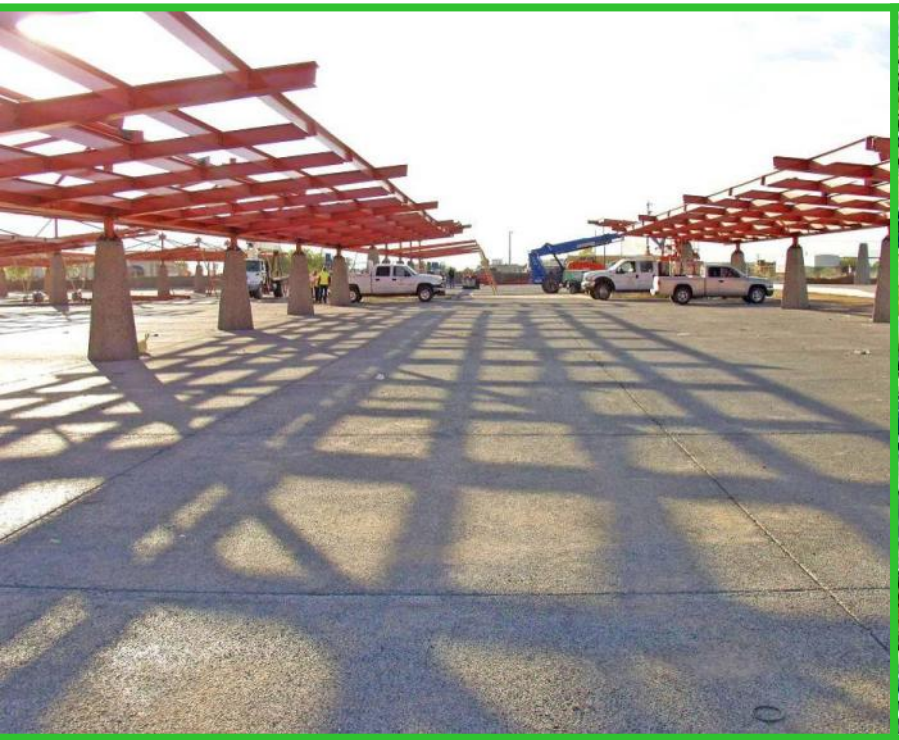
Pervious Concrete

Park & Ride Parking Lot (4 acres)

Serving Site of 2008 Super Bowl – Glendale, Ariz.




JAN 29 2003


Pervious Concrete – Portland, Oregon

Oregon Commuter Plaza – City of Beaverton

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City of Beaverton

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Condo Complex – Canby, OR

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Pervious Concrete – 8th Dr. - Portland

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Residence – Lake Oswego, OR

12th St. – Vancouver, WA

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CSO Path – Swan Island (Portland, OR)

Pervious Concrete - Ohio St. – Longview, WA

Habit for Humanity Development – Keizer, OR

Local jurisdiction required developer to tie into stormwater system 1 mi. away or use Low Impact Development (Pervious Concrete)

Photo Courtesy: Scott Erickson, Evolution Paving Resources

DESIGN

Pervious Concrete

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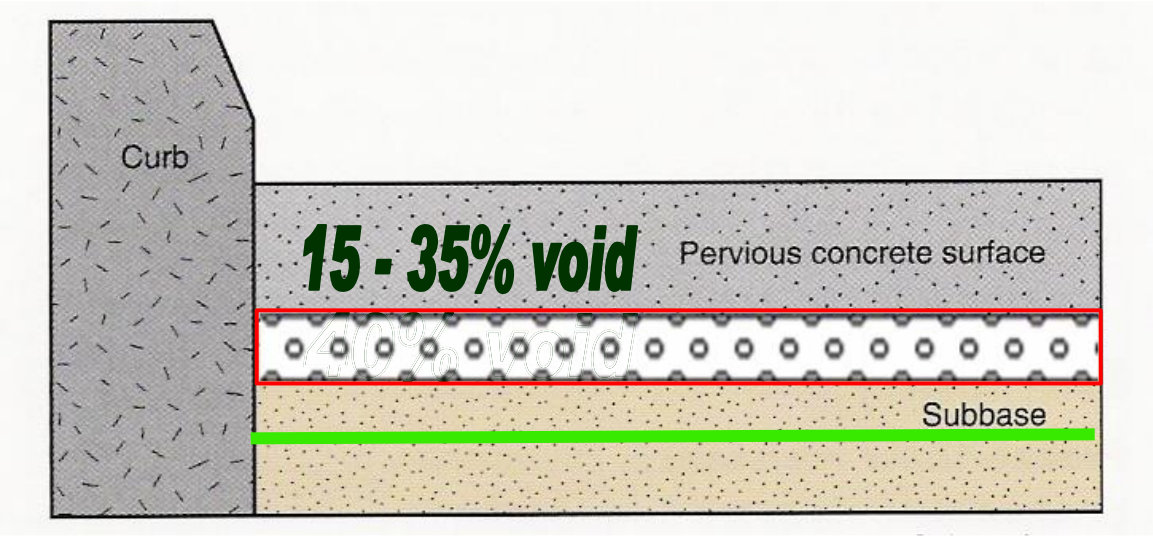
Typical Design for Pervious Concrete



- Pervious concrete: 6-8 inches
- Open-graded stone subbase: determined by local hydrologic conditions (6 - 18 inches typical)
- Geotextile prevents movement of fines into stone bed
- Perforated pipe to capture and transport water **(optional)**

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Alternative Drainage

Frequently Used for Poor Percolating Soils

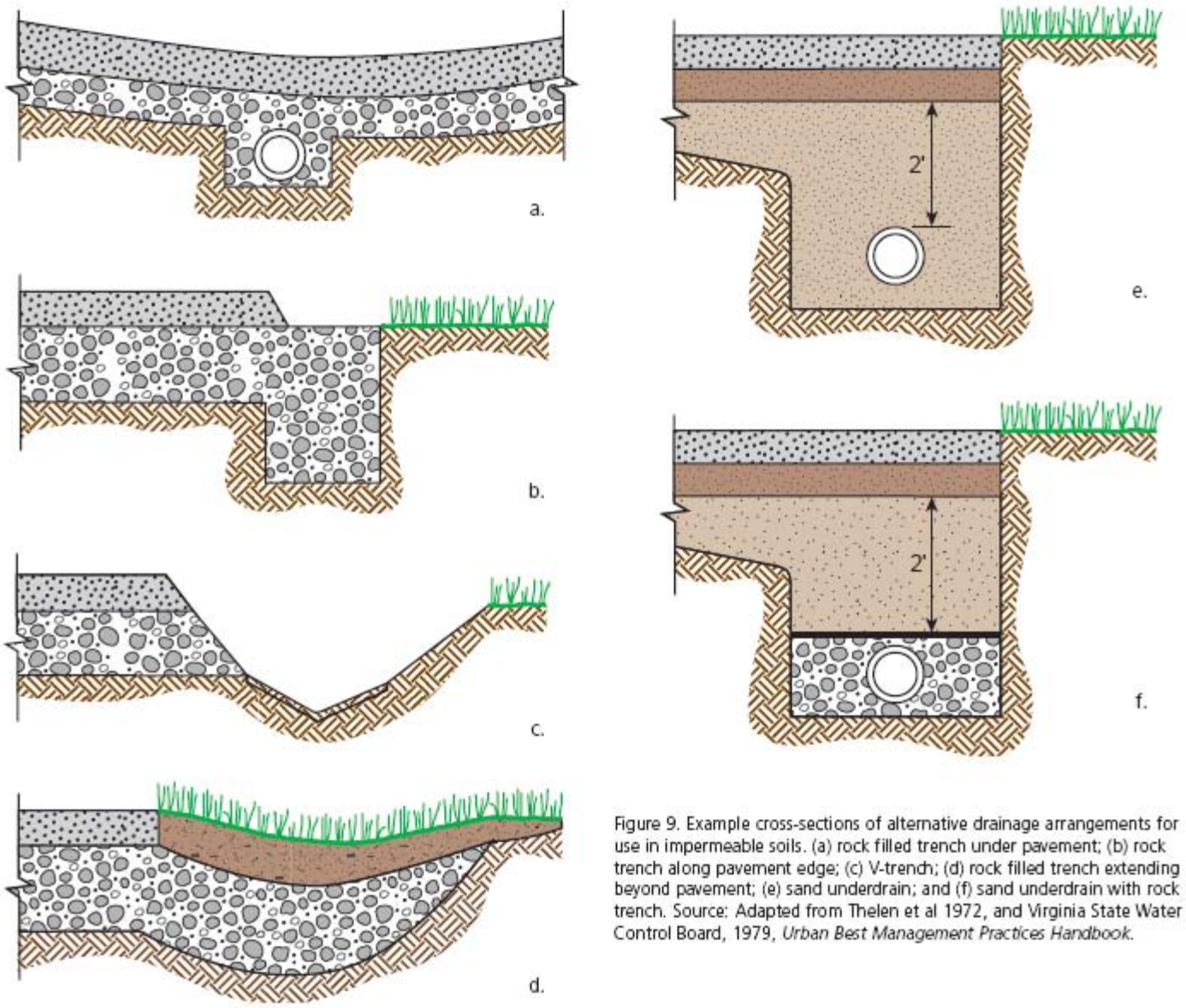

Figure 9. Example cross-sections of alternative drainage arrangements for use in impermeable soils. (a) rock filled trench under pavement; (b) rock trench along pavement edge; (c) V-trench; (d) rock filled trench extending beyond pavement; (e) sand underdrain; and (f) sand underdrain with rock trench. Source: Adapted from Thelen et al 1972, and Virginia State Water Control Board, 1979, *Urban Best Management Practices Handbook.*

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Pervious Concrete Surface

Not Graded for Runoff !

There Is No Runoff

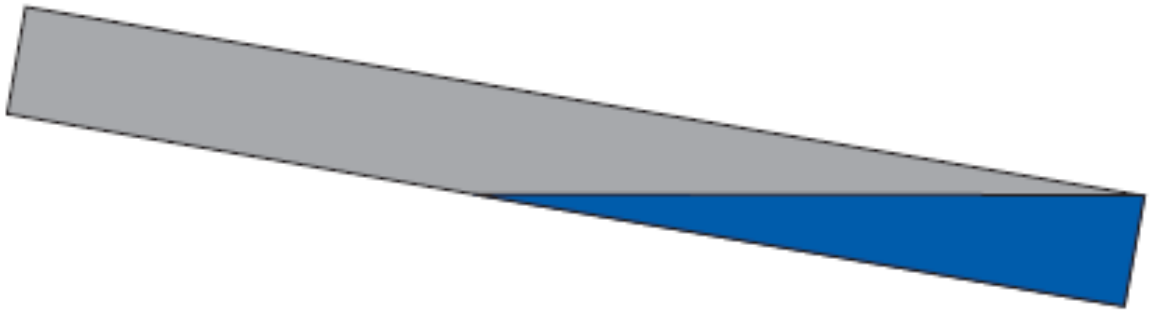

Figure 7. For sloped pavements, storage capacity calculations must consider the angle of the slope, if the infiltration rate of the subgrade is exceeded.

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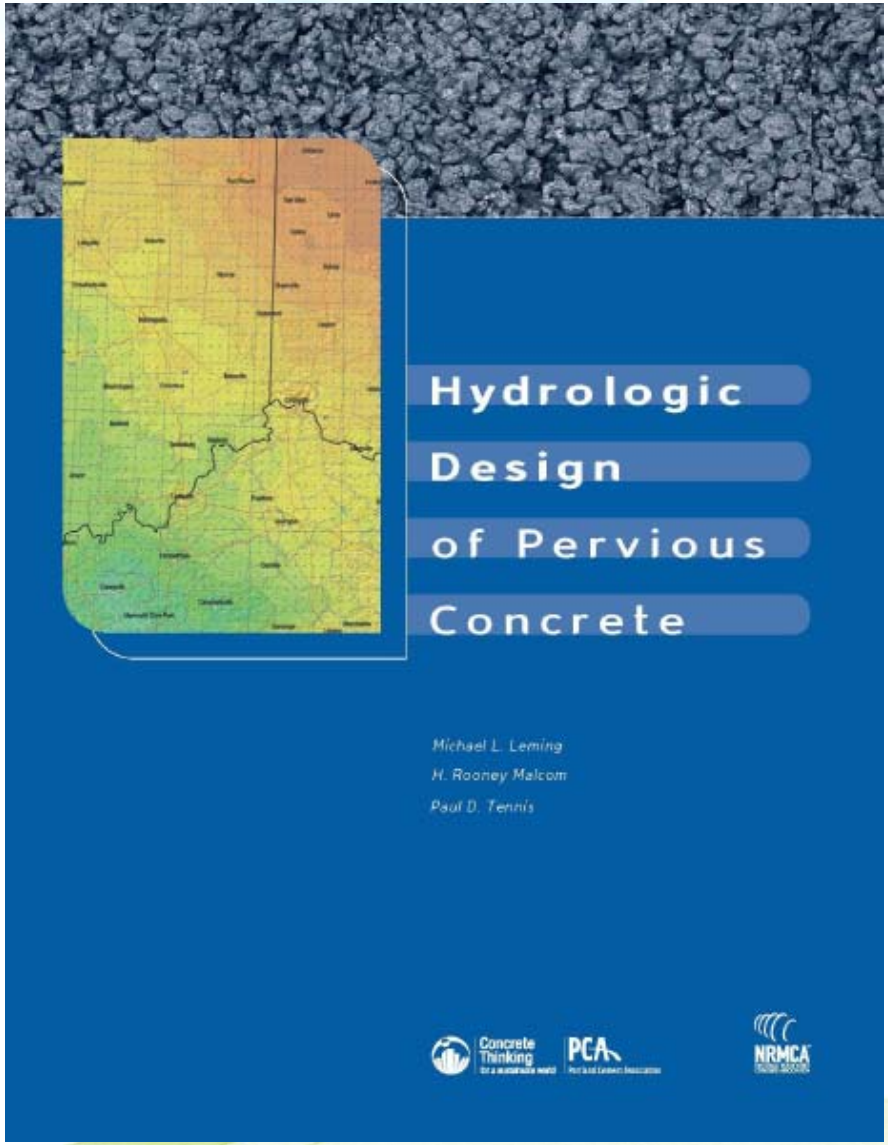
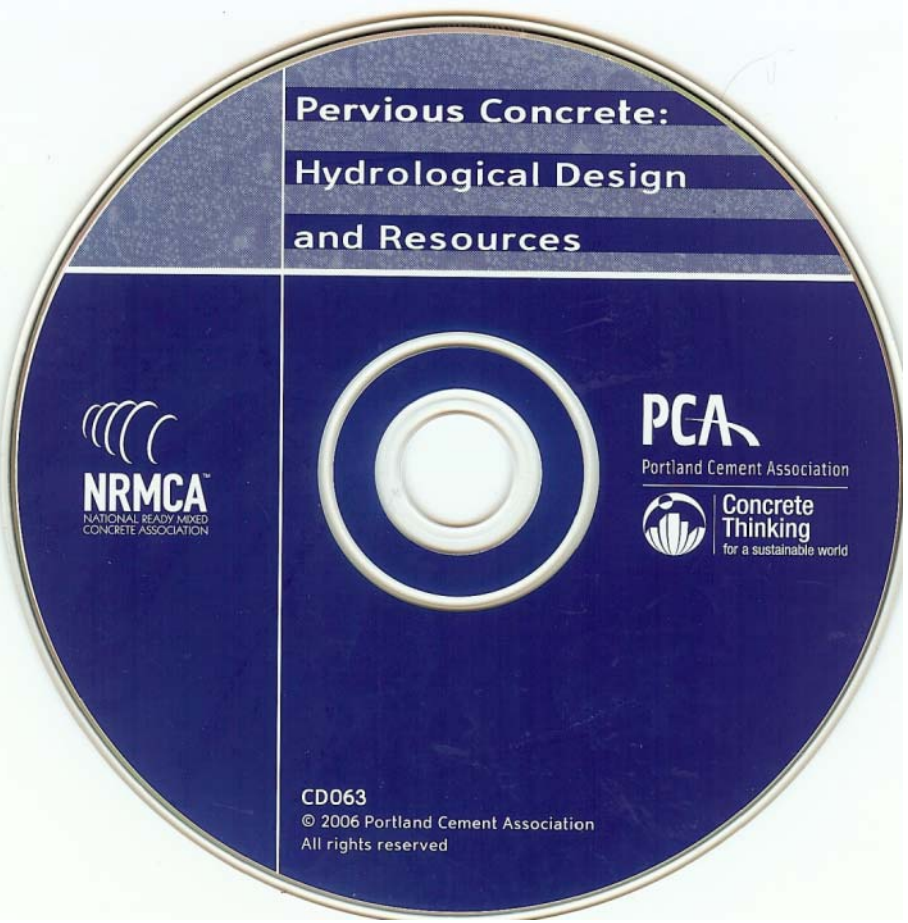
Design Guide and/or Software Program





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Pervious Concrete – Mix Design

This software program helps the user to establish mixture proportions for pervious concrete for a design void content and optimum consistency. Along with the software two documents are included. The first document is a guideline that details the pervious concrete mixture proportioning methodology. The second document is a research report that provides experimental validation of the mixture proportioning methodology based on testing conducted at the NRMCA Research Laboratory. A special feature of this software program is that the mixtures can be designed for a void content that is close to that measured by the newly standardized ASTM C1688 Standard Test Method for Density and Void Content of Pervious Concrete. The program was developed by NRMCA Engineers after more than a year of laboratory research work. The program was developed by NRMCA Engineers after more than a year of laboratory research work. Regular member price will be $45 as of March 1st. THIS PRICE INCLUDES AN INTRODUCTORY SAVINGS OF $10 PER CD

NRMCA™
NATIONAL READY MIXED CONCRETE ASSOCIATION

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INSTALLATION

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Install geotextile fabric under retention layer

Generalized Basic Const. Process

Hennessey Porsche, Roswell Georgia ©Copyright 2004, PCI Systems, LLC all rights reserved.

Cover geotextile fabric with stone

Hennessey Porsche, Roswell Georgia ©Copyright 2004, PCI Systems, LLC all rights reserved.

Retention Layer installed

Hennessey Porsche, Roswell Georgia ©Copyright 2004, PCI Systems, LLC all rights reserved.

Mixture – Usually Very “Dry” (low slump)

Pervious Concrete

Small Placement (Highly Permeable Base)

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Various Placing Equipment Types

Pervious Concrete - 2010

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Text reference for

Pervious Concrete Contractor Certification

NRMCA Publication #2PPCRT

MAINTENANCE

Pervious Concrete

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Clogging Prevention/Maintenance

Passes water at 3-5 gal. per min. per sq. ft.

or

270 – 450 in. per hour !

Vacuum Sweepers – Highly Effective

Power Washing – VERY Effective

UNIQUE FEATURES

Pervious Concrete

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Concrete: IDEAL hardscape material to put voids into for high porosity purposes:

- Rigid structure maintains voids under load & extreme temps.
- Load-Carrying Ability, Durability, & Versatility
- Does not introduce toxins to water
- Available from someone YOU KNOW – Supplier already!

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Pervious Concrete Shopping Center Entrance/Service Road

“Canyon Crossing” – Puyallup (Seattle), WA

1 Mi. Long Pervious Concrete Residential Roadway

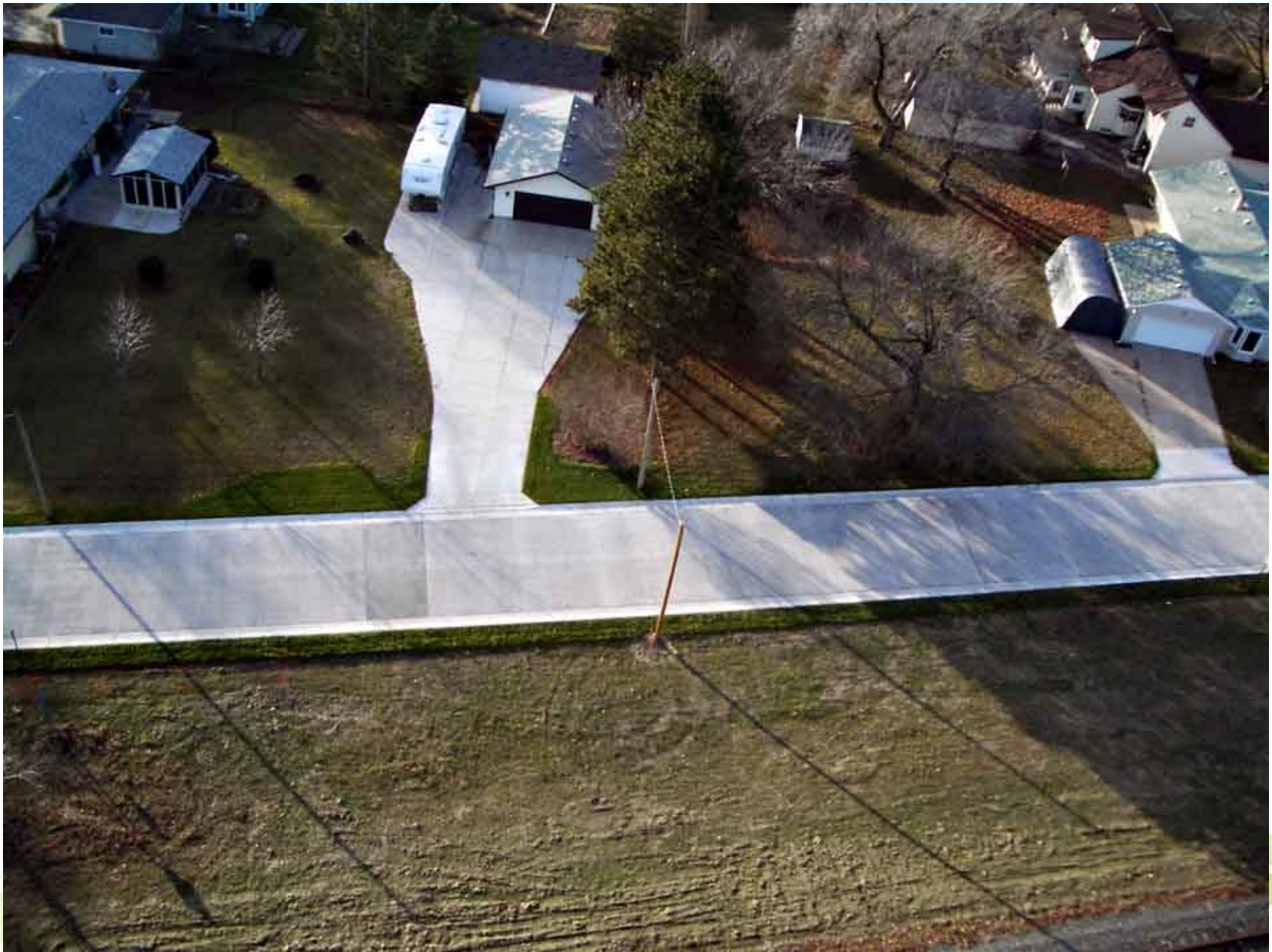
Shoreview (Minneapolis), MN

1 Mi. Long Pervious Concrete Residential Roadway

Shoreview (Minneapolis), MN

1 Mi. Long Pervious Concrete Residential Roadway

Shoreview (Minneapolis), MN



Pervious Concrete (Foreground) – Heavy Rain

Pedestrian Plaza – Phoenix, AZ

Progressive Concrete Works, Inc.

Photo courtesy of Progressive Concrete Works

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Stamped Pervious Concrete – Fresno, Calif.

Photo by David C. Mitchell, Bunyan Industries

Along Mississippi River – Minneapolis Metro

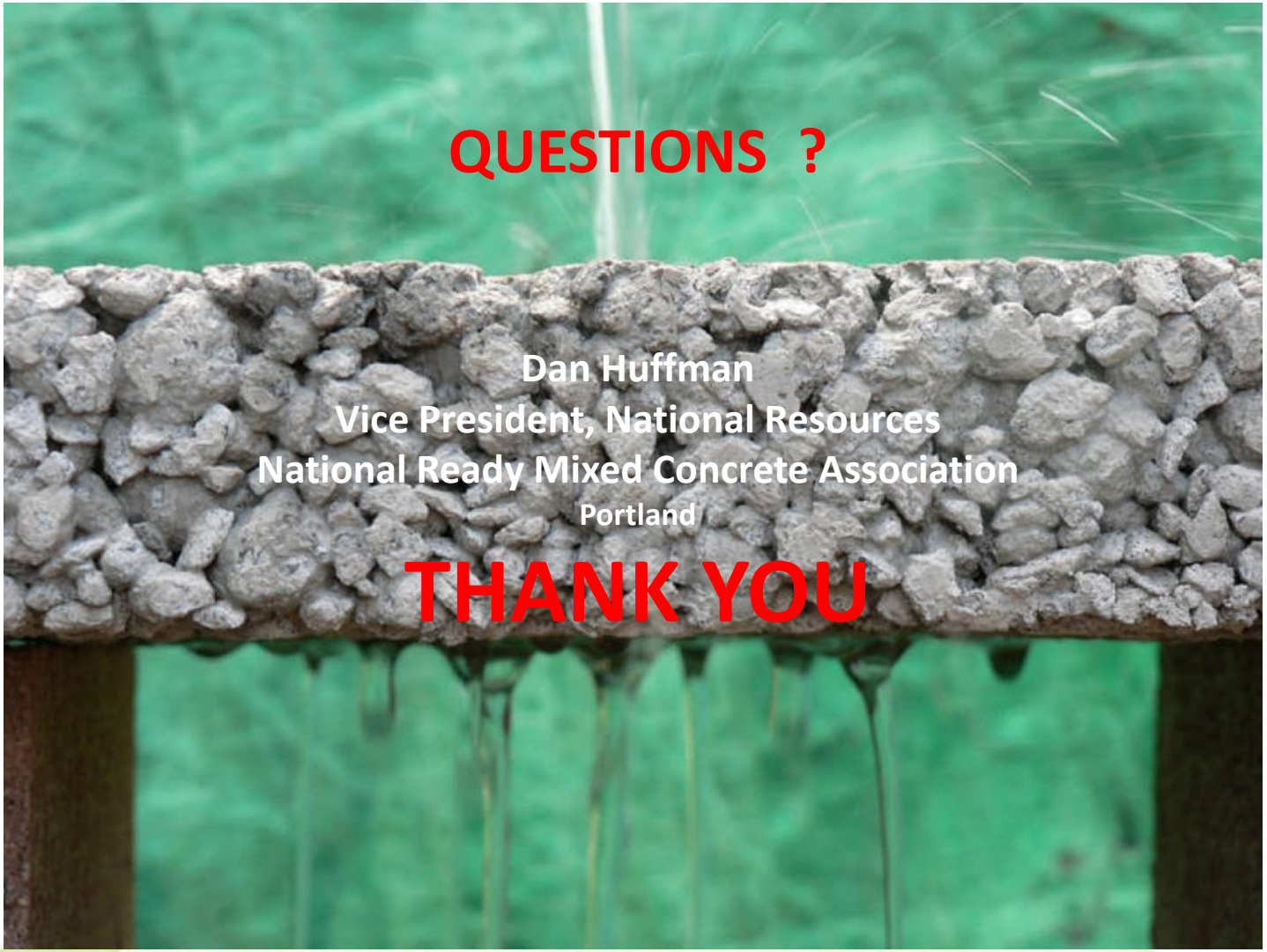
Pervious Concrete – Progressive Concrete Works, Inc.

Pervious Concrete

BEST WEB RESOURCES

- www.perviouspavement.org (Natl./Local Apps.)
- www.concretethinker.com (Portland Cement Assn.)
- www.concrete.org (American Concrete Institute)
- www.ocapa.net (OR Concrete & Agg. Prdcrs. Assn.)
- www.washingtonconcrete.org **(WA Agg. & Concrete Assn.)**
- www.nrmca.org (Natl. Ready Mixed Concrete Assn.)

Pervious Concrete



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POROUS ASPHALT FOR STORMWATER MANAGEMENT

Metro Porous Surfaces Seminar

April 2010

Jim Huddleston, P.E.
Executive Director

ASPHALT PAVEMENT ASSOCIATION OF OREGON

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THESE PARKING AREAS ARE PAVED WITH
POROUS PAVEMENT
PAVEMENT THAT LEAKS
SINCE 1977, IT HAS RAISED THE LOCAL
WATER TABLE WHILE REDUCING EROSION,
POLLUTION, AND THE NEED FOR STORM
DRAINS OR ROAD SALT.
A BROCHURE IS AVAILABLE.
A DEMONSTRATION PROJECT BY
MASS. D.E.P. & MASS. DEM.

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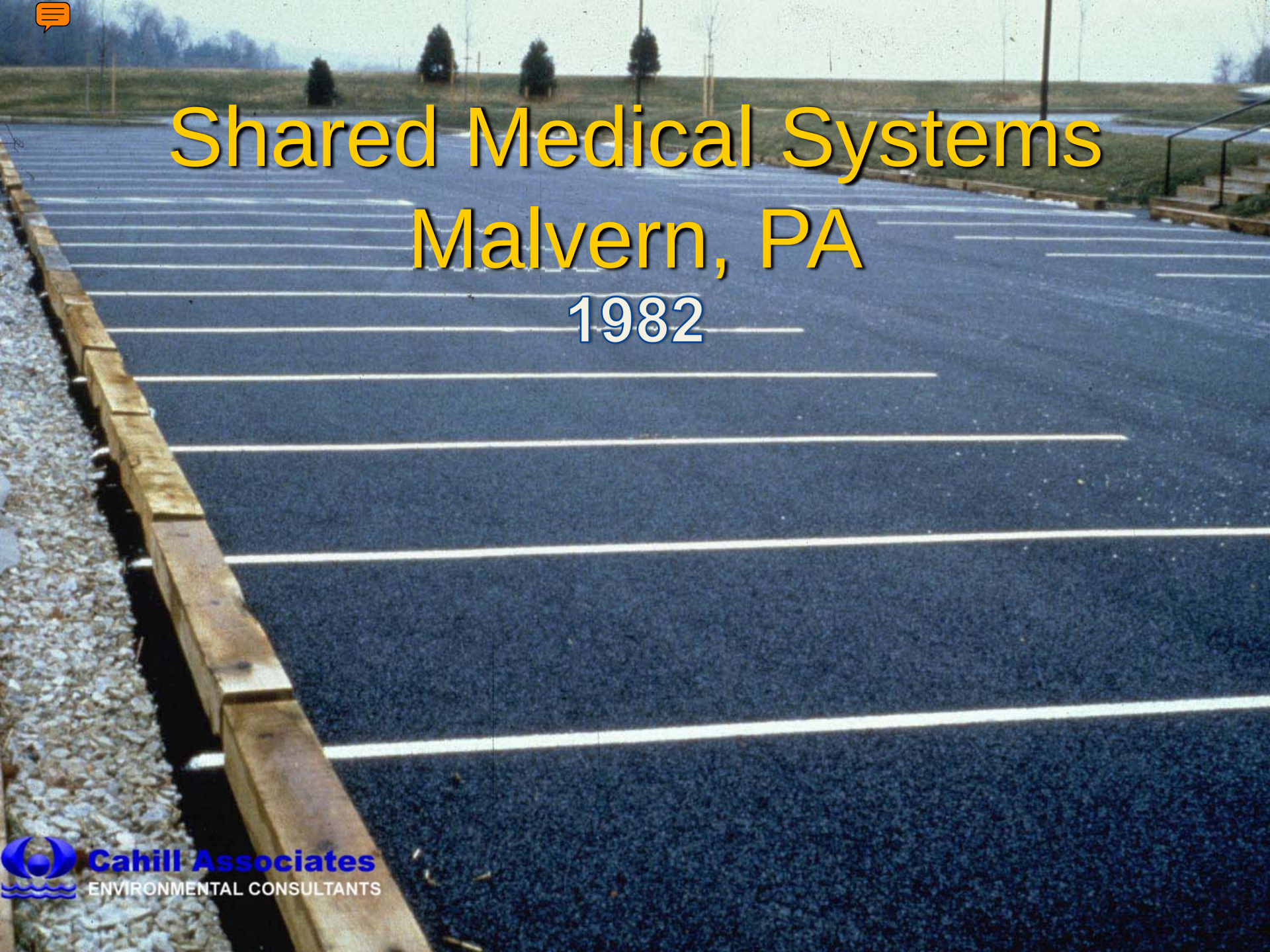
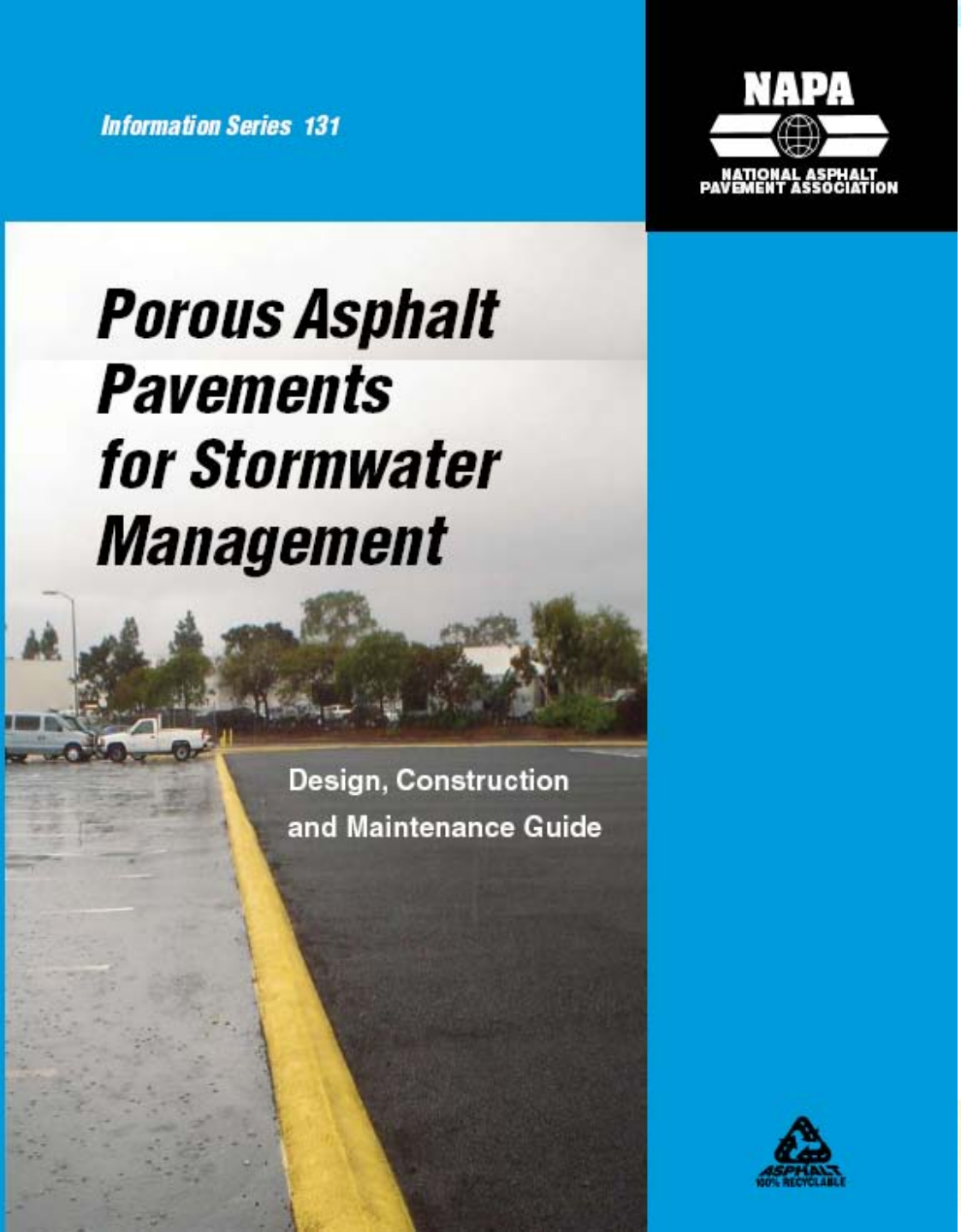
Morris Arboretum
Philadelphia, PA
1984
Cahill Associates
ENVIRONMENTAL CONSULTANTS


Shared Medical Systems
Malvern, PA
1982
Cahill Associates
ENVIRONMENTAL CONSULTANTS



- Introduction
- Overview and History
- Water Quality
- Design
- Materials
- Construction Guidelines
- Maintenance
- Conclusion

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Porous Asphalt Design and Construction

- Structural Design
- Materials
- Mix selection and design
- Construction
- Maintenance
- Case Studies

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Structural Design

- Follow AASHTO Design Procedures
  - Layer coefficients
    - Open-Graded 0.40-0.42
    - Asphalt Treated Permeable Base 0.30-0.35
    - Stone bed 0.10-0.14
- Minimum Asphalt thickness
  - 2.5” Parking areas (few or no trucks)
  - 4.0” Residential type streets
  - 6.0” Heavy truck traffic

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Hot Mixed Asphalt Materials

- Use Oregon Standard Specifications:
  - 3/4” Open-Graded Mixture
  - 1/2” Open-Graded Mixture
  - (3/8”* Open-Graded Mixture)
  - 3/4”Asphalt Treated Permeable Base

- Use PG 70-22 or PG 70-22ER binder
- In Cold climates Use PG 70-28 or PG 70-28ER

Oregon Gradation “Control Points”

Sieve Size	3/8”*	1/2”	3/4”	ATPB
1”		-	99-100	99-100
3/4”	-	99-100	85-96	85-95
1/2”	99-100	90-98	55-71	35-68
3/8”	90-100	-	-	-
#4	22-40	18-32	10-24	2-10
#8	5-15	3-15	6-16	0-5
#200	1-5	1-5	1-6	0-2

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Porous Asphalt Mix Options

Mix Size	Application	Layer Thickness
3/8” Open	Parking/Recreational Facilities/Roads and Streets	1.5 – 2.5 Inches
1/2” Open	Wearing Surface, Roads, Streets, Heavy Commercial	2.0 – 4.0 Inches
3/4” Open	Wearing Surface, Roads, Heavy Commercial	2.0 – 5.0 Inches
3/4” ATPB	Base Course	3.0 – 6.0 Inches

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Asphalt Design "System"

- To minimize clogging select mix types so the aggregate size and air void content increase with depth
- ATPB makes outstanding base-stable platform, low binder content, high air voids
- Topped with ½" or 3/8" porous wearing to provide low maintenance high performance porous system

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Two Layer System

- ATPB can provide a construction platform and allow staged construction
- ATPB is relatively low cost low binder content product with high air voids high stability
- ATPB can be placed directly on top of reservoir course eliminating need for choker course

HMAC Mix Design
(the recipe)

- Require an ODOT Certified Mix Design Technician (CMDT)

- Use current version of the ODOT Contractor Mix Design Guidelines for Open-Graded mixtures

Mix Design Criteria

	3/4", 1/2", & 3/8"* Open-Graded	3/4" ATPB
Air Voids, %	> 16	-
Draindown, %	70 - 80	-
TSR, min	80	-
Coating, %	-	90
VFA, %	40 - 50	-
VIR, %*	14.0 – 15.5	-

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Construction of Porous Asphalts

- Conventional Paving Equipment

- Lower mixing and placement temperatures to minimize draindown in haul vehicles

Construction of Porous Asphalts

- **Compaction Equip**:
  - Steel wheel rollers only
  - Generally static mode
  - 8 ton minimum
  - 3-4 complete coverages

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Post Construction Guidelines

- Restrict traffic for 24 hrs.

  Protect porous pavement from contamination:
  - Run-off sediment
  - Construction debris

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Maintenance/Snow Removal

- Inspect several times first few months during storm events.
- Inspect annually thereafter.
- Pavement surface should be vacuumed and may be flushed or jet washed annually.
- Damaged pavement can be repaired using dense hot mix provided <10% area.
- Use liquid de-icing compounds as needed
- Do *not* use sand, ash, or salt for snow or ice

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Porous Pavements

Port of Portland
Terminal 6

Pringle Creek
Green Streets

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Terminal 6 – Porous Pavement Project -- Overview

- 35.7 acres of porous pavement and 15.4 acres of impervious pavement
- 100% onsite storm water management through porous pavement system and vegetated swales

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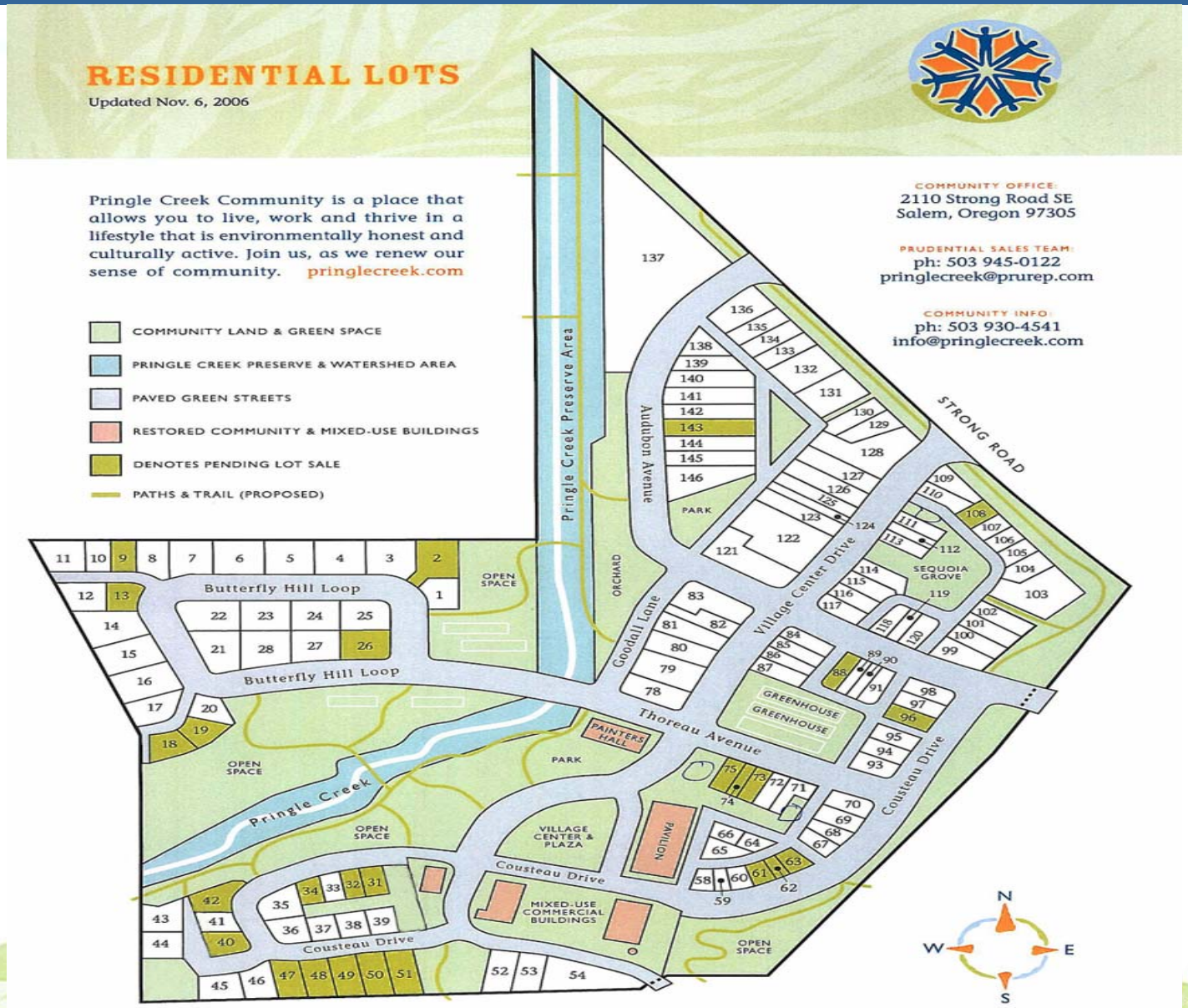
Terminal 6 – Porous Pavement Project -- Overview

Port of Portland is extremely proud and happy with project

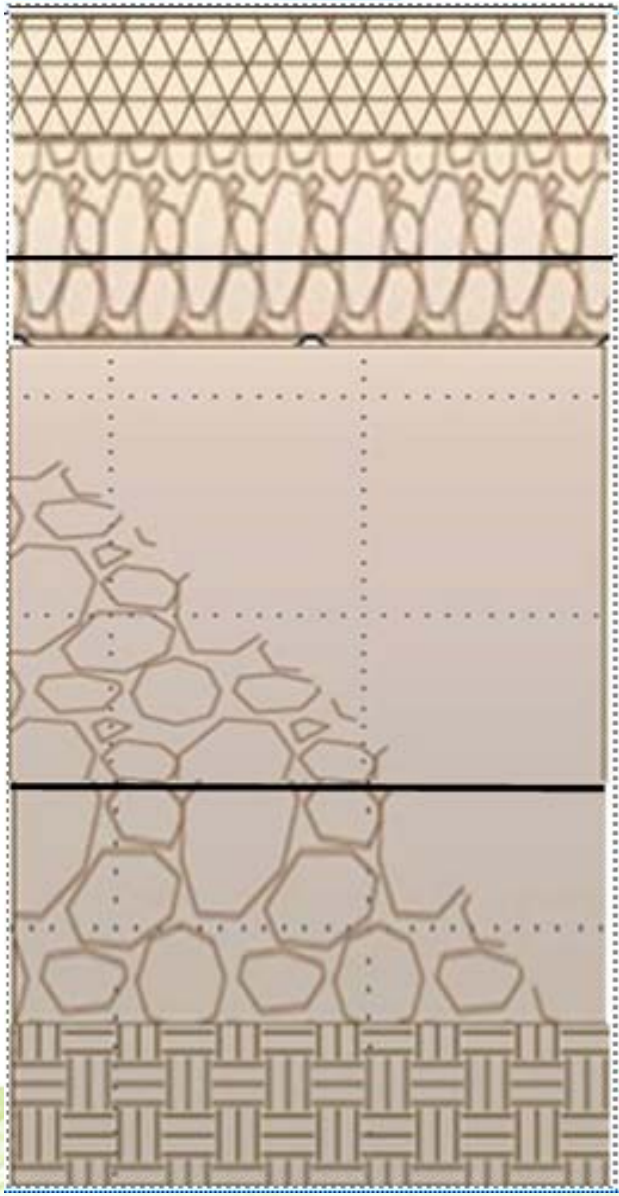

Pringle Creek
COMMUNITY
A Sustainable Living Community
pringlecreek.com
Prudential
Real Estate Professionals
(503) 945-0122

Pringle Creek Community – Porous Asphalt Streets



Metro

Pringle Creek Community – Porous Asphalt Streets



1.5 " Porous Surface Course
3/8" Porous Asphalt Cement Concrete
w/Polymer modified PG 70-22 binder

3.0 " ATPB

1—2" Choker Course
AASHTO #57 stone

10.0" Reservoir Course
Clean, uniformly graded, AASHTO #2 stone, or equivalent
Crushed Aggregate
Approximately 40% voids

8.0 " Pit Run Subbase
4" - 0 Clean

Uncompacted Subgrade
Uncompacted to retain permeability

Pringle Creek Community – Porous Asphalt Streets

- Paving asphalt treated permeable base (ATPB)
- 3” lift
- 3% asphalt
- 30%-35% voids
- Paved full width
- Crowned section 2½%

Metro

Pringle Creek Community – Porous Asphalt Streets

- Base paving was completed before utilities
- How do you keep it clean?
- Contractor had the idea to cover it all with a Geotextile

Metro

Pringle Creek Community – Porous Asphalt Streets

- And than winter came early
- November storms gave us record rainfall of more than 11”
- Lots of wind as well

Metro

Pringle Creek Community – Porous Asphalt Streets

- Pavement held up exceedingly well under saturated conditions
- Not a single weak spot on the project

Metro

Pringle Creek Community – Porous Asphalt Streets

- April 2007
- Utilities all in
- Grading complete
- Sidewalks, curbs and some landscaping complete
- All in winter/ spring running on the ATPB

Metro

Pringle Creek Community – Porous Asphalt Streets

Contractor removed Geotextile and cleaned surface to prepare for top lift

Metro

Pringle Creek Community – Porous Asphalt Streets

Top Lift	
Sieve	**% Passing**
1/2”	100
3/8”	97
1/4”	55
#4	34
#8	7
#30	3
#200	2.1
Asphalt %	6.0
Binder	PG 70-22 ER
(Polymer Modified)	

Metro

Pringle Creek Community – Porous Asphalt Streets

The completed project came out very nice, owner is extremely happy

Metro

Pringle Creek Community – Porous Asphalt Streets

Performance in wet weather has been outstanding

Metro

Pringle Creek Community – Porous Asphalt Streets

Porous Asphalt Benefits

- Low cost – similar to conventional
- Easy to produce and construct - same as conventional
- Speed of Construction – can built on same time line as conventional
- Allows staged construction
- Proven performance:
  - 20 years common application
  - 30 years as highway wearing surfaces
  - Can handle heavy truck traffic

Metro

Resources

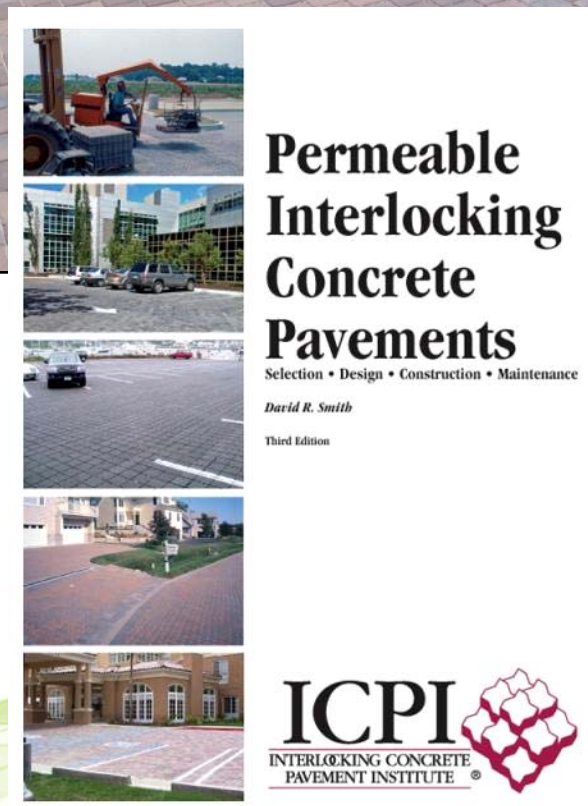
- Asphalt Pavement Association of Oregon, Salem, OR (apao.org)
- National Asphalt Pavement Association NAPA (hotmix.org)
- Asphalt Pavement Alliance APA (Pavegreen.com)

Permeable Interlocking Concrete Pavements

Willamette Graystone
MANUFACTURING SOLID SOLUTIONS

www.willamettegraystone.com

www.icpi.org

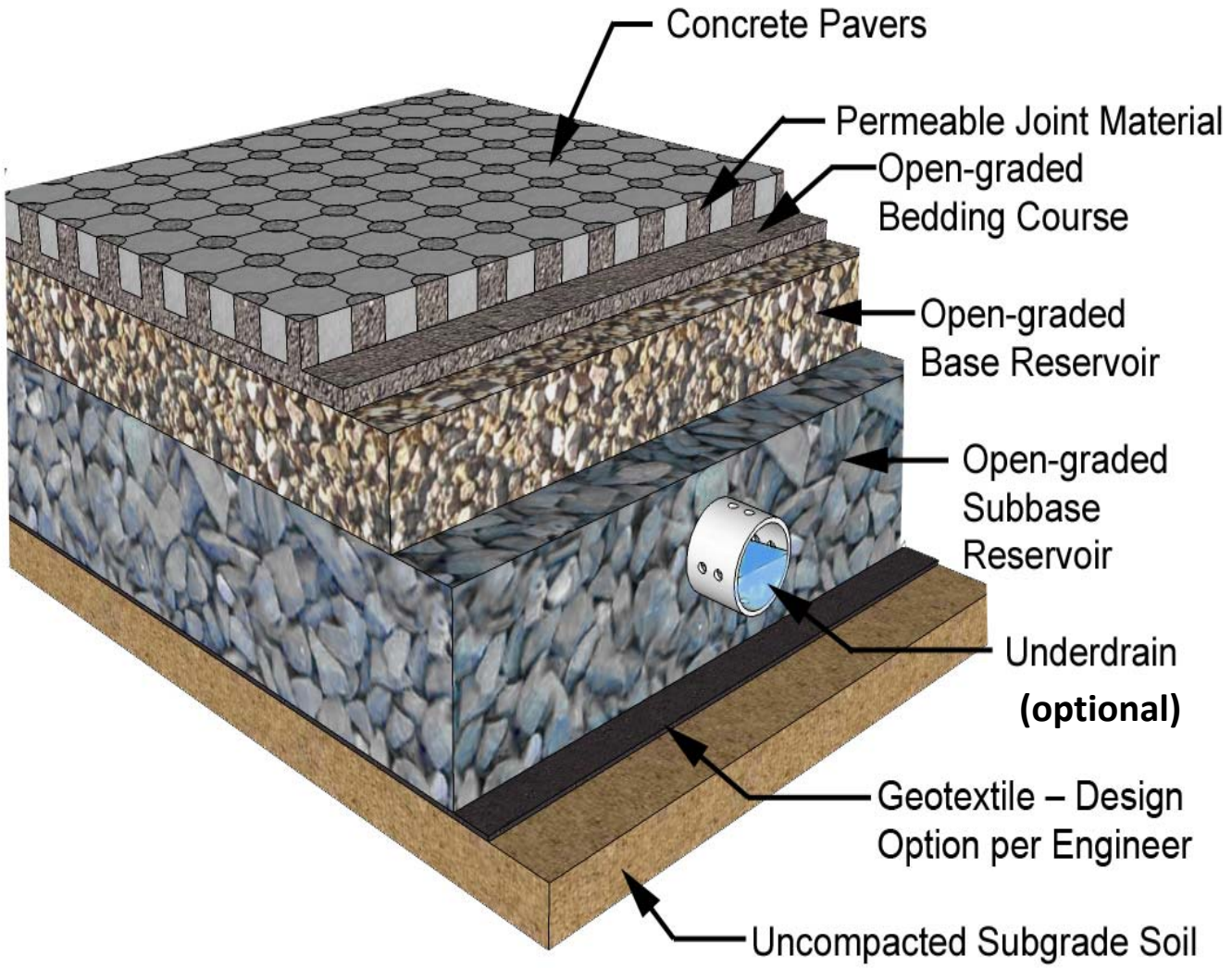


Learning objectives:

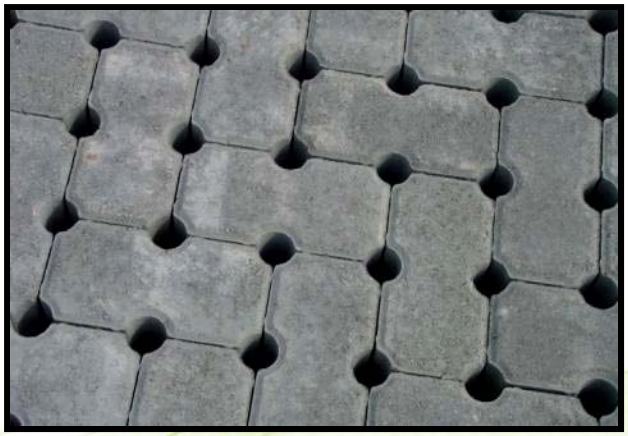
- Introduction of structural design principles of permeable paver pavement.
- Introduction to the steps of construction
- Maintenance
- Benefits of permeable paver pavement

Metro

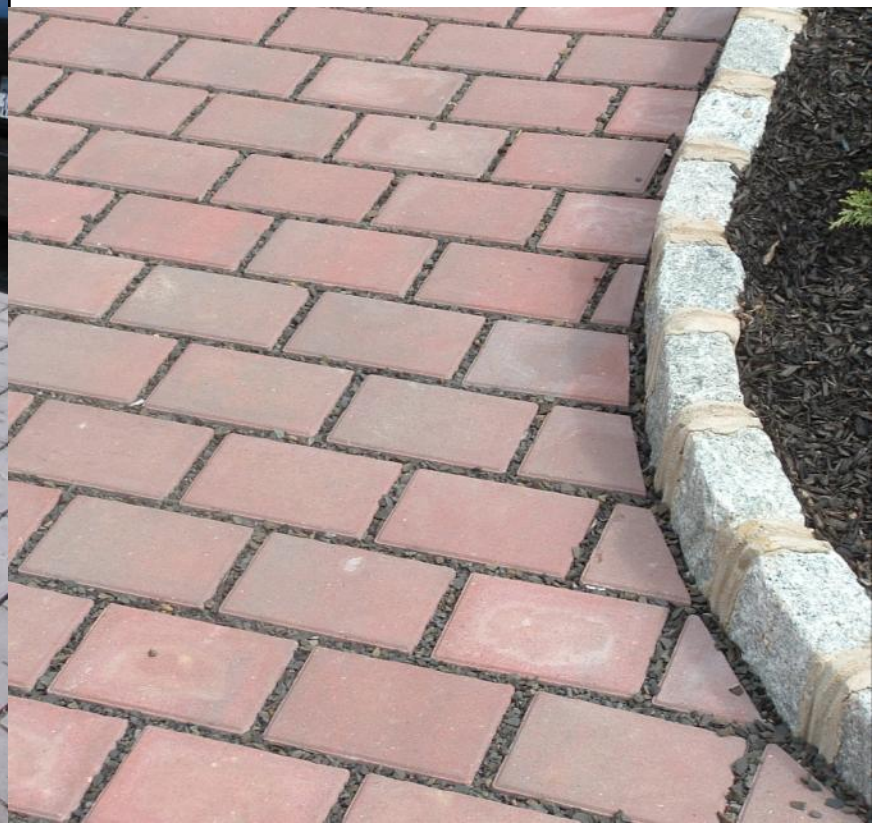
Permeable Interlocking Concrete Paver Pavement



Paver Types Interlocking shapes/patterns



Paver Shapes

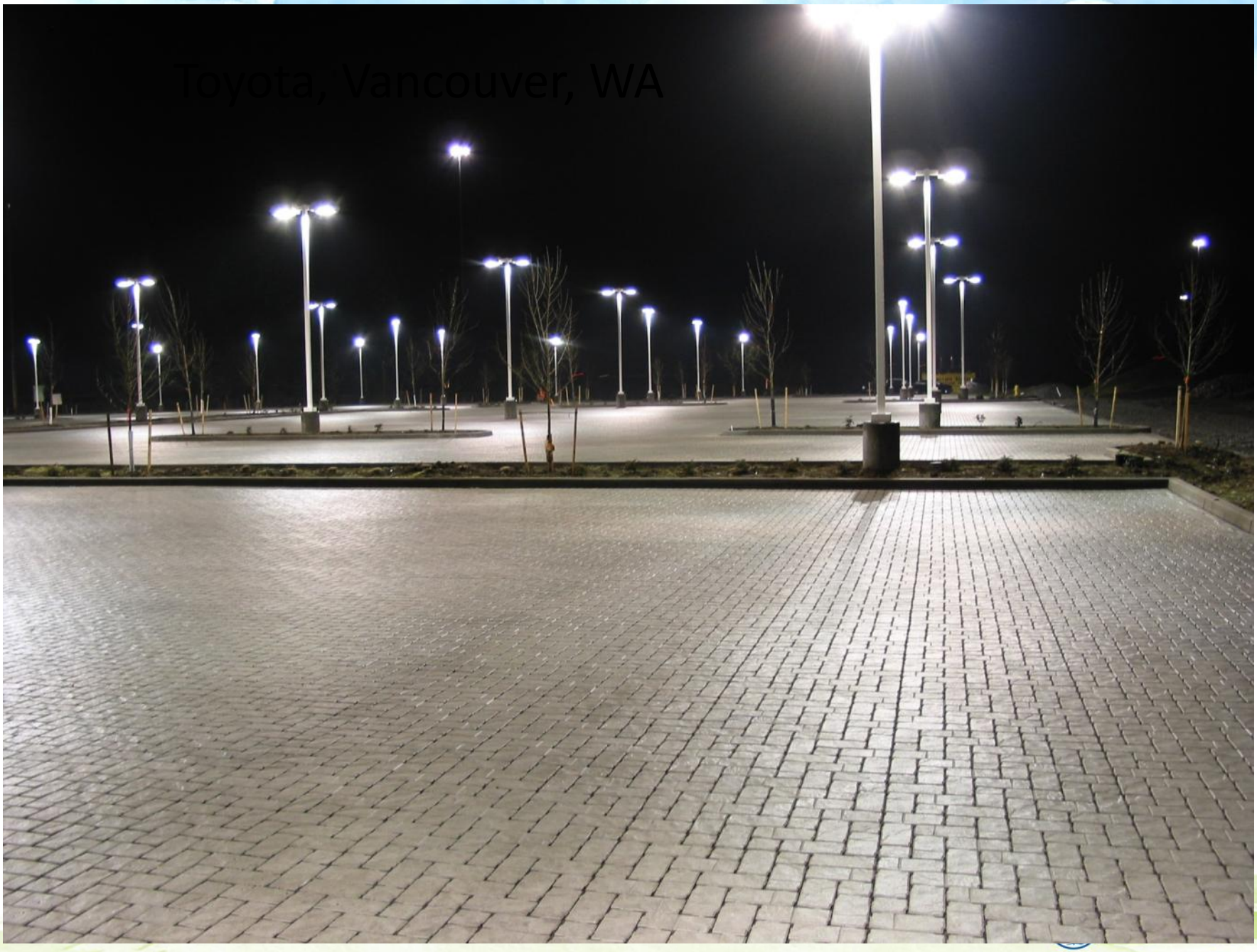


Completed Projects

Eugene, OR


Creswell, OR


Wilsonville, OR


Toyota, Vancouver, WA

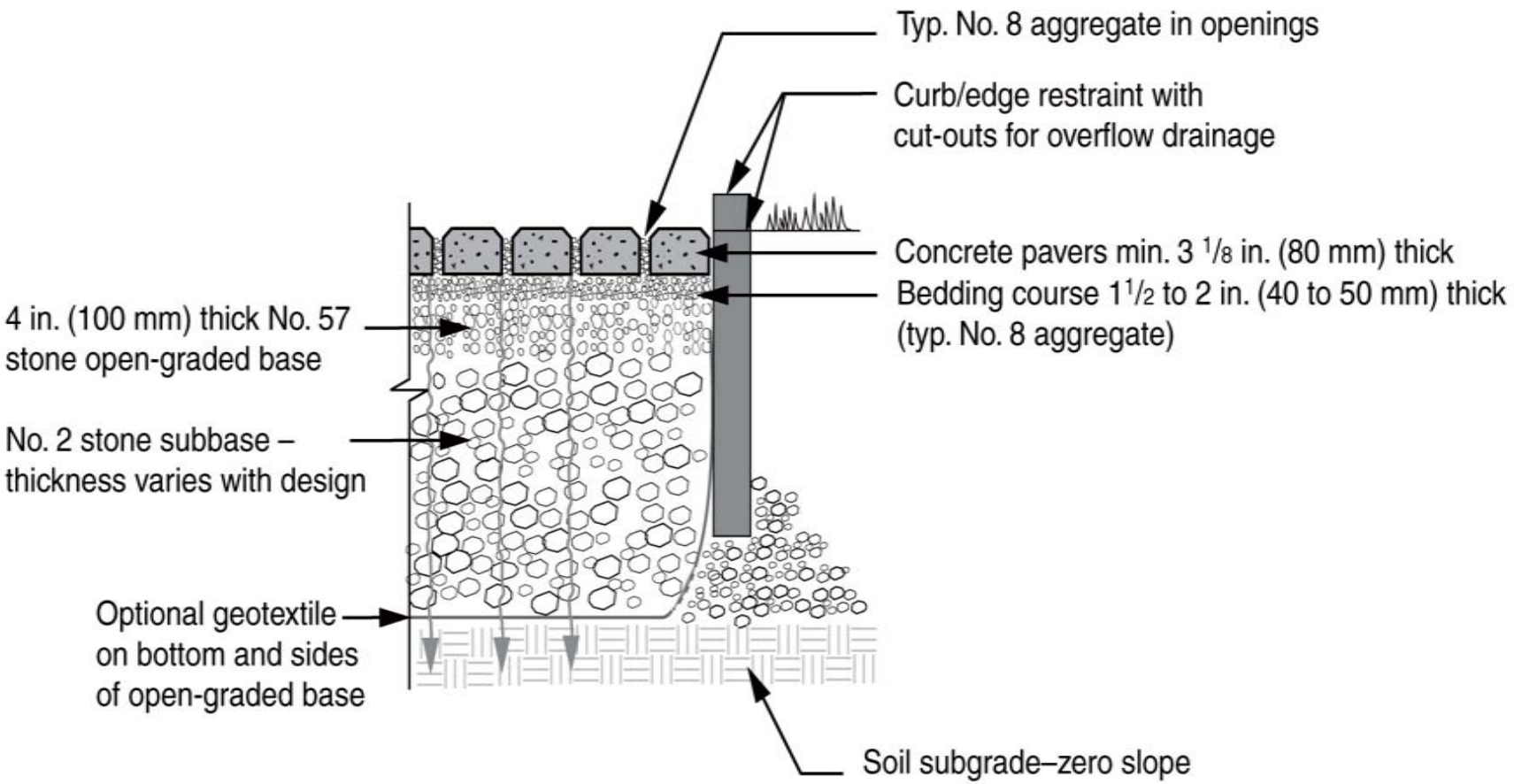
Portland, OR

Three Design Options

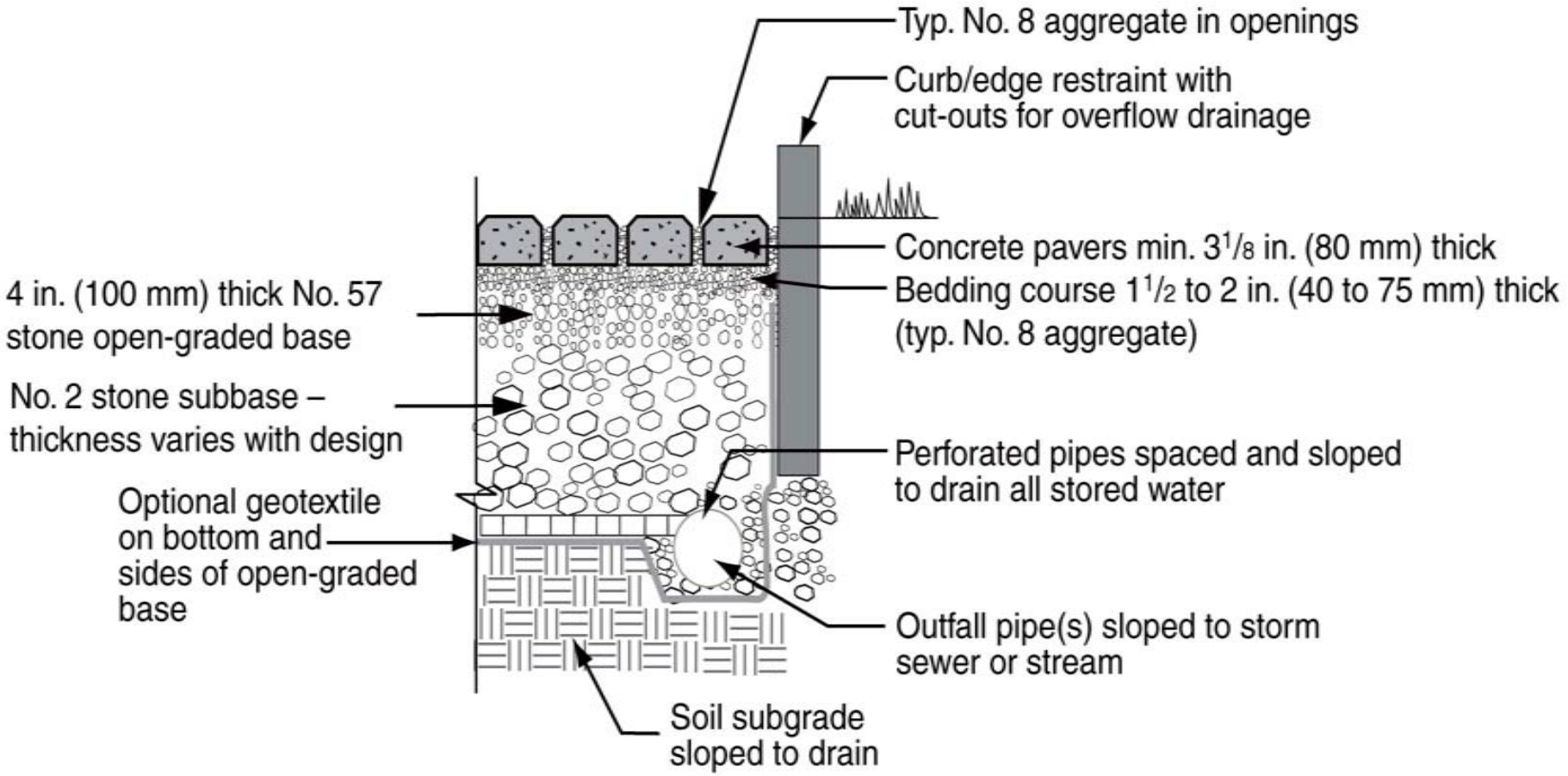
- Full Exfiltration
- Partial Exfiltration
- No Exfiltration

Metro

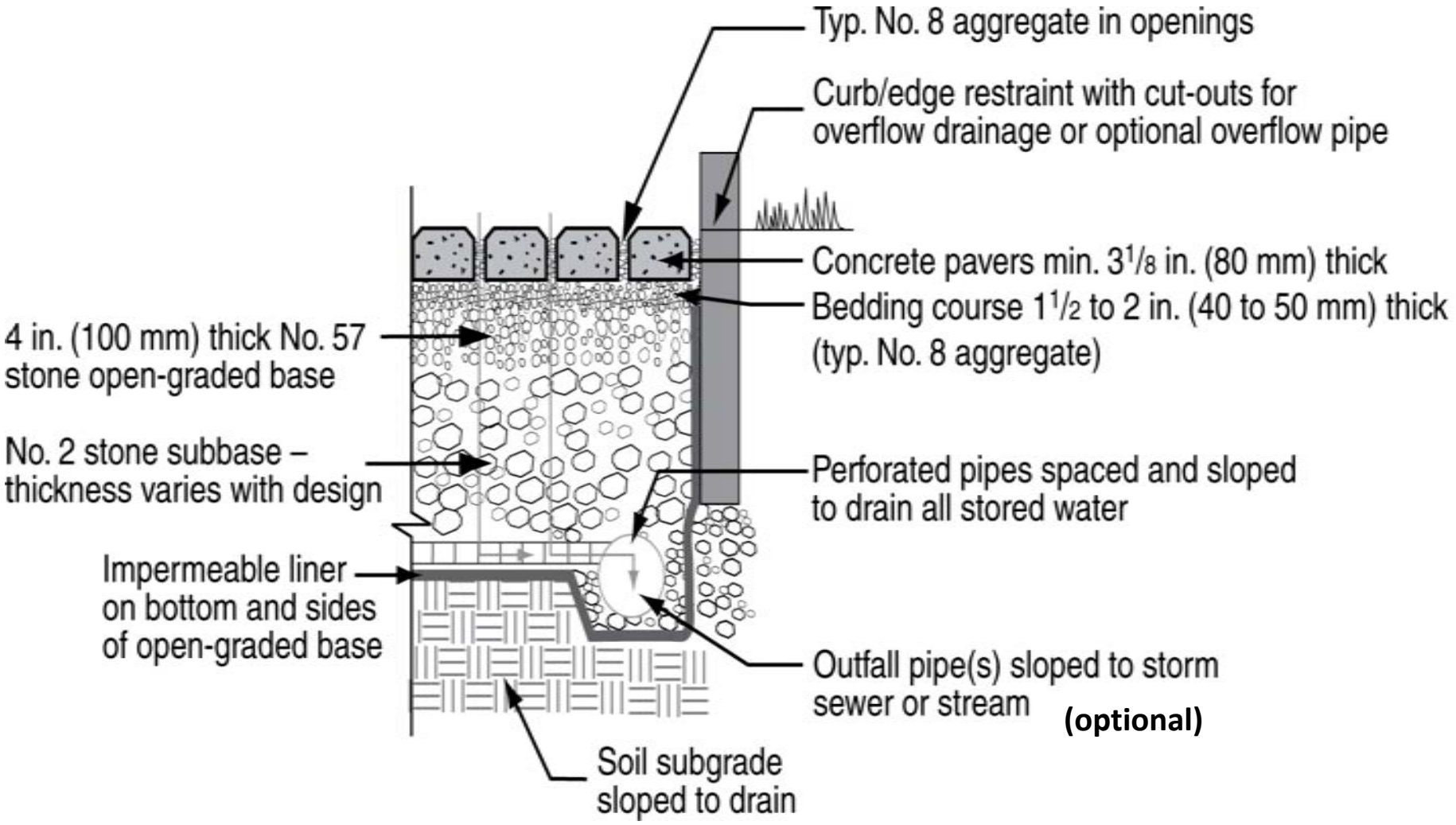
1. Full Exfiltration Option



2. Partial Exfiltration Option



3. No Exfiltration Option



Residential Driveway
Excavation, Drain Tile, Base

Level Base Aggregate

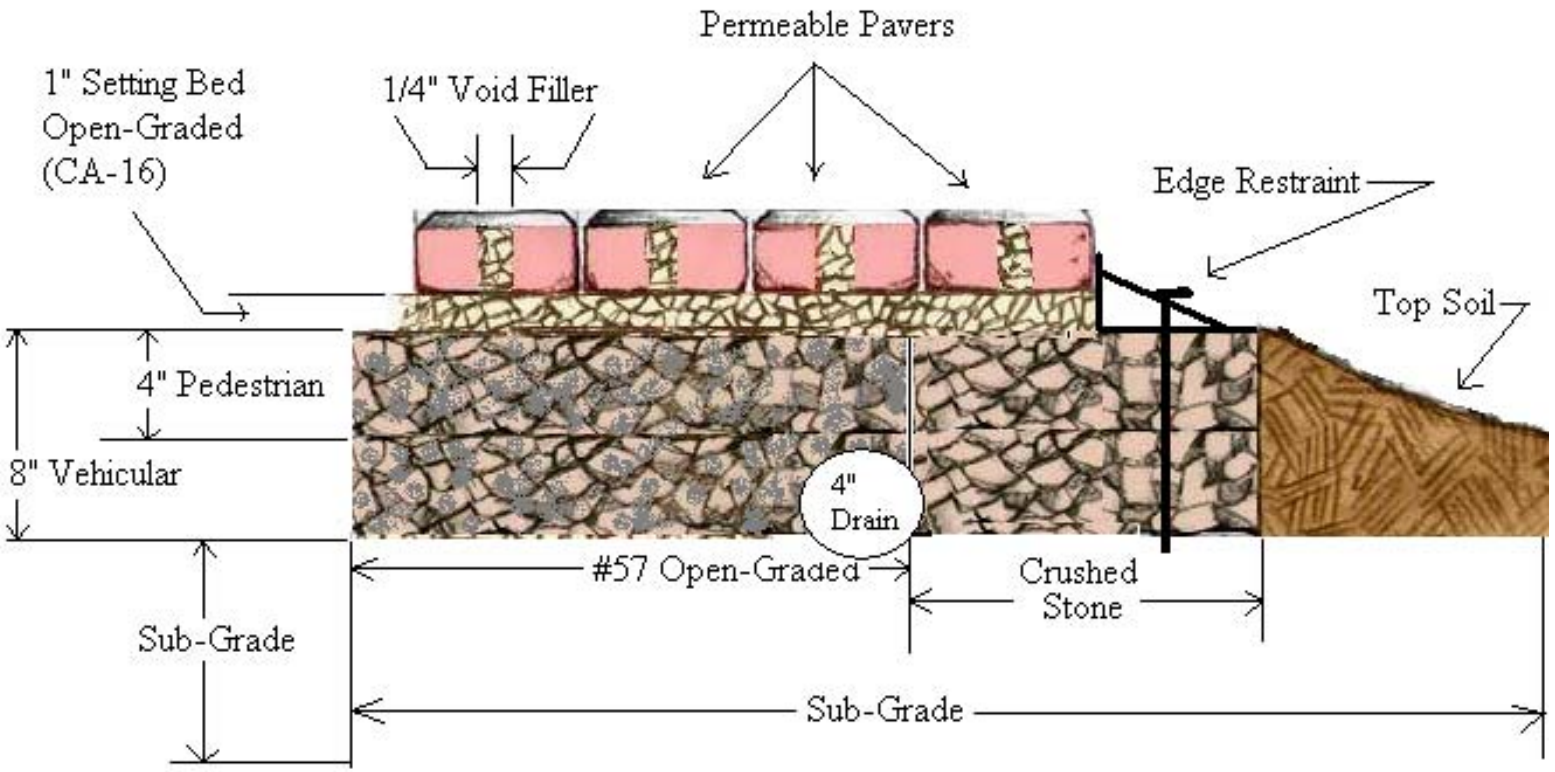
Compact Base Aggregate

- Screed Leveling Layer #8 Stone

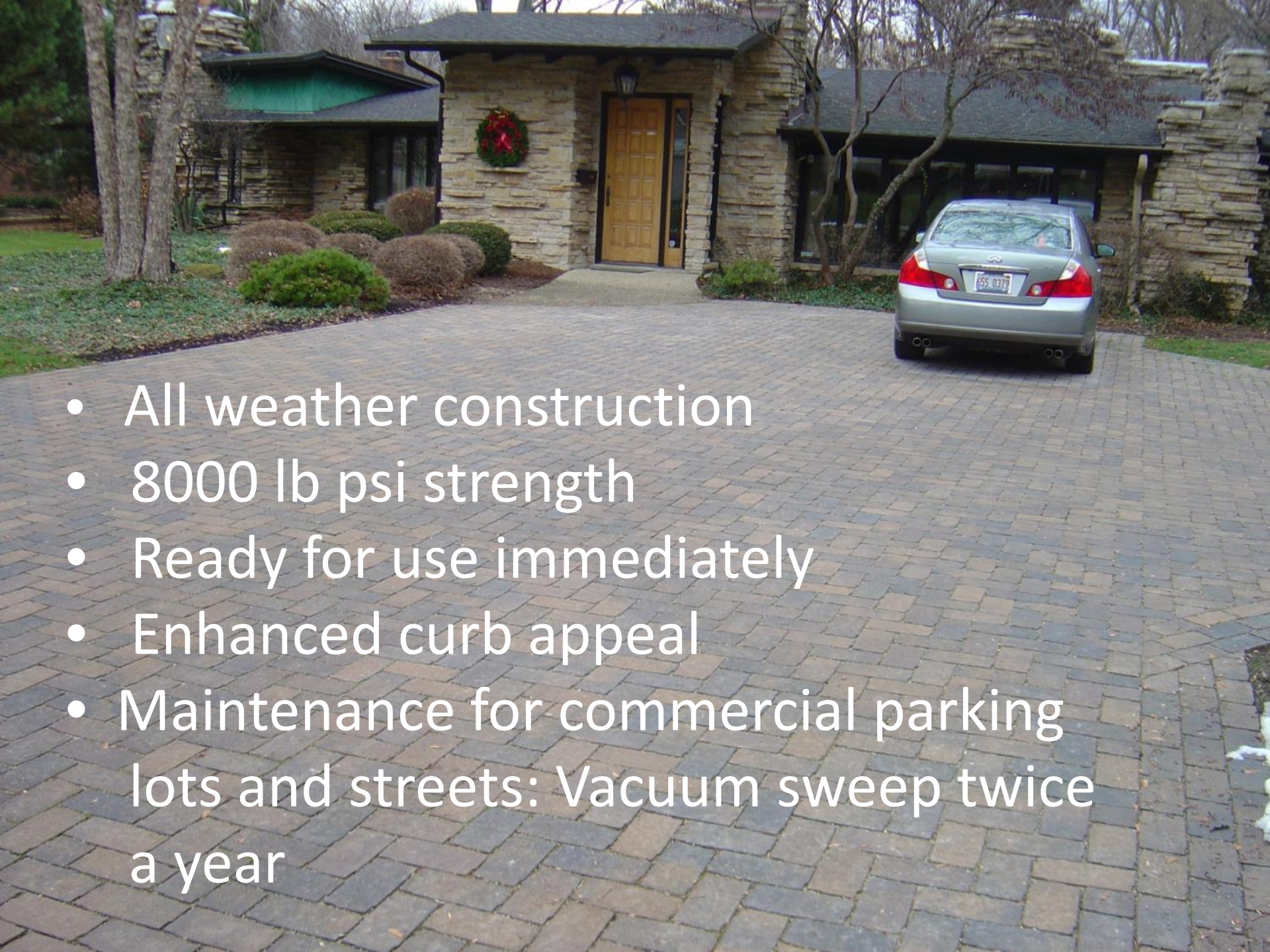
Paver Shape: Aqua Bric
Laying Pattern: Herringbone

Invisible Edge Restraint

Optional Residential Installation Method



Metro



- All weather construction
- 8000 lb psi strength
- Ready for use immediately
- Enhanced curb appeal
- Maintenance for commercial parking lots and streets: Vacuum sweep twice a year

Questions?

Metro

Pervious Flexible Paving Systems

Presented by Andy Gersen
The Gersen Co.
Stormwater Product Specialists

Metro

Pervious Flexible Paving Systems

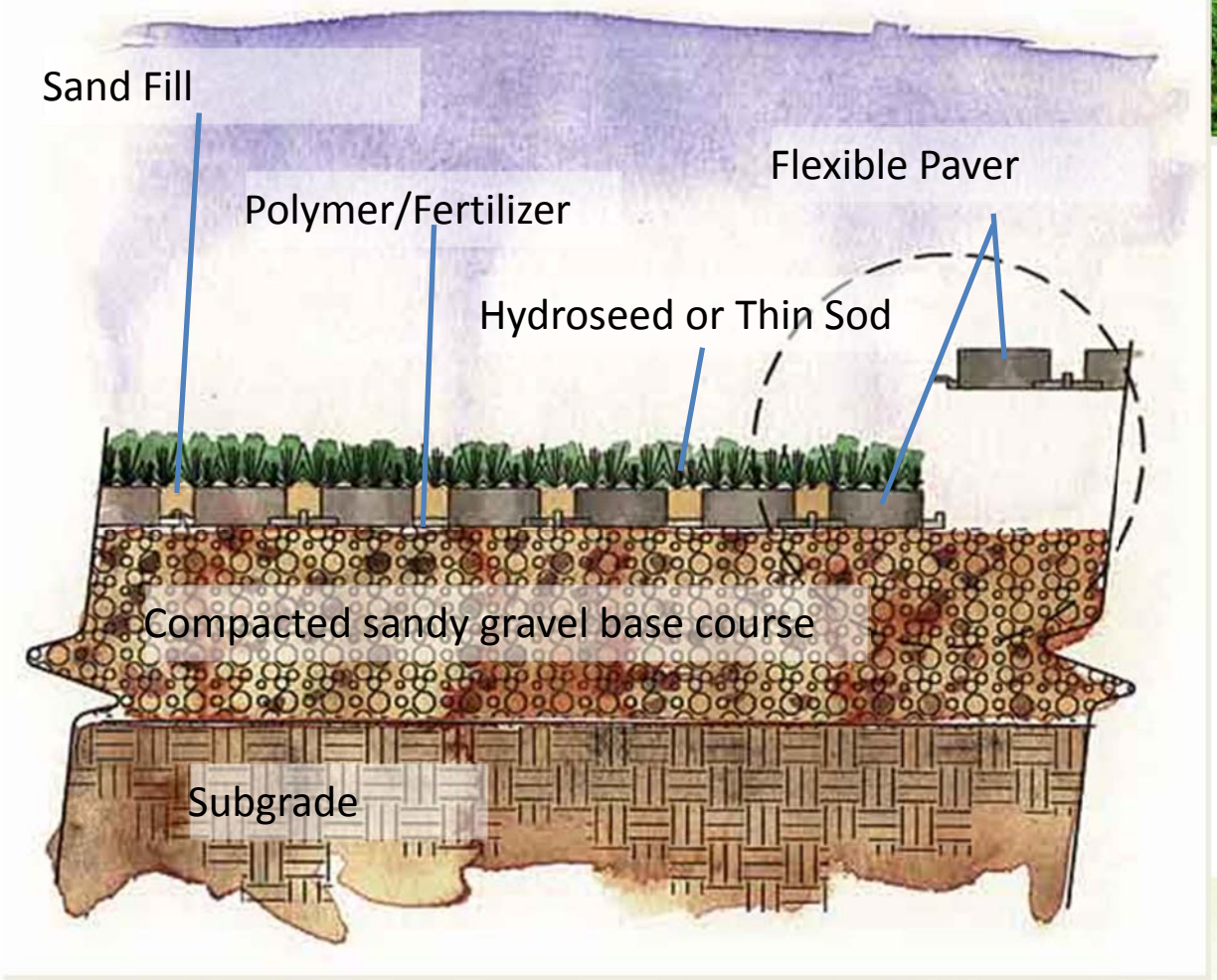
aka Plastic Permeable Pavers

- Grass Systems (Turf reinforcement)
- Gravel Containment

Grasspave2 by Invisible Structures

Gravelpave2 by Invisible Structures

Grass Flexible Pervious Pavers



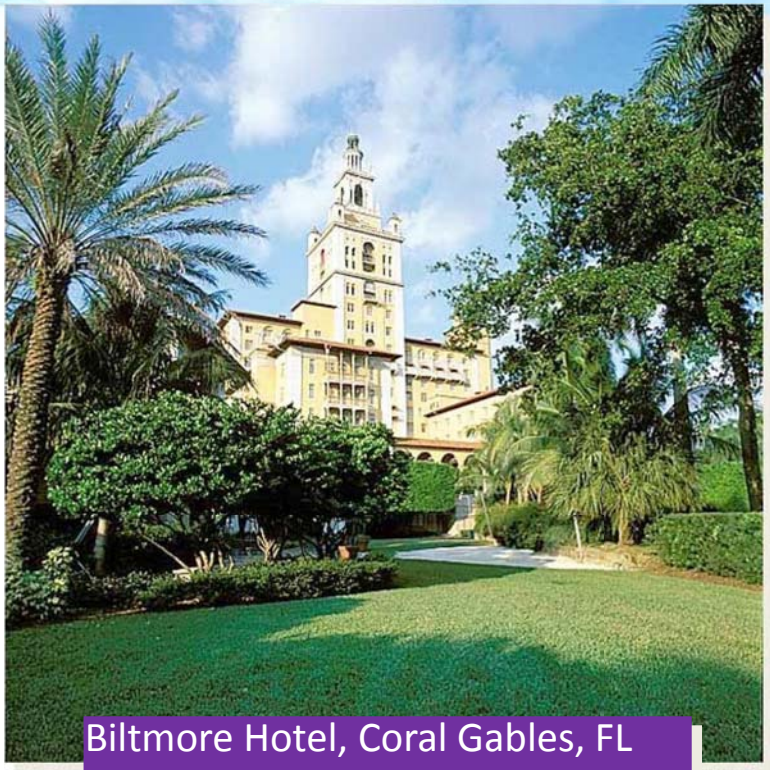
Trade Names

From BuildingGreen.com

- Grasspave2
- Netpave 50
- GT Interlocking Panels
- MODI Porous Paving Grid
- Salvaverde

Metro

Grass Pervious Paving Systems

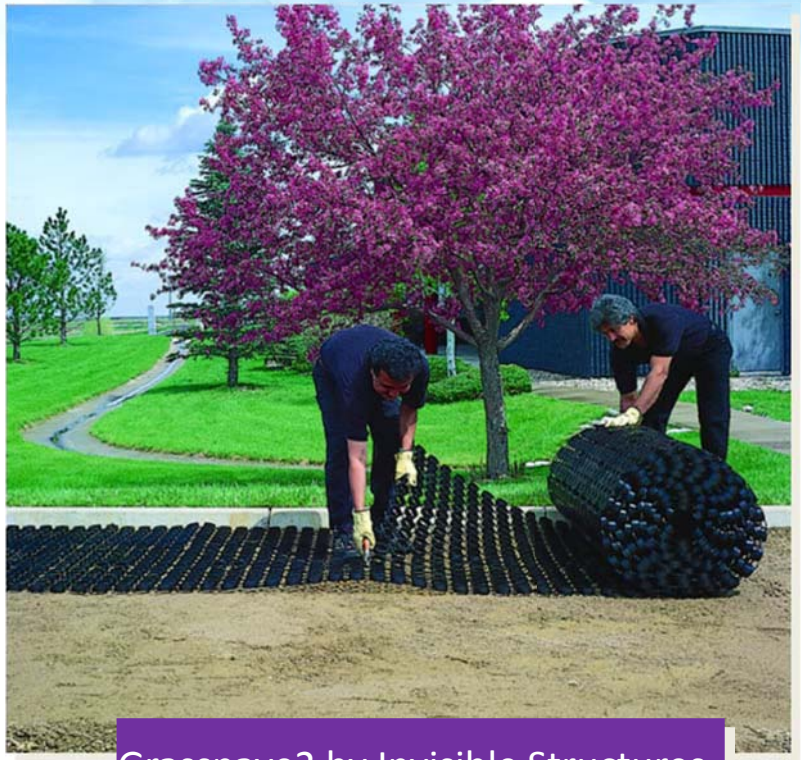


Biltmore Hotel, Coral Gables, FL
Grasspave2 by Invisible Structures

- Recharges Groundwater
- Reduces Runoff Volume
- Captures Suspended Solids
- Cleans Hydrocarbon Drips/Pollutants
- Protects Grass Root Zone from Compaction

Competitive Features

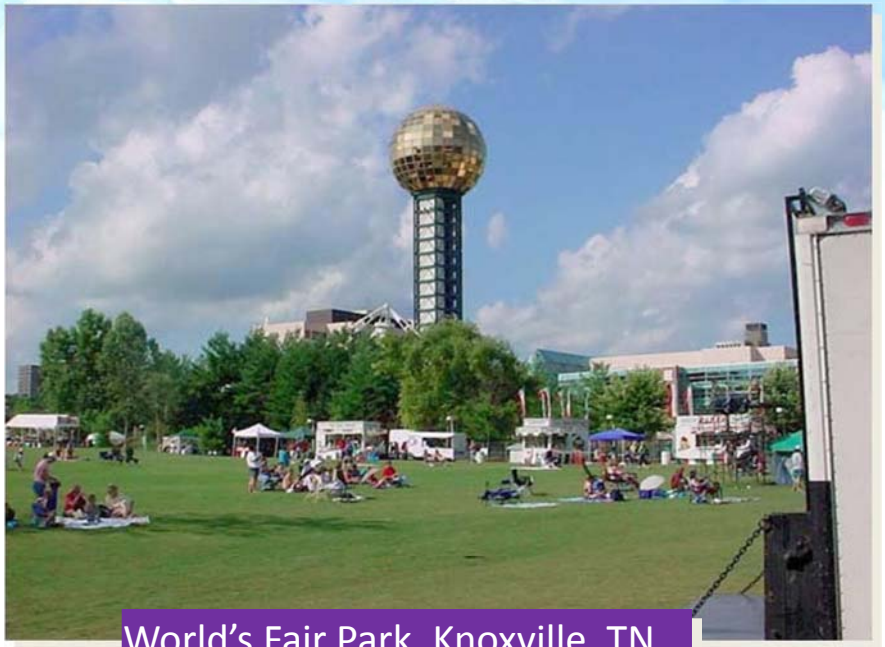
- 100% Grass Coverage
- 92% Open for Root Zone
- Hydrogrow - Polymer Fertilizer
- Only Flexible Mat System
- Large Pre-assembled Rolls
- Quick Install
- Sand to Fill the Rings



Grasspave2 by Invisible Structures

Metro

Primary Applications

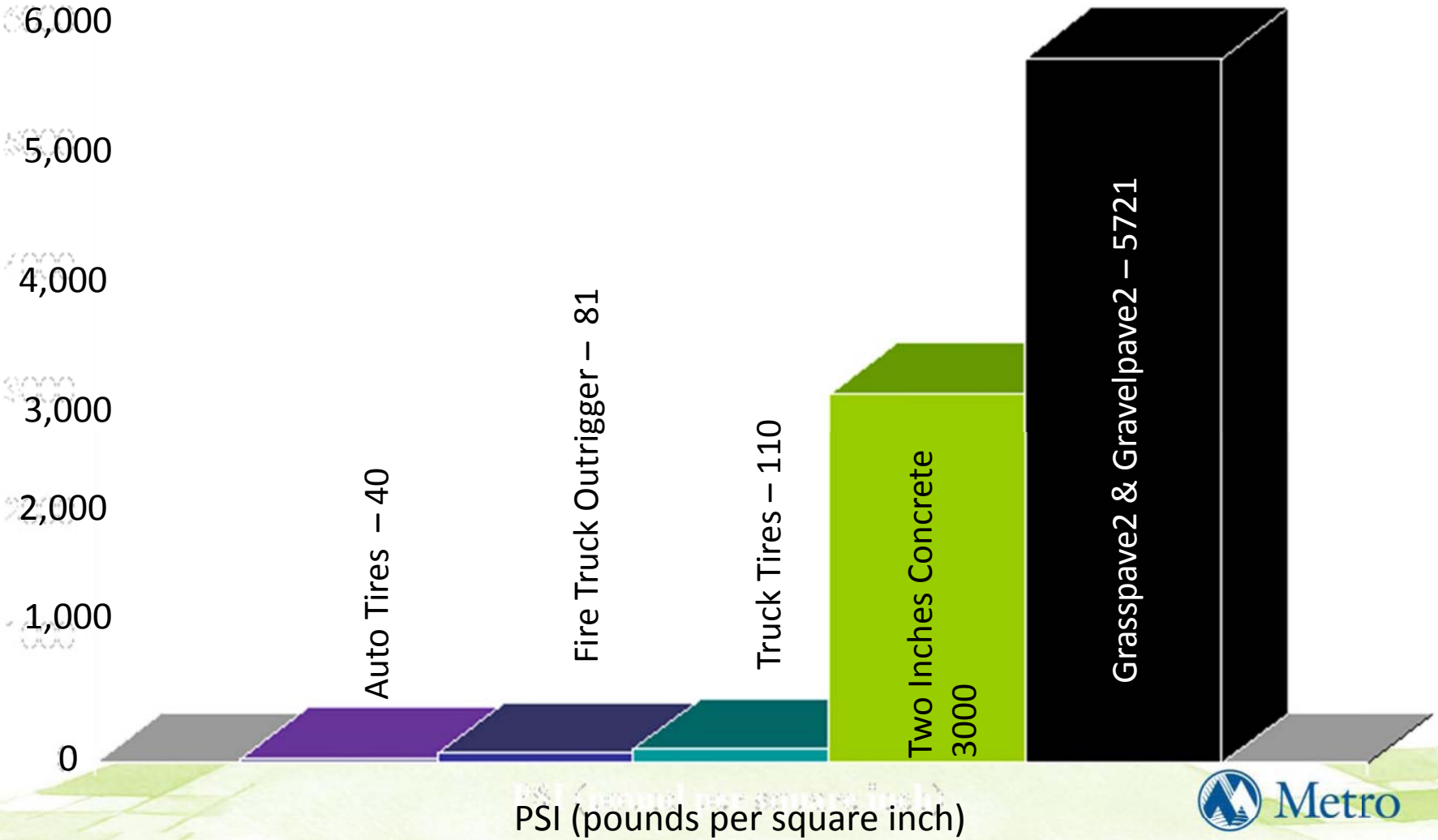


World's Fair Park, Knoxville, TN
Grasspave2 by Invisible Structures

- Parking
- Fire/Emergency Access
- Utility Access
- Residential Drives, Parking
- Pedestrian Traffic

Metro

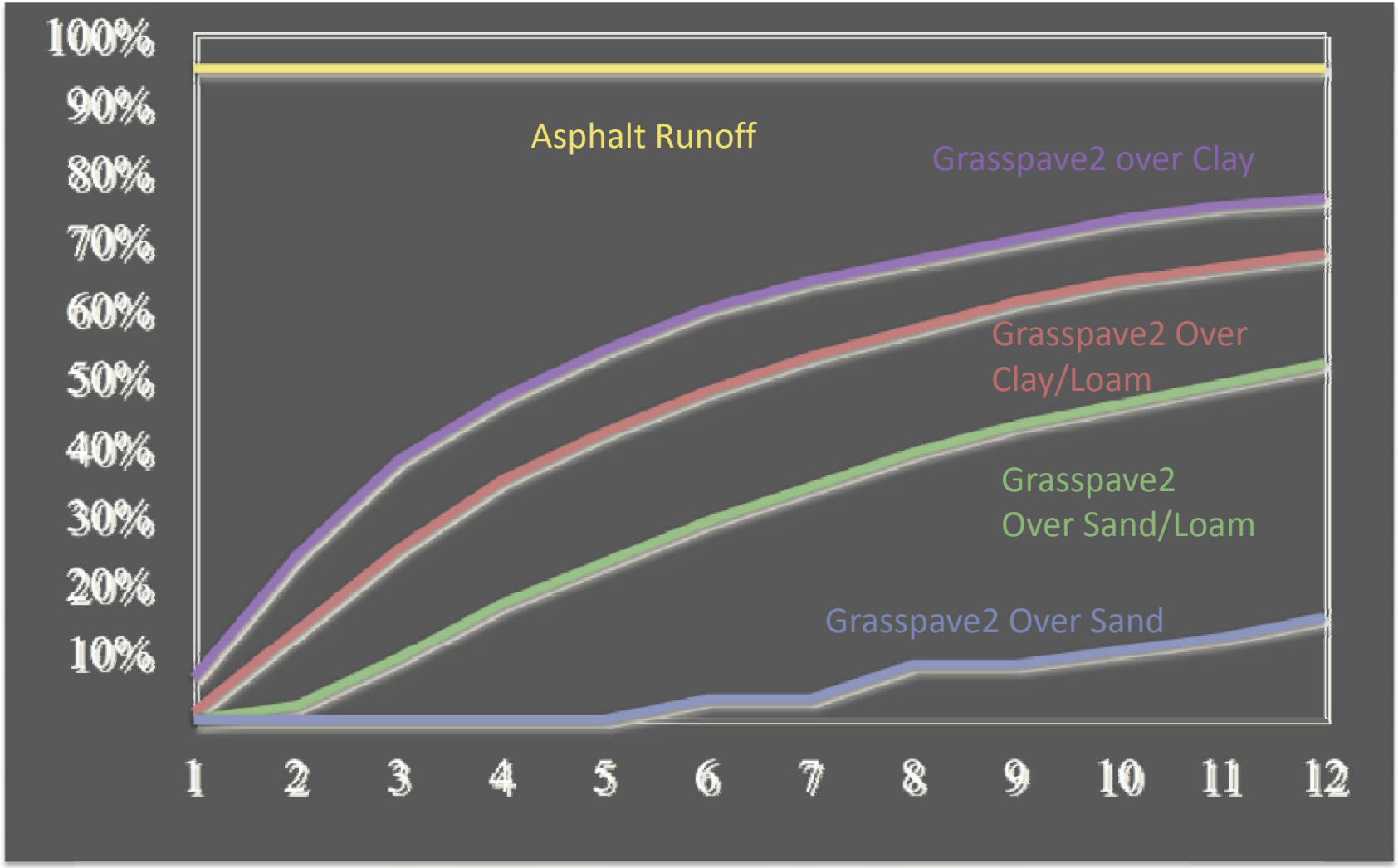
Lab Compression Test Results



Metro

Runoff Comparison Chart

Runoff coefficients, Grasspave^2 and sandy gravel base over various soil types



Inches of Rain During 24 Hours

Calculations include Grasspave2 placed over 6” of sandy gravel base course, laid over native soils indicated
Gravelpave2 estimated

Pervious Pavements and Runoff Reduction

- Pervious pavements allow water to infiltrate back into the ground instead of runoff
- The rate of infiltration is dependant upon the type of paver
- The Effective Imperviousness to the right relates to the runoff coefficients of the previous slide.
- Like golf, the lower the number, the better

Source: Urban Drainage and Flood Control District - Drainage Criteria Manual vol. 3

Type of Paver E.I.*

Asphalt/Concrete	95%
Cobble Block	60%
Modular Block (20% open)	40%
Pervious Concrete	40%
Modular Block (40% open)	25%
Gravel Paver	**25%**
Grass Paver	**25%**
Undeveloped Land (Meadow)	**21-40%**

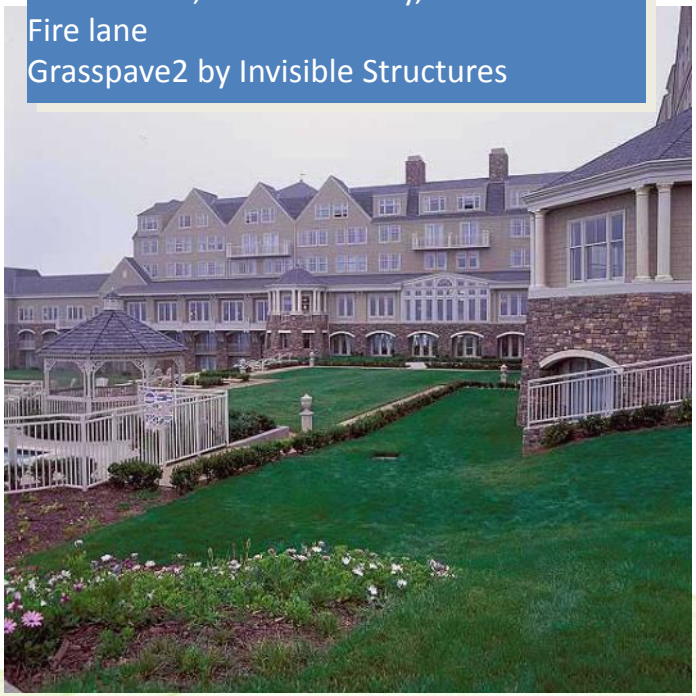
*E.I. = Effective Imperviousness assuming no tributary from other surfaces

This means that similar to a grass surface, only 25% of stormwater that falls onto Gravel or Grass pavers runoff - the other 75% can infiltrate into the ground

100% Grass Coverage

Blue Cross Blue Shield, MI – Event Parking
Grasspave2 by Invisible Structures

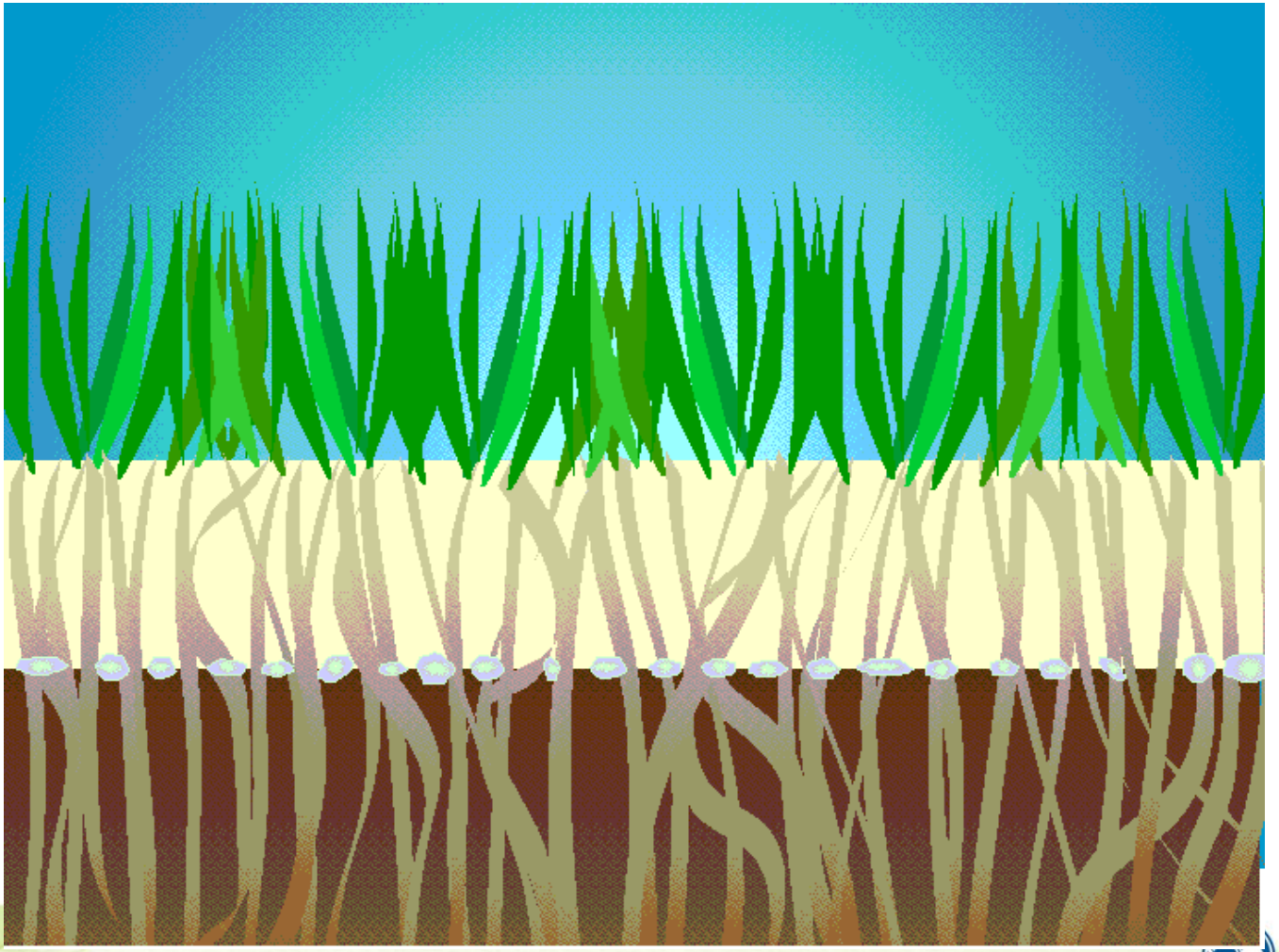
Ritz-Carlton, Half Moon Bay, CA
Fire lane
Grasspave2 by Invisible Structures



Oracle, Rocklin, CA – Fire lane
Grasspave2 by Invisible Structures

Polymer Fertilizer

Lasts Six to Twelve Months



Metro

Maintenance $56,000 Savings

Over 20 years using Grasspave2/Gravelpave2 instead of asphalt
*126,000 sq ft. parking lot (11,700 m2)

UNIVERSITY OF SOUTH ALAB

GROUNDS DEPARTMENT

2. Since no historical data exists for this type of surface at t
estimates. We have estimated that the 1.6 acres of Grass
(This is based upon areas similar in shape and size). We
year – once per week for 30 weeks during Bermuda gras
during remaining 22 weeks of the annual ryegrass (over
have also assumed 4 hours/month of box blading and le

Mowing
Labor 80 hrs @ $9.00/hr = $720
Mower costs 80 hrs @ $3.25/hr = $260.00

Fertilizer & Lime $64.00 per acre x 1.6 acres

Irrigation Maintenance $20.00 per acre x 1.6 acres

Water Cost

Painting/Striping

Box Blading & Leveling of Gravelpave² 48 hrs @ $30.00

Sincerely,

Andy E. Lindsey
(334)460-6356
AEL/mls – 02/18/99

UNIVERSITY OF SOUTH ALABAMA

GROUNDS DEPARTMENT

TELEPHONE: (334) 460-6356
MW 1565 • MOBILE, ALABAMA 36688-0002
FAX: (334) 414-8238

COMPARISONS OF MAINTENANCE

Grasspave²/Gravelpave² Vs Conventional Asphalt Parking Lots

ASPHALT - $0.497/square yard/year

Over 20 year assumed life span, the 13,944 square yards of the Mitchell Center parking lot would require a maintenance total of $138,603.00.

GRASSPAVE²/GRAVELPAVE² - $0.296/square yard/year

Over 20 years assumed life span, the 7,667 square yards of Grasspave² and 6,277 square yards of Gravelpave², the maintenance total would be $82,709.00.

Thus, the projected maintenance costs of the Grasspave² and Gravelpave² lots are 40.4% less than asphalt.

Notes

1. The figures for asphalt maintenance are based on historical costs from University of South Alabama Grounds Department records for FY's 1993 – 94, '94 - 95, '95 – 96, '96 – 97, and '97 – 98. The costs include seal coating, paint striping, patching and crack filling, and resurfacing. The $.214/yard² represents the 5 year mean. We have assumed a 20 year life span of the surface, with a resealing scheduled 4 times during this life span (years 1, 6, 11, and 16).

Annual Mean	Resurfacing		Sealing	Total
	$0.126/yd²	+	$0.088/yd²	$0.214/yd²
	Painting & Striping			$0.148/yd²
	Pothole Repair			$0.131/yd²
	Crack Filling			$0.004/yd²
	Annual mean total			$0.497yd²
				x 20 years
				= $9.94/yd²
				x 13,944 yd²
				= $138,603.36

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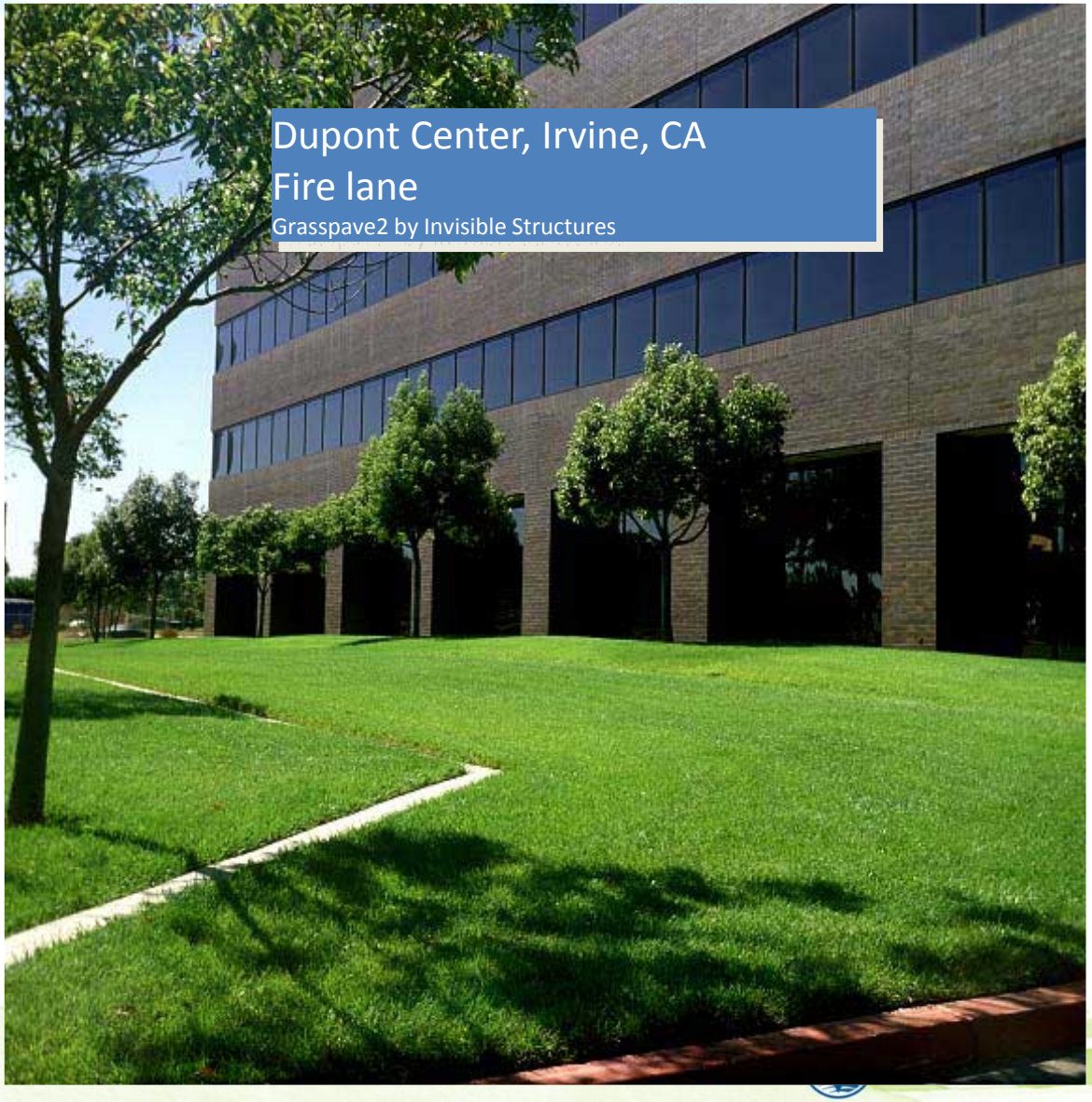
Fire Lanes and Emergency Access

100’ Ladder With Outrigger
70,000 lbs.
Grasspave2 by Invisible Structures



Dupont Center, Irvine, CA
Fire lane
Grasspave2 by Invisible Structures

LEED™ Points

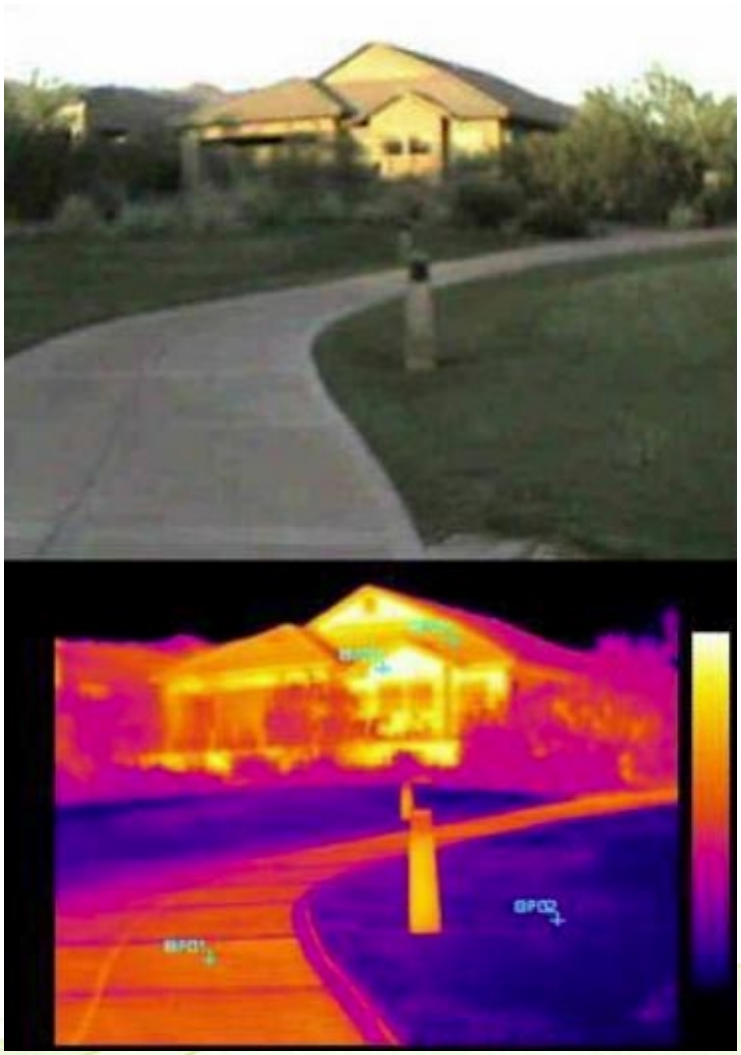
(Leadership in Energy and Environmental Design)

LEED points for all products - Grasspave2 photos shown

- Reduced Site Disturbance
- Stormwater Management
- Reduced Heat Island Effect
- Water Efficient Landscaping
- Innovative Wastewater Technology
- Water Use Reduction
- Recycled Content
- Erosion and Sediment Control

U.S. GREEN BUILDING COUNCIL MEMBER

Urban Heat Island Mitigation



Grass Albedo 0.40

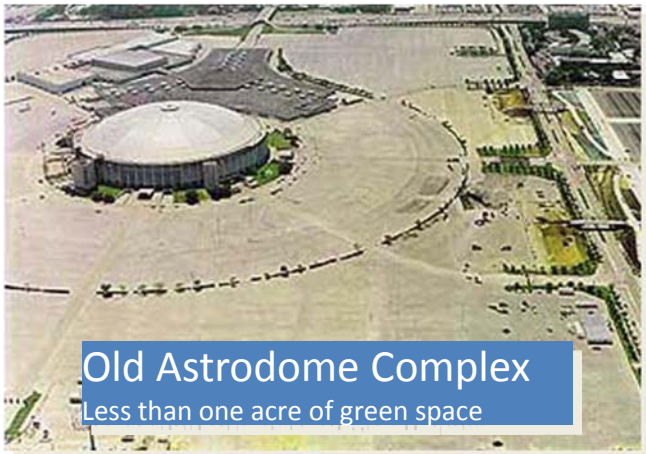
Air Conditioning Effect Through Transpiration

Reprinted with permission from The National Center of Excellence on SMART Innovations for Urban Climate and Energy, Arizona State University

Metro

World's Largest Grass Pervious Paving System

Parking - 317,000 sq ft Grasspave2
Reliant Stadium, NFL's Houston Texans

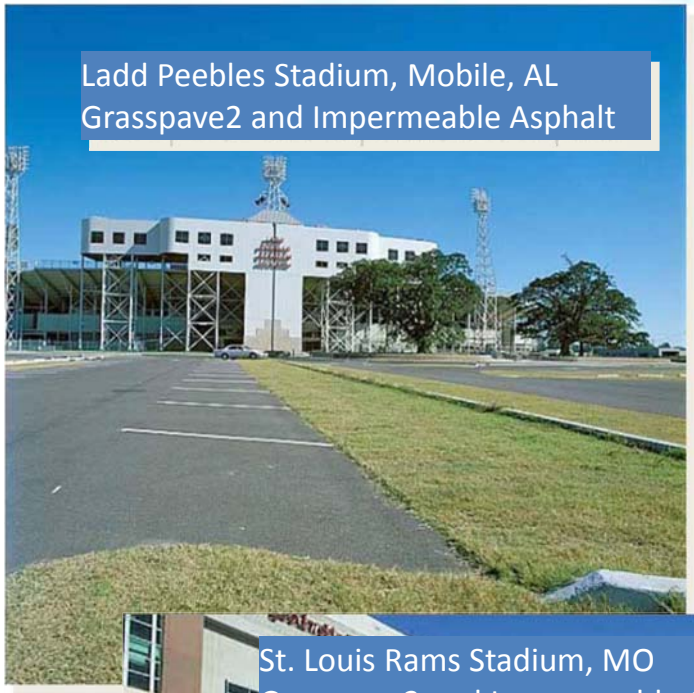


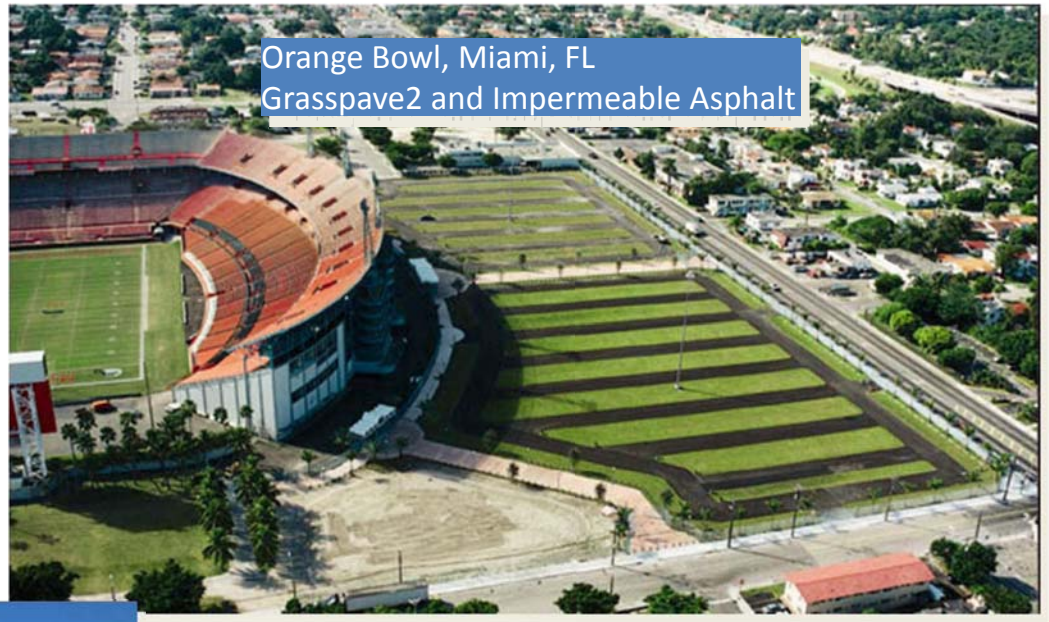
Provides:

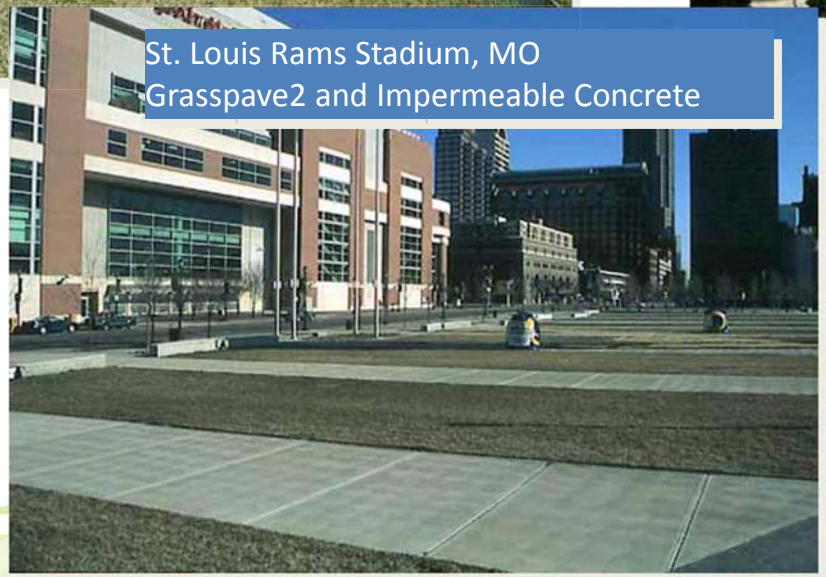
- Stormwater filtering and Storage
- Parking
- "Greening of Reliant"
- Allows for Festivals and Other Revenue Generating Use

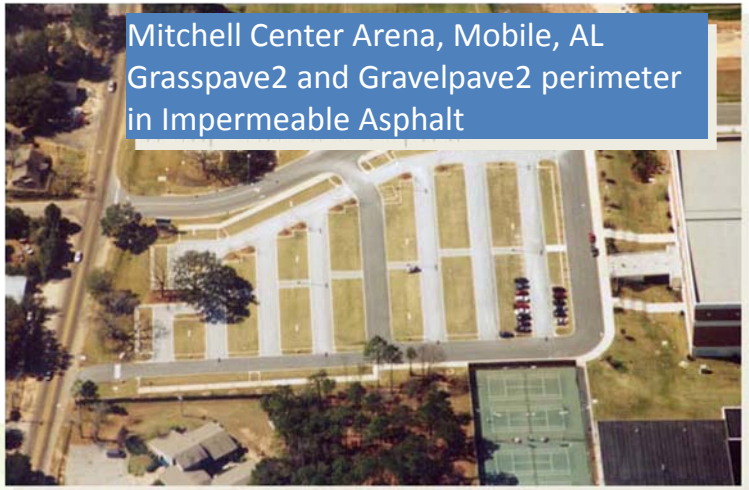
Metro

Stadium and Arena Parking Lots



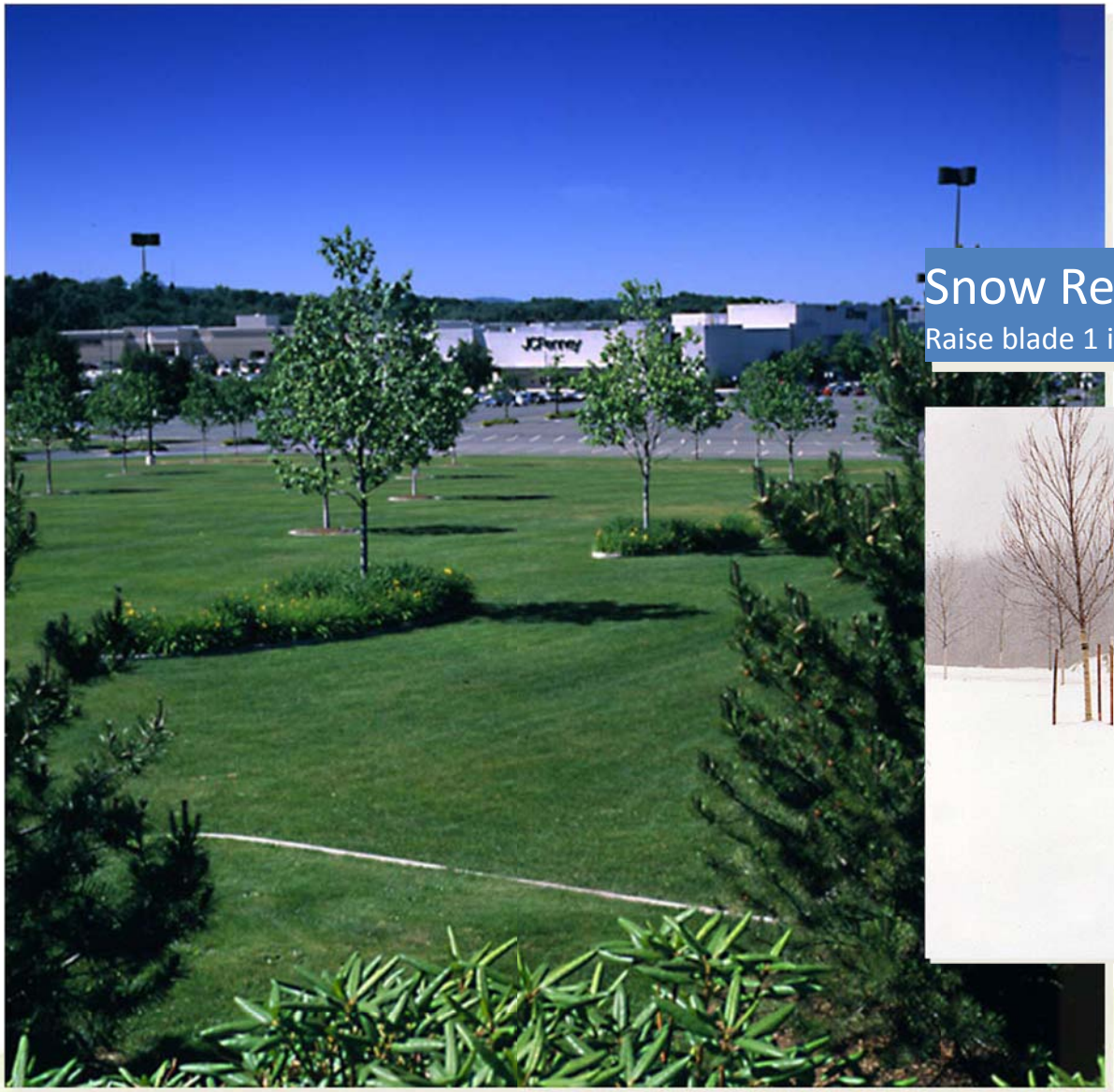






Seasonal and Overflow Parking

Westfarms Mall, West Hartford, CT



Snow Removal

Raise blade 1 inch above surface and/or attach skids

Metro

Joe Leiberis, Westfarms' facilities director, says that he doesn't worry much any more. “We're really happy with it,” he says emphatically, after witnessing the durable, natural parking lot (Grasspave2) handle winters, summers, hurricanes, heavy traffic and more.]

http://nemo.uconn.edu/case_studies/west_farms_cs.htm

BMP for Cold Climates

- Porous pavements are well suited to cold regions as a method for managing stormwater.

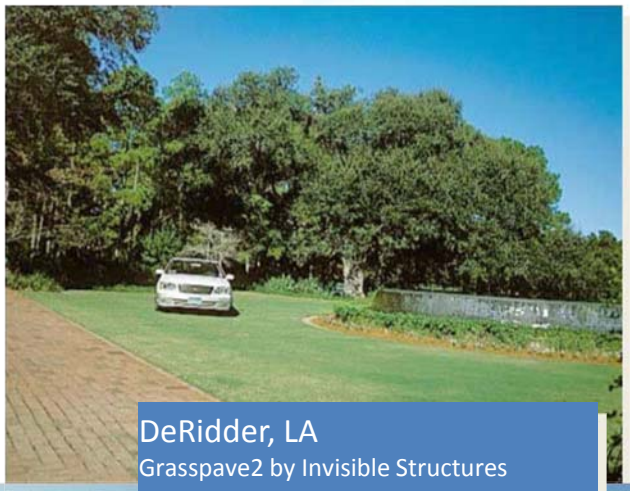
- Studies conducted in Lulea, North Sweden showed porous pavement to out perform less suitable systems, such as dry basin or stormwater reuse.

Backstrom and Viklander 2000

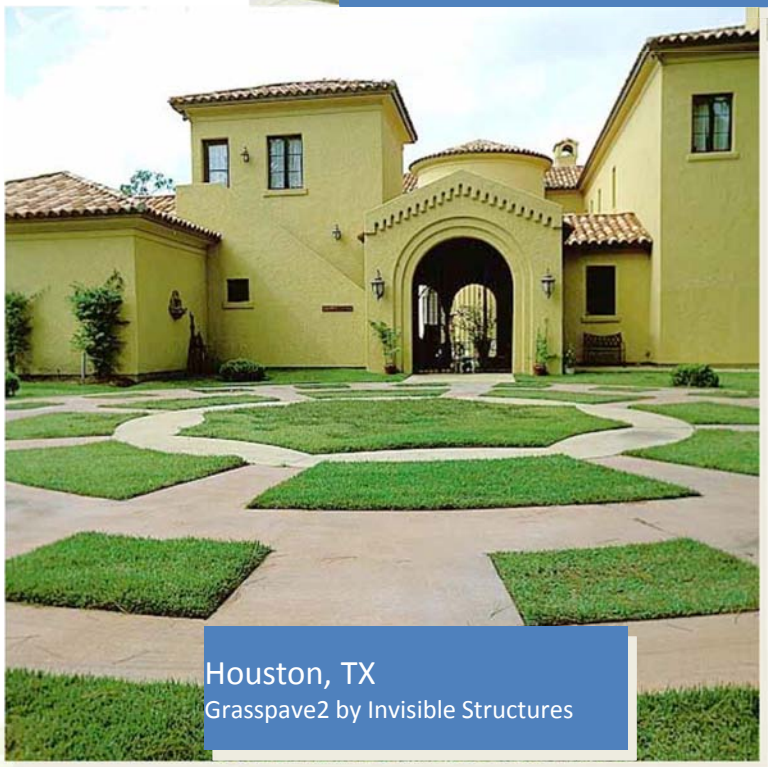
Metro

Residential and Commercial Driveways

Brookfield, OH
Grasspave2 by Invisible Structures



DeRidder, LA
Grasspave2 by Invisible Structures



Houston, TX
Grasspave2 by Invisible Structures

Colorado Springs, CO
Grasspave2 by Invisible Structures

Metro

Helicopter Landing Pads

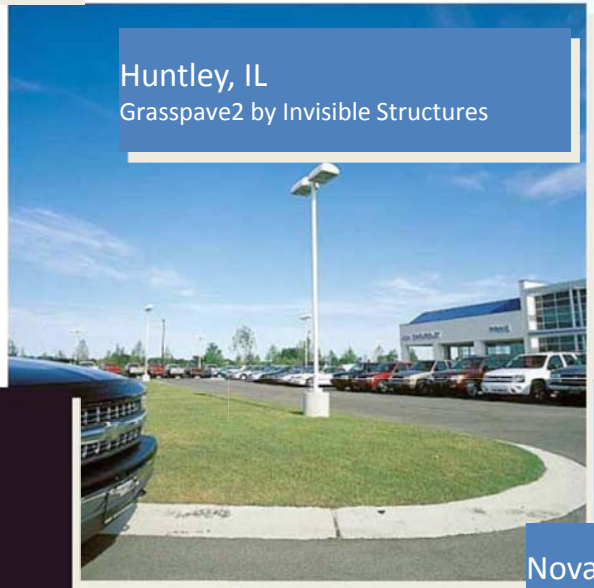
Pentagon RDF, Washington, DC
16,000 sq ft
LEED™ 2.0 Certified

Reinforced with Flexible Pervious Pavement
Grasspave2 by Invisible Structures

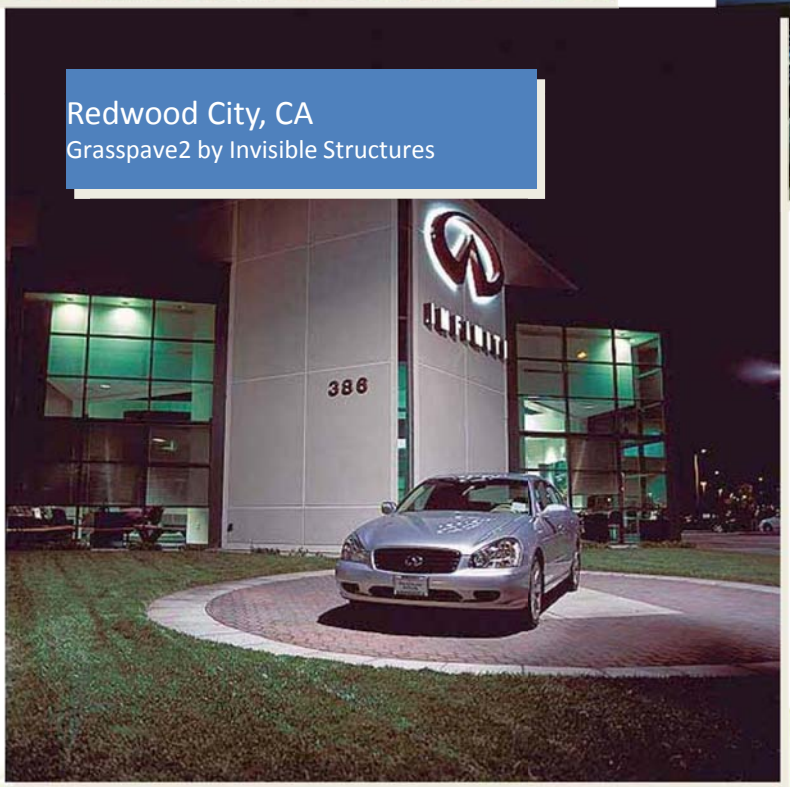
Metro

Automobile Dealership Displays

Yuma, AZ
Grasspave2 by Invisible Structures



Huntley, IL
Grasspave2 by Invisible Structures



Redwood City, CA
Grasspave2 by Invisible Structures

Nova, MI
Grasspave2 by Invisible Structures

Installation of Flexible Plastic Pervious Pavement with Grass Coverage

(Refer to Manufacturer's Technical Specifications for Complete Installation Details)

1. Install and compact base

2. Add soil amendment - fertilizer/polymer*

3. Unroll paver, connect, and cut as needed

4. Fill with sand**

5. Lay sod or hydroseed

6. Use and maintain - irrigate, fertilize, mow. Do Not Aerate

*Check with Specific Manufacturer. Some do not supply a Fertilizer/Polymer

**Some Manufacturers fill with top soil or existing soil. Sand is the preferred method of Prof. Bruce K. Ferguson, author, Porous Pavements: Integrated Studies in Water Management and Land Development

Installation Costs

$4.50 to $6.00/sq foot

- Base Course including Excavation
- Polymer/Fertilizer
- Flexible Grass Paver
- Sand
- Hydroseeding or Thin Cut Sod
- Labor

Reduces Site Costs

- No Root Barrier for Trees
- No Additional Drainage Lines
- Stormwater Mitigation
- Multiple Use Site
- Reduced Maintenance
- 60 Year Lifespan (Grasspave2)

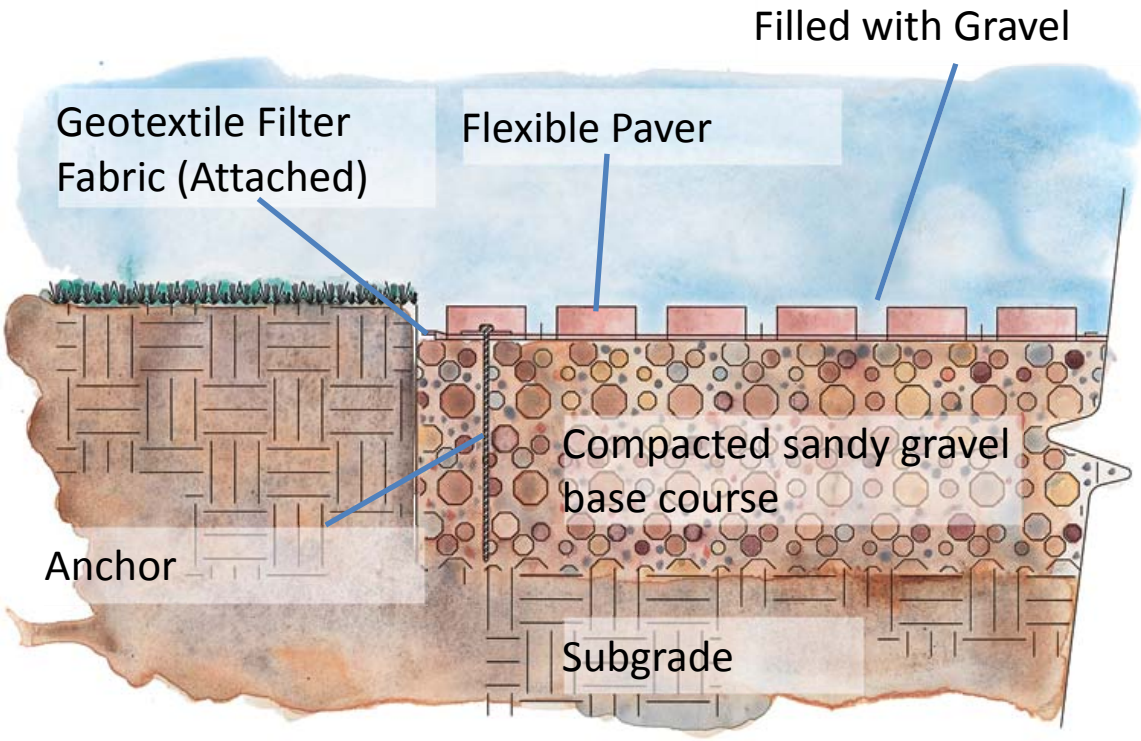
Metro

Grass Flexible Pervious Paver Recap

- Applications
  - Light to Moderate Vehicular Use
  - Reinforce Turf
- Benefits
  - True Pervious Paving
  - Stormwater Pollution Filtration and Treatment
  - Heat Energy Reflection and Reduction (Reducing “Urban Heat Island” Effect)
  - Tree Growth in Parking Areas
  - 100% Grass Coverage
  - Easy to Install Rolls

Metro

Gravel Flexible Pervious Pavers



Trade Names

- Gravelpave2
- Agrablock
- Integra 500
- Ground Grid
- Netpave 50

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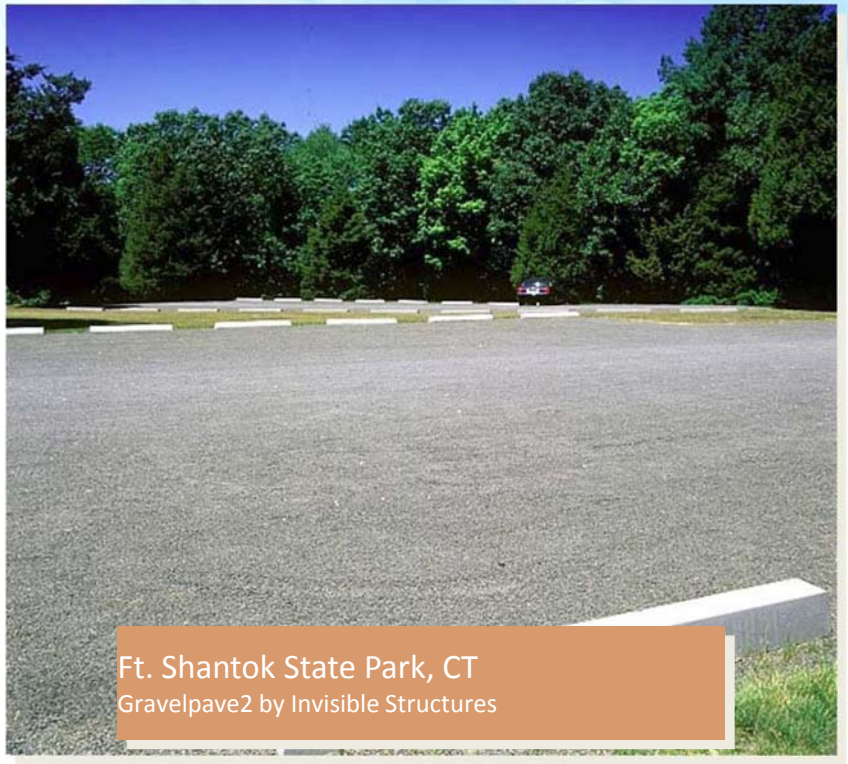
Gravel Pervious Paving System


Ft. Shantok State Park, CT
Gravelpave2 by Invisible Structures

- True containment of gravel
- Pervious surface
- Unlimited traffic volume and duration of parking
- Pollution treatment, removal and filtration
- Heavy load capacity

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MasterFormat 32 12 43 *Porous Flexible Paving*

Gravel Flexible Pervious Pavement Applications

Glendale Community College, AZ
Gravelpave2 by Invisible Structures

- Parking Aisles and Bays
- ADA Trails - Multiple Use
- Service, Access Drives, and Firelanes
- Driveways
- RV Parking, Boat and Truck Storage
- Boat Ramps
- High Use Pedestrian Areas

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Gravel Flexible Pervious Pavement Competitive Features

National Garden, United States Botanic Gardens, Washington D.C.
Gravelpave2 by Invisible Structures

- Pervious Stabilization
  - Fine gravel fill
  - Fabric Backing
- Very Low Maintenance
- Prevents Gravel Migration
- ADA Accessible (Gravelpave2 Tested 1998) - Firm, Stable, and Slip Resistant
- Dust Free
- Large, Flexible Rolls for Easy Installation

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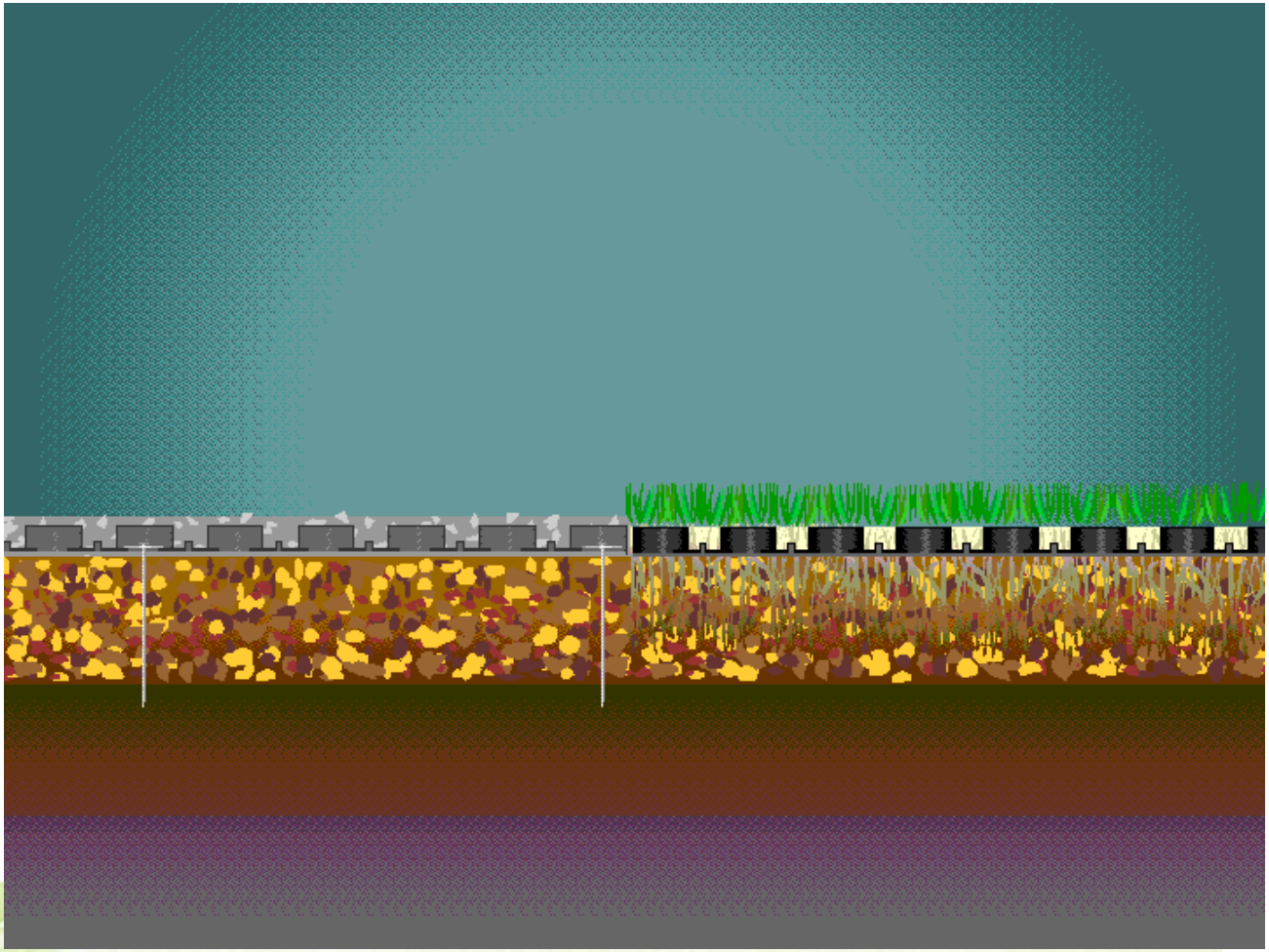
Reduce Runoff, Cleans Stormwater and Filters Pollutants

Airborne and Surface



Gravel Fill Examples

Clean, Sharp, Hard, Uniform Size - 3/16 inch to 3/8 inch

Crushed Granite
3/16”

Decomposed Granite
3/8”

Hard Limestone 3/8”
Add 25-30% sharp
mason’s
sand to maintain porosity

Carbon Canyon
5/16” minus

Sanora Tan
3/8””

Sharp Angular Pea Gravel
Do Not Use
Rounded Pea
Gravel

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Colors to Match Aggregate

Americans with Disabilities Act
(ADA)

Gravelpave2 - Tested to Meet Required Standards
By Beneficial Designs, Inc.
April 1999

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Tree Preservation

7 years after planting in dense pavement
From *Porous Pavements* by Bruce Ferguson, 2006,
CRC press Taylor and Farncis

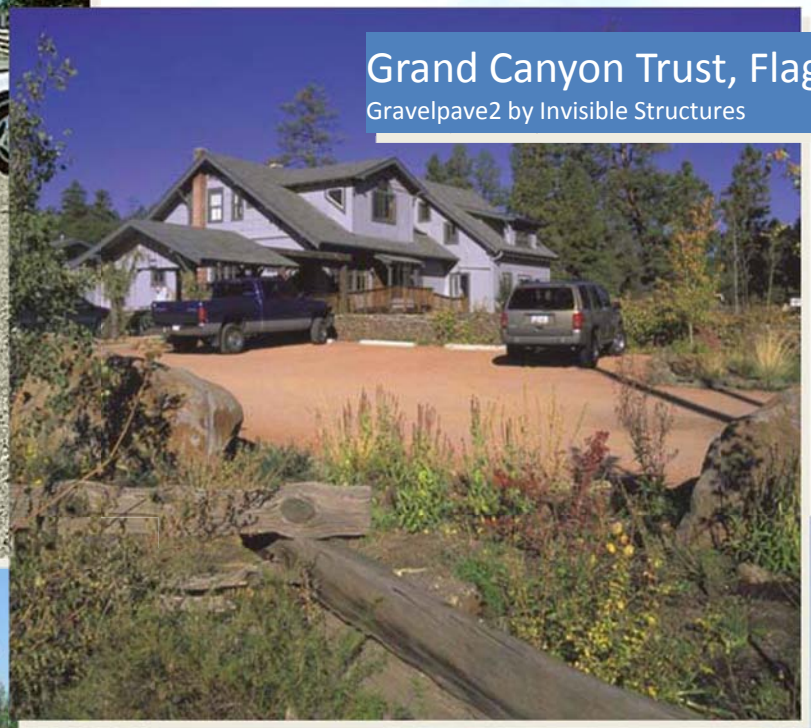
Tree Preservation and Slope Protection, Ronald Reagan Park, Washington D.C.
Grasspave2 by Invisible Structures

Tree Preservation in Parking lot, Ada, MI
Gravelpave2 by Invisible Structures

- Pervious paving allows for water, oxygen, and CO_2 transference.
- Flexible plastic pavements protect roots from compressive damage.

Parking Lots

Bowditch Point Park,
Ft. Meyers, FL
Gravelpave2 by Invisible Structures



Grand Canyon Trust, Flagstaff, AZ
Gravelpave2 by Invisible Structures

Vancouver City Works Yard,
Vancouver, BC - LEED™ Winner
Gravelpave2 by Invisible Structures

Westtown School, Westtown, PA
Gravelpave2 by Invisible Structures

Urban Heat Island Mitigation

- Light Aggregate Fill Albedo 0.16
- Void Space in Gravel Creates Insulation
- Angular Aggregate Reduces Solar Absorption

Reprinted with permission from The National Center of Excellence on SMART Innovations for Urban Climate and Energy, Arizona State University

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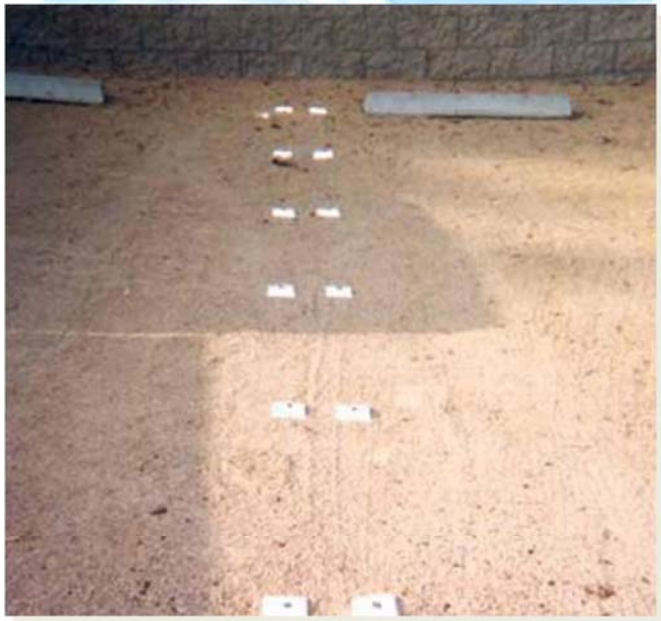
Parking Delineation



Trails

Saperton Landing, BC
Gravelpave2 by Invisible Structures

Daniel Boone National Forest, KY
Gravelpave2 by Invisible Structures

Oakdale Nature Preserve, IL
Gravelpave2 by Invisible Structures

Private Residence Trail, CO
Gravelpave2 by Invisible Structures

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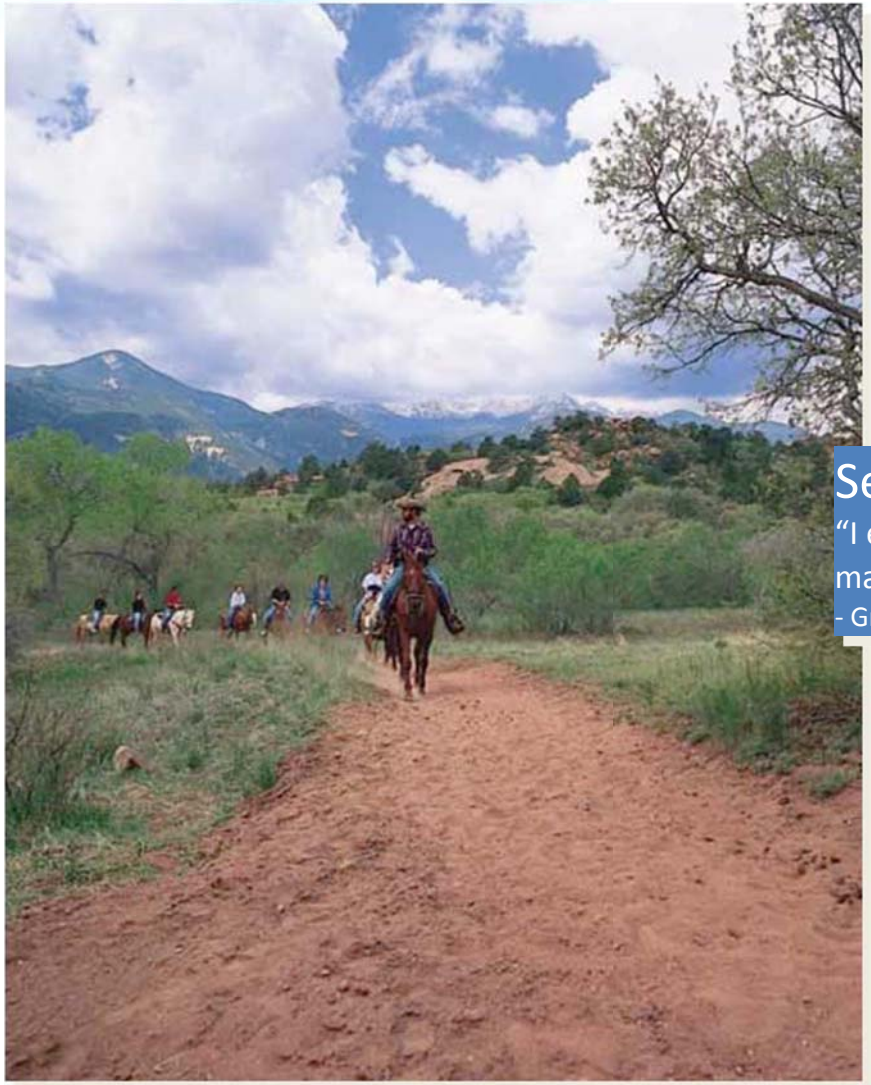

Garden Of the Gods

Colorado Springs Park and Recreation Dept.
Colorado Springs, CO

Severe Rutting Prior to Installation

"I estimate the [Gravelpave2]installation has cut maintenance cost and time by 80 percent."
- Greg Jensen, Senior Park Maintenance Technician

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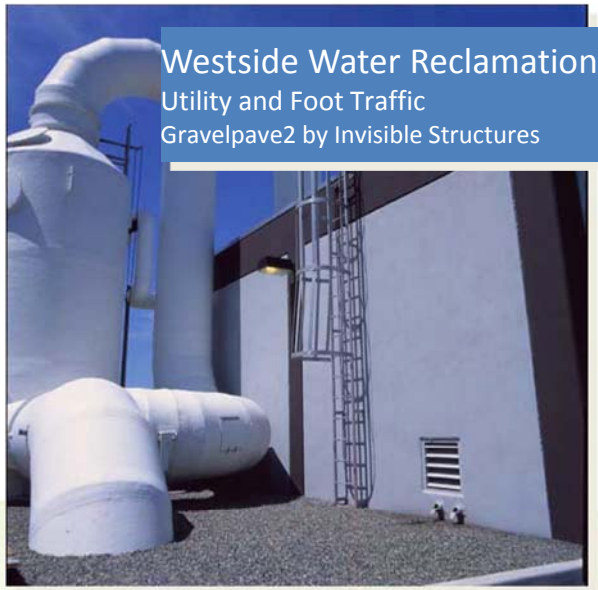
Utility Access, Fire Lanes and Specialty Installs

Colorado Springs City Building, CO
Firelane
Gravelpave2 by Invisible Structures

Tri Rail Station, Miami Airport, FL
Utility and Foot Traffic
Gravelpave2 by Invisible Structures

Seneca Post Office, PA
Eave drip line erosion control
Gravelpave2 by Invisible Structures



Westside Water Reclamation, Vancouver, WA
Utility and Foot Traffic
Gravelpave2 by Invisible Structures

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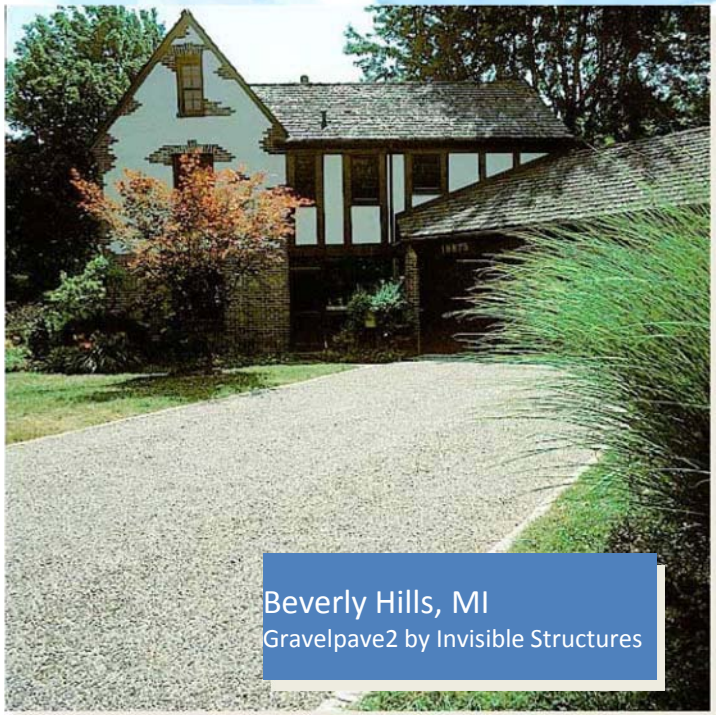
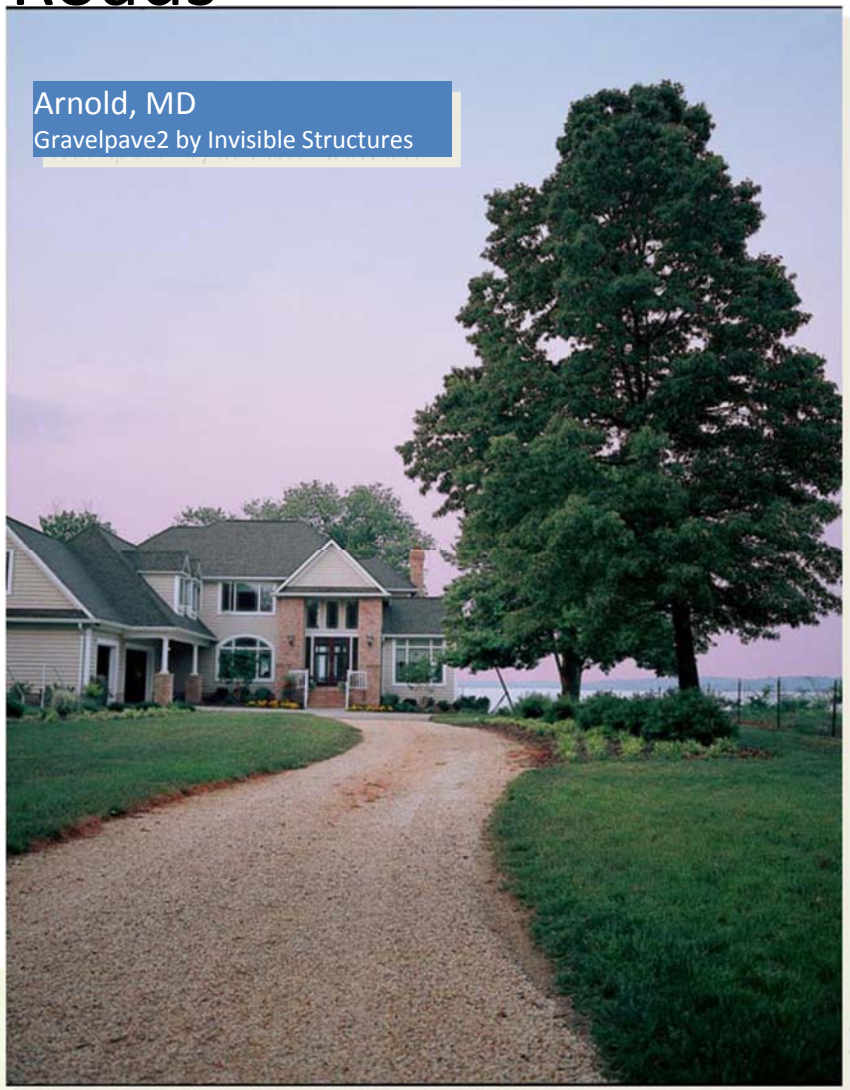
Driveways and Roads



Beverly Hills, MI
Gravelpave2 by Invisible Structures

Austin Museum of Art, Laguna Gloria, Austin, TX
Gravelpave2 by Invisible Structures



Arnold, MD
Gravelpave2 by Invisible Structures

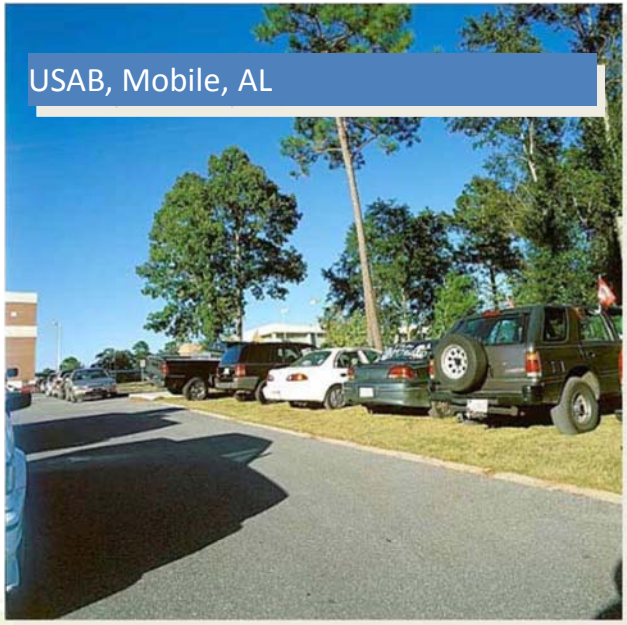
Grass and Gravel Flexible Pervious Paving Combinations

City Works Yard, Vancouver, BC

Resort and Spa, Scottsdale, AZ

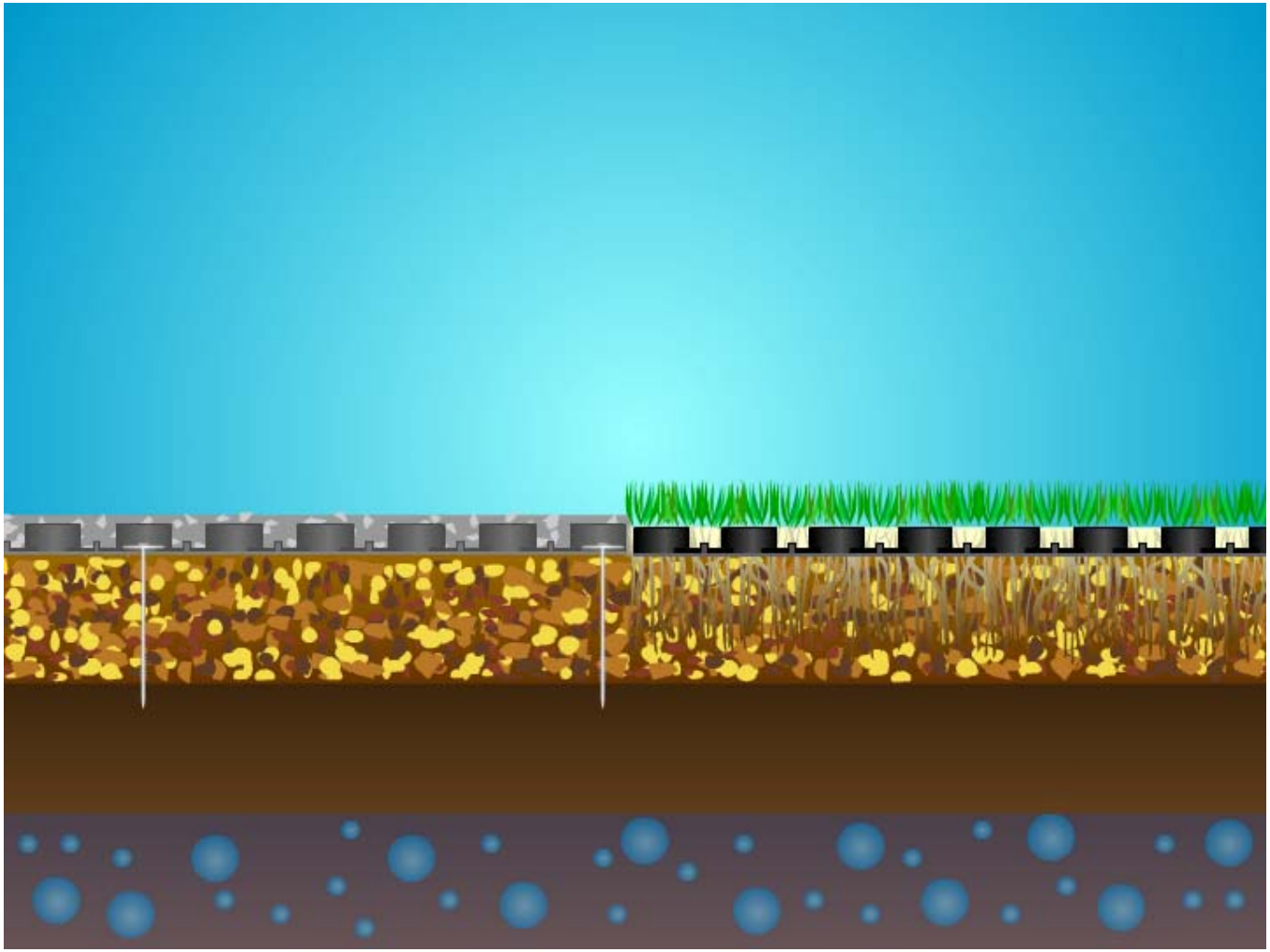
Glendale Comm. College, AZ

USAB, Mobile, AL



Goodyear Park, Goodyear, AZ

Pervious Base Filters Surface and Airborne Pollutants from Rain Water



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Percentage of Pollutants Removed by Pervious Pavements

Total Suspended Solids	95%
Total Phosphorous*	65%
Total Nitrogen*	82%
Nitrogen Oxides (NOx)*	NA
Heavy Metals*	96-99%
Hydrocarbons**	Up to 100%

Data will vary depending on design characteristics and underlying soils

*2000, R Winer, Center For Watershed Protection, (5 data points)

**"In-Situ Bioremediation of Contaminated Subsurface Media", published by Water Environment Federation, 1993

Installation of Flexible Plastic Pervious Pavement with Gravel Surface

(Refer to Manufacturer's Technical Specifications for Complete Installation Details)

1. Install and compact base

2. Unroll paver, connect, and cut as needed

3. Secure to base with anchors*

4. Fill with open graded 3/8" aggregate (gravel)

6. Use and maintain

*Check with Specific Manufacturer. Some do not supply Anchors

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Installation Costs

$5.00 to $6.50/sq foot

- Base Course including Excavation
- Anchors
- Flexible Gravel Paver
- Gravel Fill
- Labor

Reduces Site Costs

- No Root Barrier for Trees
- No Additional Drainage Lines
- Stormwater Mitigation
- Multiple Use Site
- Reduced Maintenance
- 25 Year Lifespan (Grasspave2)

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Gravel Flexible Pervious Pavement Recap

- Applications
  - Unlimited, Lower Speed Vehicular Traffic
  - ADA Multiple Use Trails
- Benefits
  - Pervious Load Bearing Surface
  - Stormwater Pollution Filtration and Treatment
  - Heat Energy Reflection and Reduction (Reducing "Urban Heat Island" Effect)
  - Fabric Injection Molded to Grid for Added Stability
  - Gravel Containment Eliminates Rutting
  - Tree Growth within Parking Areas

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100% Recycled Content

Recycled High Density Polyethylene

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Invisible Structures, Inc.

Thank You!

Andy Gersen
The Gersen Co.
Stormwater Product Specialists

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ROGER LANGELIERS
CONSTRUCTION CO.
Concrete Paving and Flatwork
Curb and Gutter ✦ Catch Basins

PERVIOUS CONCRETE

A Contractor's Point Of View

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Bioswale Acres

Pervious Concrete Is:

- A proven alternative to asphalt and conventional concrete
- A unique product which provides savings for the site owner - storm water can be addressed much earlier in the development process than it historically has been

ZERO RUNOFF

THIS PROVIDES THE ULTIMATE ENVIRONMENTAL AND LOW COST SOLUTION !!!

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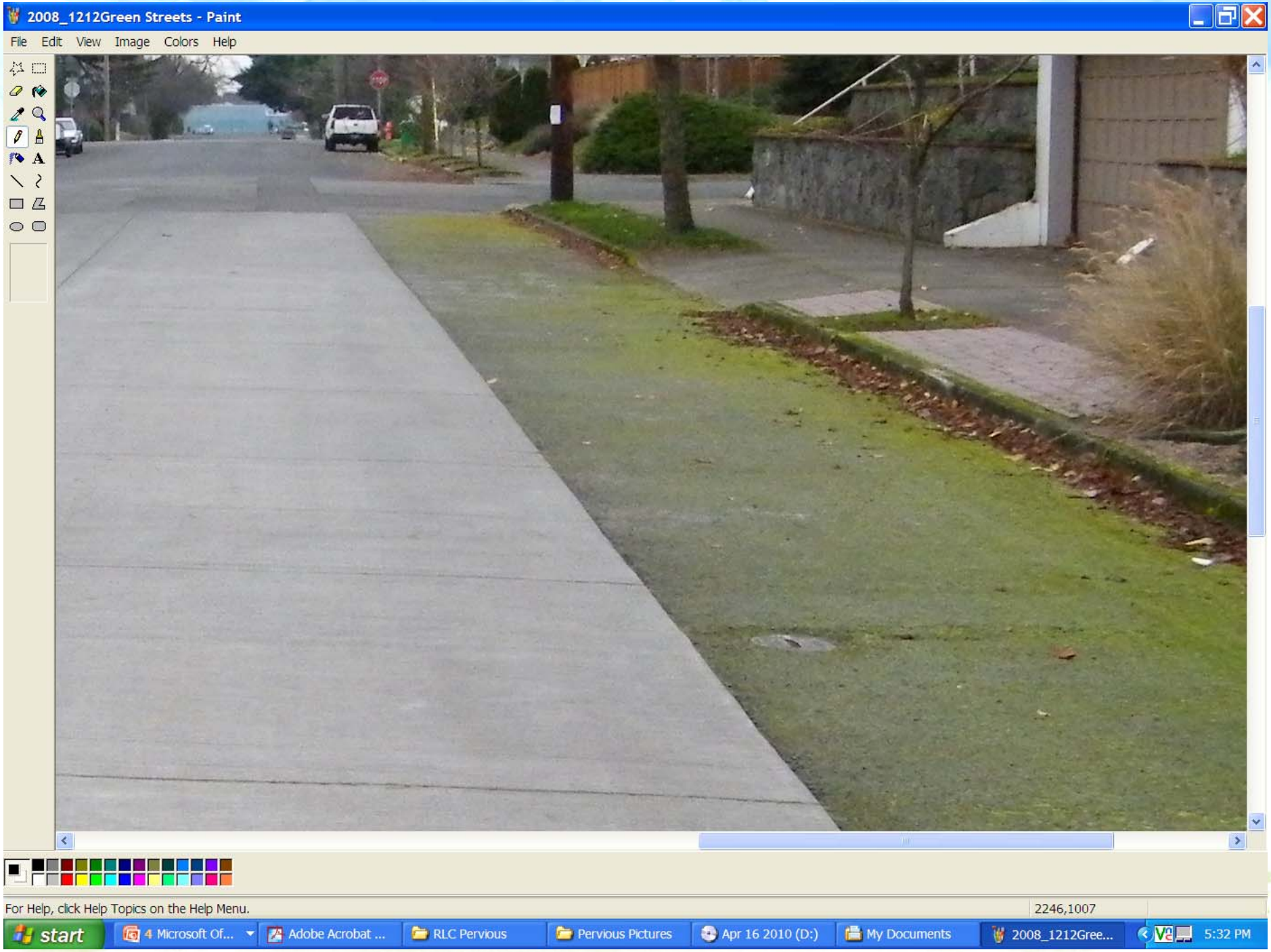
Hard pavement collects runoff and sends it downstream.
Concentrated Runoff is created.
Pervious pavement keeps rainfall on site
by Infiltration & Dispersion
No Runoff is created.

Limitations

- Plugging (tree lined streets)
- Raveling of aggregate
- Not meant for high speed traffic.
- Soil conditions
- Hard to place compared to normal concrete.
- Difficult to place in hot weather.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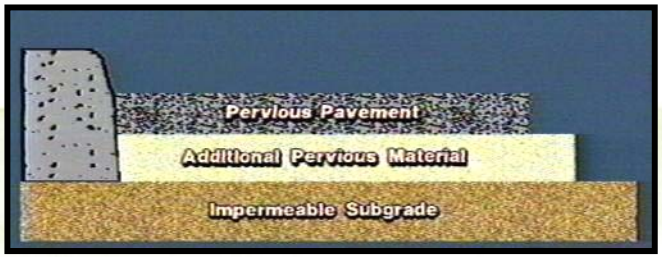
Design

- Two factors determine design thickness:
  - Hydraulic properties such as permeability and volume of voids
  - Structural properties such as pavement tensile strength and subgrade stiffness
- Select appropriate material properties and thickness for:
  - Hydrological requirements
  - Anticipated loading
  - Larger of two values governs design

Designing Pervious Concrete Pavement Structure

- Define loading condition
- Assess soil support value
- Select thickness based on flexural strength (MR=375 psi)
- Check against overweight loading
  - ½" thickness increase can increase strength and life expectancy by 33% to 50%



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Design for Storm Water

- Gravel Storage volume – 30 to 40% voids
- Protect storage layer with fabric over native soil
- Design retention volume and outlet control if needed.
- Retention period = time to saturate voids
- Permeability = 200”/hr. minimum
  - Excess capacity – Can clog to 95% and still have 500% factor of safety
  - **Soils and storm event will *always* control base**
- Water Quality Treatment - ?

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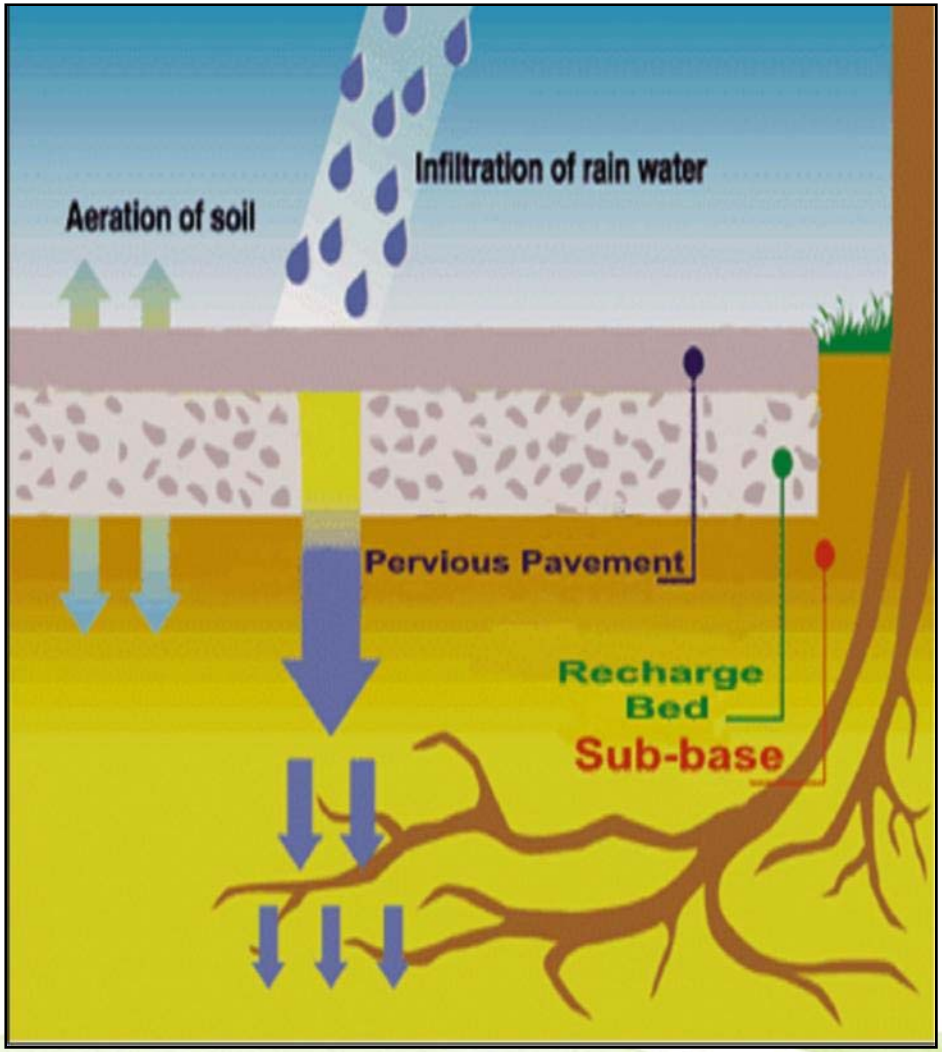
TREE GROWTH ENHANCED

Pervious pavement allows rainfall to have the same impact as rainfall on a grassy field.

Roots get air and water and will not push up pavement



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Appropriate Situations

- Parking Lots
- Sidewalks
- Low speed residential streets

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Lake Grove Chriopractic
Pervious Concrete Parking Lot
10/19/2005

rvious Concrete Paving

Sultan, WA. Stratford Place

Site Conditions

- 6” of open graded aggregate for sub base
- A minimum of 6” of pervious concrete for traffic areas.

Subbase and Subgrade Soils

- Estimating infiltration rates is complex
- Simple models are accepted
- TR-55 from Dept. of Agriculture provides values
- Percolation rates of ½ in./hr are suitable
- Sandy soils often don't require a porous subbase
- Replace clay soils with porous subbase
- Drawdown time (100% recovery) as short as possible & not more than 5 days

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Base & Water Storage
Open Graded 30-40%

Installation


Sheeting
08/09/2005


08/09/2005

Maintenance

- Little maintenance required
- Prevent clogging with debris
- Design site to minimize flow of soil and leaves onto pavement

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Cost

- Pervious concrete is estimated at $1.00 / 1” sq. ft. installed.

Conclusions

- Pervious concrete always “works”, depending on the goal and application.
- Science is sound
  - “StreetPave” for structural design
  - Approved hydrological design procedure, or generic, such as PCA
  - ACI 522 for specification
  - NRMCA Certified Contractors
- Barriers to use are human and related to regulations – we are working through them.
- Applications are limited only by your imagination

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Second annual

GREEN from the Ground Up

Seminars for land-savvy developers

Stormwater management with pervious surfaces

April 22, 2010

Preserving natural features can benefit both the developer and the development. Learn how.

Keep Nature in Neighborhoods METRO

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