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Permeable Interlocking Concrete Pavement Maintenance



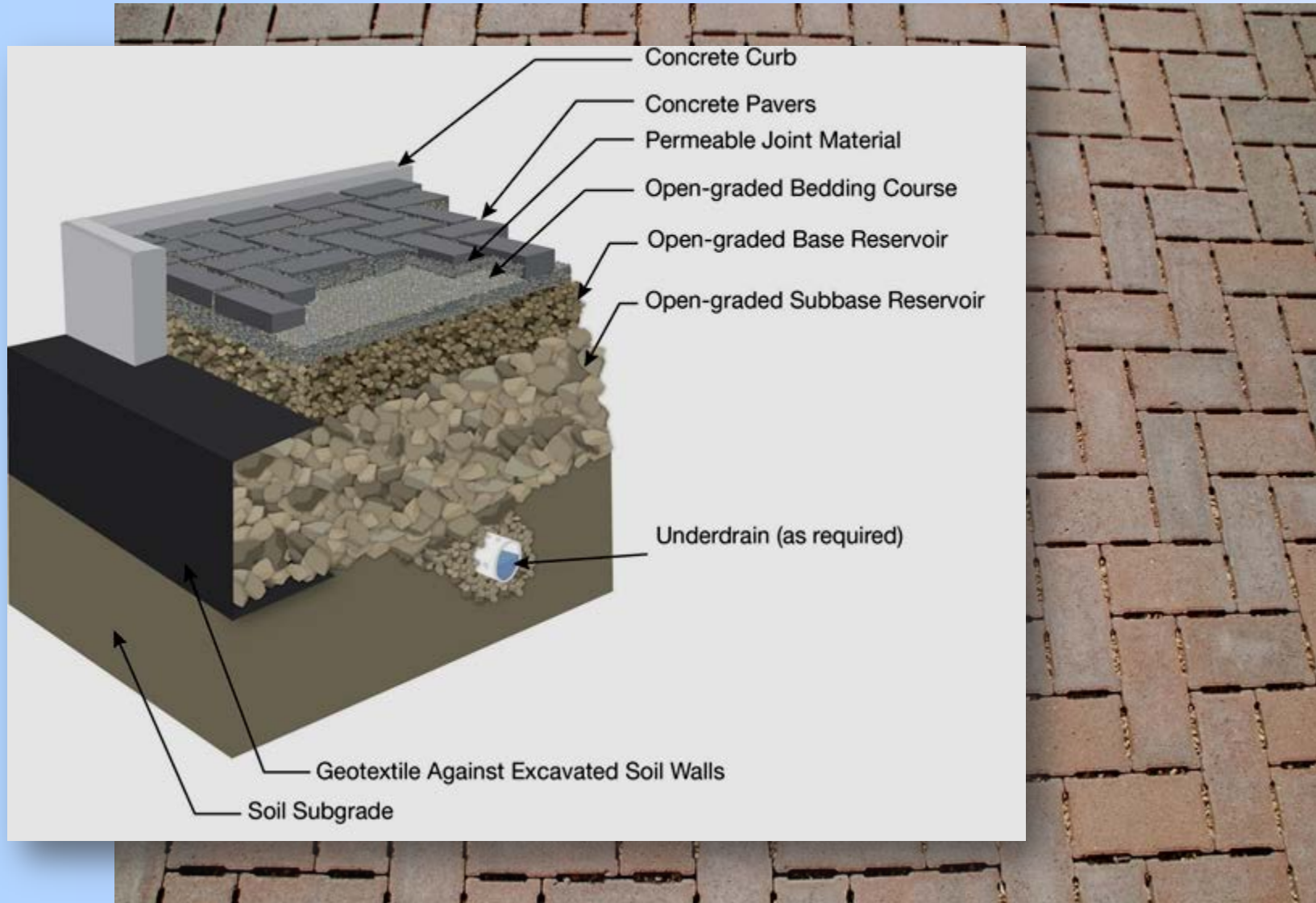
Jennifer Drake, Ph.D., Assistant Professor, University of Toronto

Rob Bowers, P.Eng., Director of Engineering, Interlocking Concrete Pavement Institute

Charles City, IA - 27 blocks

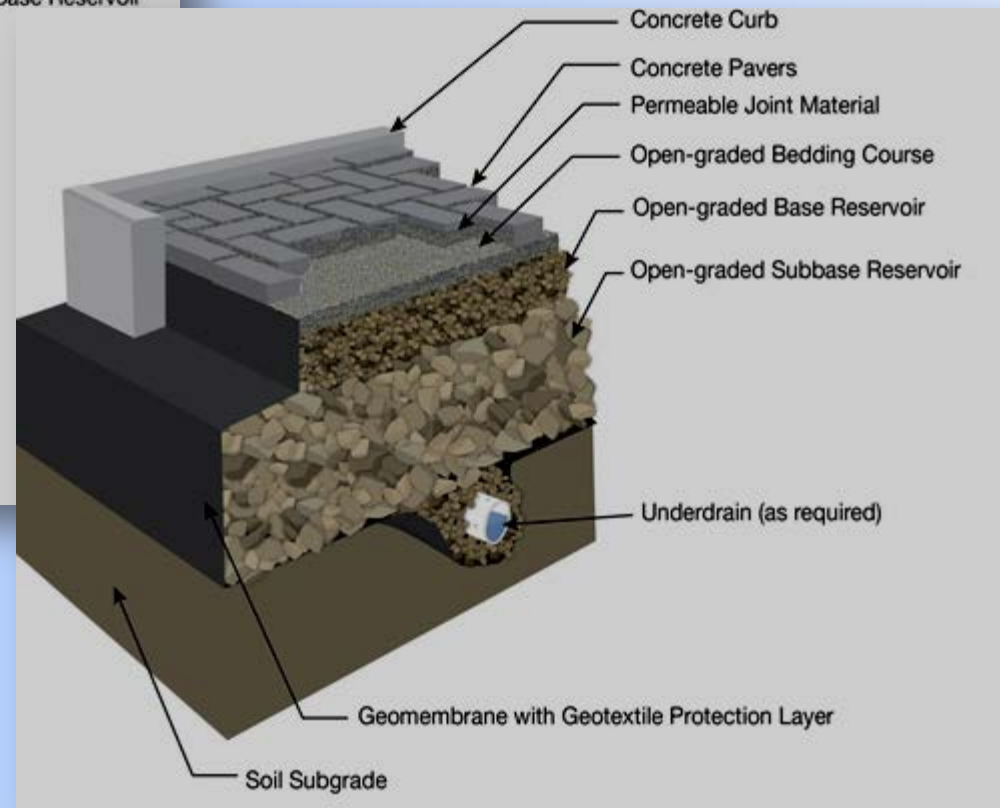
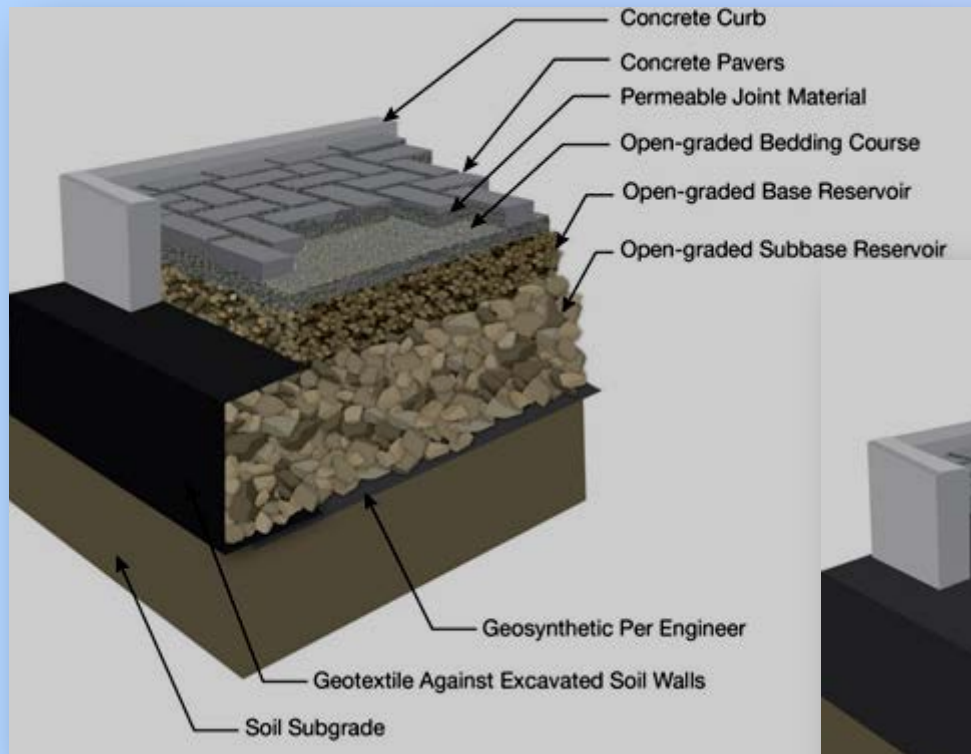


Partial Infiltration



Other PICP Options

Full infiltration



**No infiltration
with geomembrane**

Denver UDFCD PICP Test Area



Sediment Traps

entrances, pavement junctions
& low lying areas



Maintenance

**2 yrs – residential street
Oregon**



Vegetation = maintenance!



**10 yrs street side parking
Maryland**



**New construction
Minnesota
mulch spill**



ICPI Recommendations



- Inspect & vacuum sweep 2x annually
- Sweeping only equipment not effective in removing sediment
- Check infiltration during or just after a storm
- Test w/ ASTM C1781 as needed

ASTM C 1781-Surface Infiltration Testing



Designation: C1781/C1781M - 13

Standard Test Method for Surface Infiltration Rate of Permeable Unit Pavement Systems¹

This standard is issued under the fixed designation C1781/C1781M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the field surface infiltration rate of in place permeable unit pavement systems surfaced with solid interlocking concrete paving units, concrete grid paving units, or clay paving brick.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 The text of this test method references notes that provide explanatory material. These notes shall not be considered as requirements of the test method.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

- 2.1 *ASTM Standards:*²
 - C902 Specification for Pedestrian and Light Traffic Paving Brick
 - C920 Specification for Elastomeric Joint Sealants
 - C936 Specification for Solid Concrete Interlocking Paving Units
 - C1232 Terminology of Masonry
 - C1272 Specification for Heavy Vehicular Paving Brick
 - C1319 Specification for Concrete Grid Paving Units
 - C1701 Test Method for Infiltration Rate of In Place Pervious Concrete

¹This test method is under the jurisdiction of ASTM Committee C15 on Manufactured Masonry Units and is the direct responsibility of Subcommittee C15.04 on Research. Current edition approved Sept. 1, 2013. Published September 2013. DOI: 10.1520/C1781-13.

²For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Documents Summary page on the ASTM website.

2.2 Other Standards:³

Federal Specification A-A-3110 (TT-P-1536A) Plumbing Fixture Setting Compound

3. Terminology

3.1 *Definitions*—The terms used in this test method are defined in Terminology C1232.

4. Summary of Test Method

4.1 An infiltration ring is temporarily sealed to the surface of a permeable unit pavement system. These pavements typically consist of solid concrete paving units conforming to Specification C936, concrete grid paving units conforming to Specification C1319, or clay paving brick conforming to Specification C902 or C1272. These pavements allow drainage through joints between the units or through voids formed by the intersection of two or more units or intentionally manufactured into the units. The results of this test method for unit pavement systems can be compared to that using Test Method C1701 for pervious concrete. After pre-wetting the test location, a given mass of water is introduced into the ring and the time for the water to infiltrate the pavement is recorded. The infiltration rate is calculated in accordance with 9.1.

5. Significance and Use

5.1 This test method can be used for acceptance of surface infiltration of new permeable unit pavement systems.

5.2 Tests performed at the same location across a span of years may be used to detect a reduction of infiltration rate of the permeable surface, thereby identifying the need for any remedial maintenance intended to increase the infiltration rates to predefined levels.

5.3 The infiltration rate obtained by this method is valid only for the localized area of the pavement where the test is conducted. To determine the surface infiltration rate of the entire permeable pavement, multiple locations must be tested and the results averaged.

³Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, <http://dodssp.daps.dla.mil>.



ASTM C1781 - Preparation

1



2



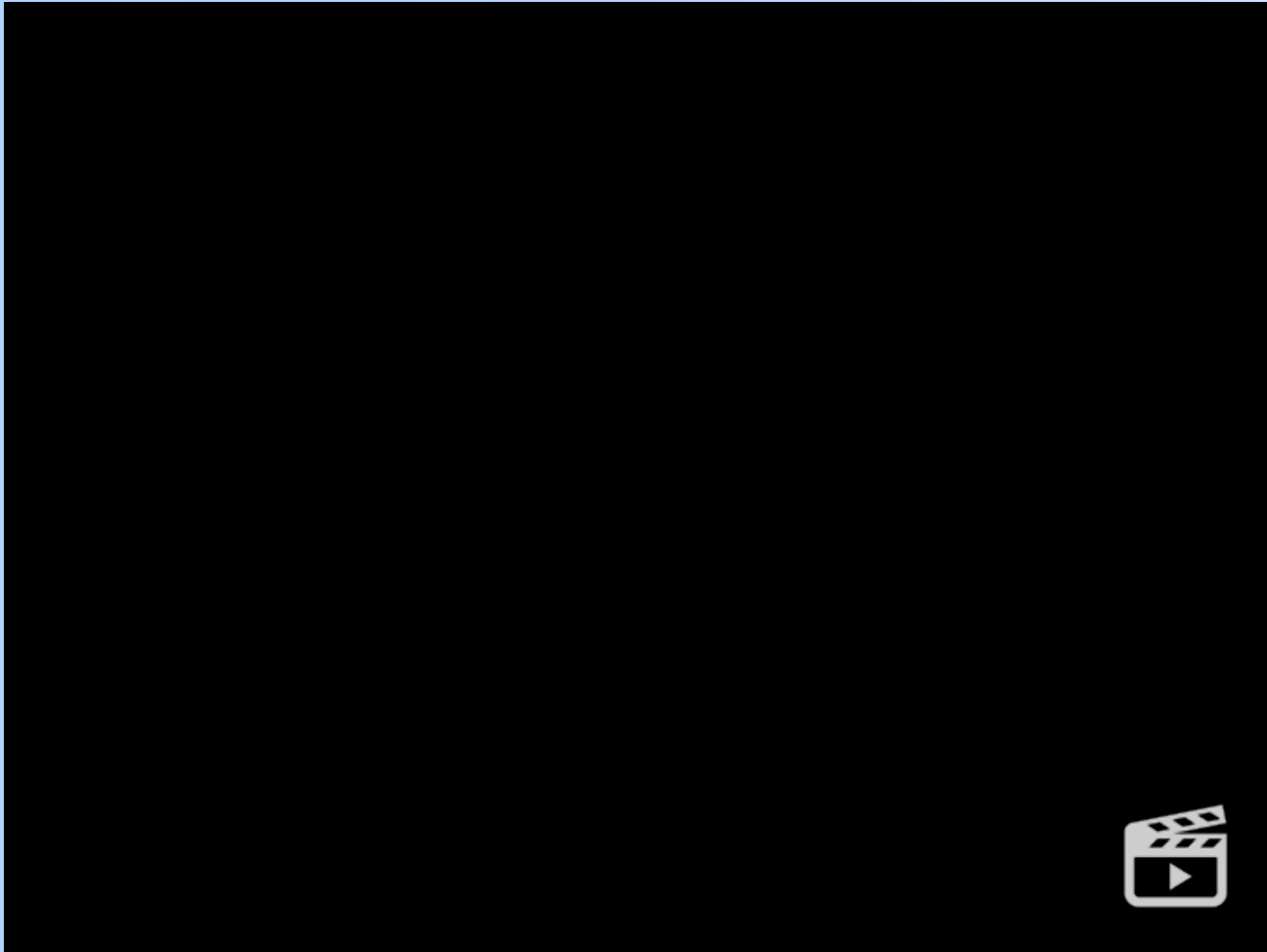
3



4



ASTM C1781



Jointing Materials: Infiltration Comparisons Using ASTM C1781

- Testing by Middle Tennessee State University
- 13 PICP paver shapes
- 6.3% to 13.5% open surface area
- Clean jointing stone

Jointing stone size	ASTM No. 8 stone	ASTM No. 9 stone	ASTM No. 10 stone
Average infiltration rate, in./hr	973	378	73
Standard deviation, in./hr	123	78	7

Total suspended solids (TSS) concentrations by land use (Pitt et al. 2011)

Land Use	Average concentration mg/m ³ (observations)	Range mg/m ³
Commercial	13(1342)	56-247
Freeways	114 (381)	24-183
Industrial	160 (918)	97-385
Institutional	83 (69)	68-91
Open Space	182 (329)	98-846
Residential	137 (3472)	102-528

Florida Gulf Coast University

PICP Infiltration Research

By Jong-Yeop Kim, Ph.D., P.E., Christopher Slater & Gilberto Gil

- 9% surface open area – No. 8, 9 & 10 jointing stone
- Simulated 20 years of urban sediment & sand loads
- Evaluated surface infiltration w/ ASTM C1701/1781
- Used New Jersey Corporation for Advanced Technology protocols (NJCAT = third party technical group w/ methods for evaluating TSS removal in BMPs)
- Simulated 60-80% TSS removal at surface from jointing stones over 20 years w/ 100, 200 & 300 mg/m³
- Recorded decrease in surface infiltration rates from jointing stones over 20 years w/ 100, 200 & 300 mg/m³

ICPI Guidelines using ASTM C1781



- New Construction:
min. 100 in./hr
- In-service:
No less than 10 in./hr
- ASTM No. 8, 89 or 9
stones

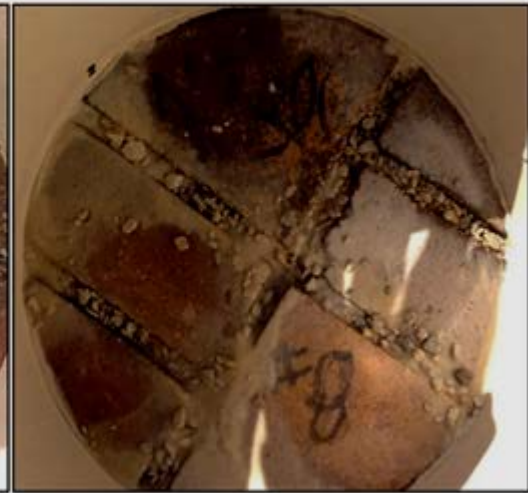
#8NJ100 (Before solid loading)

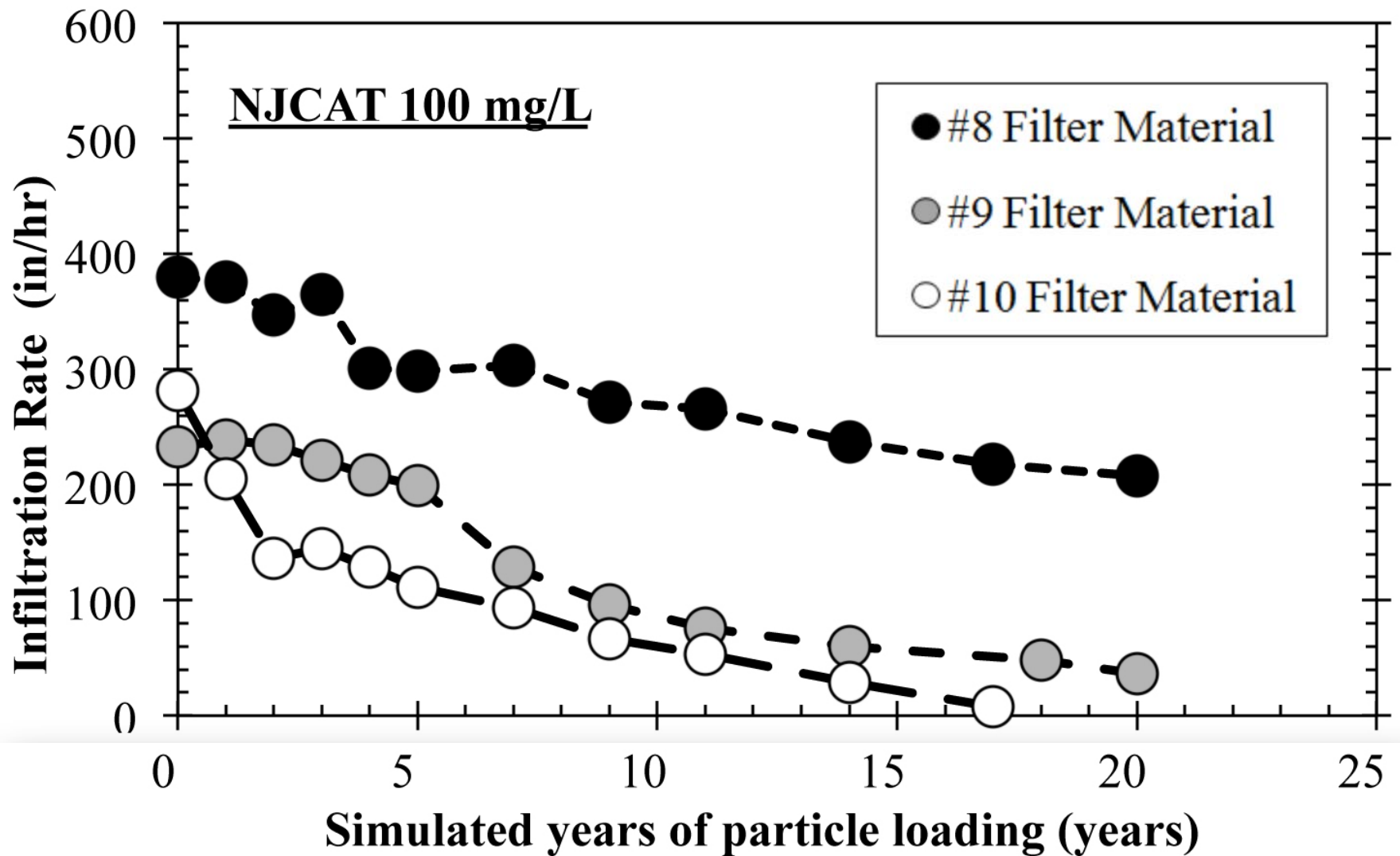


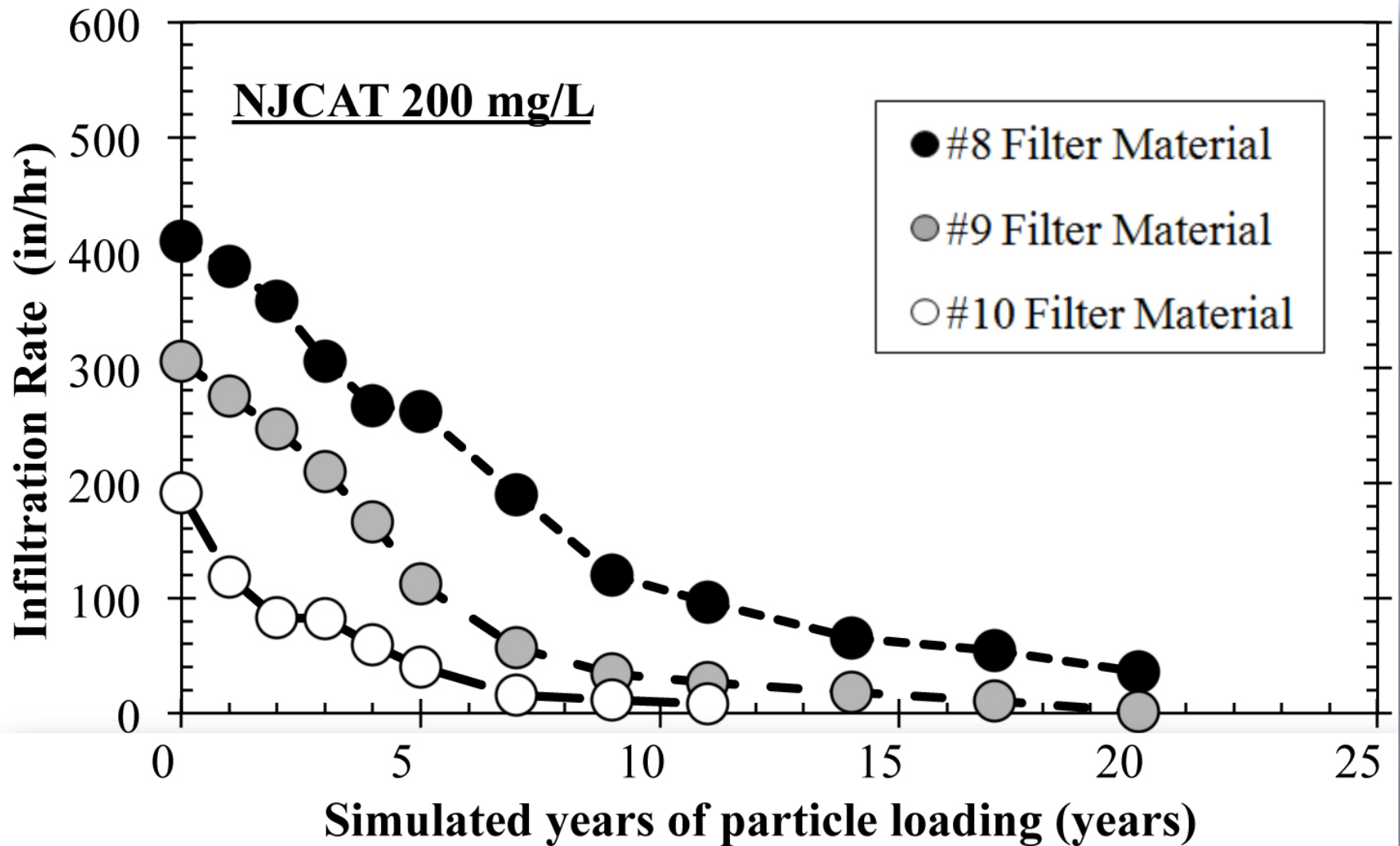
#8NJ200 (After 3-year loading)

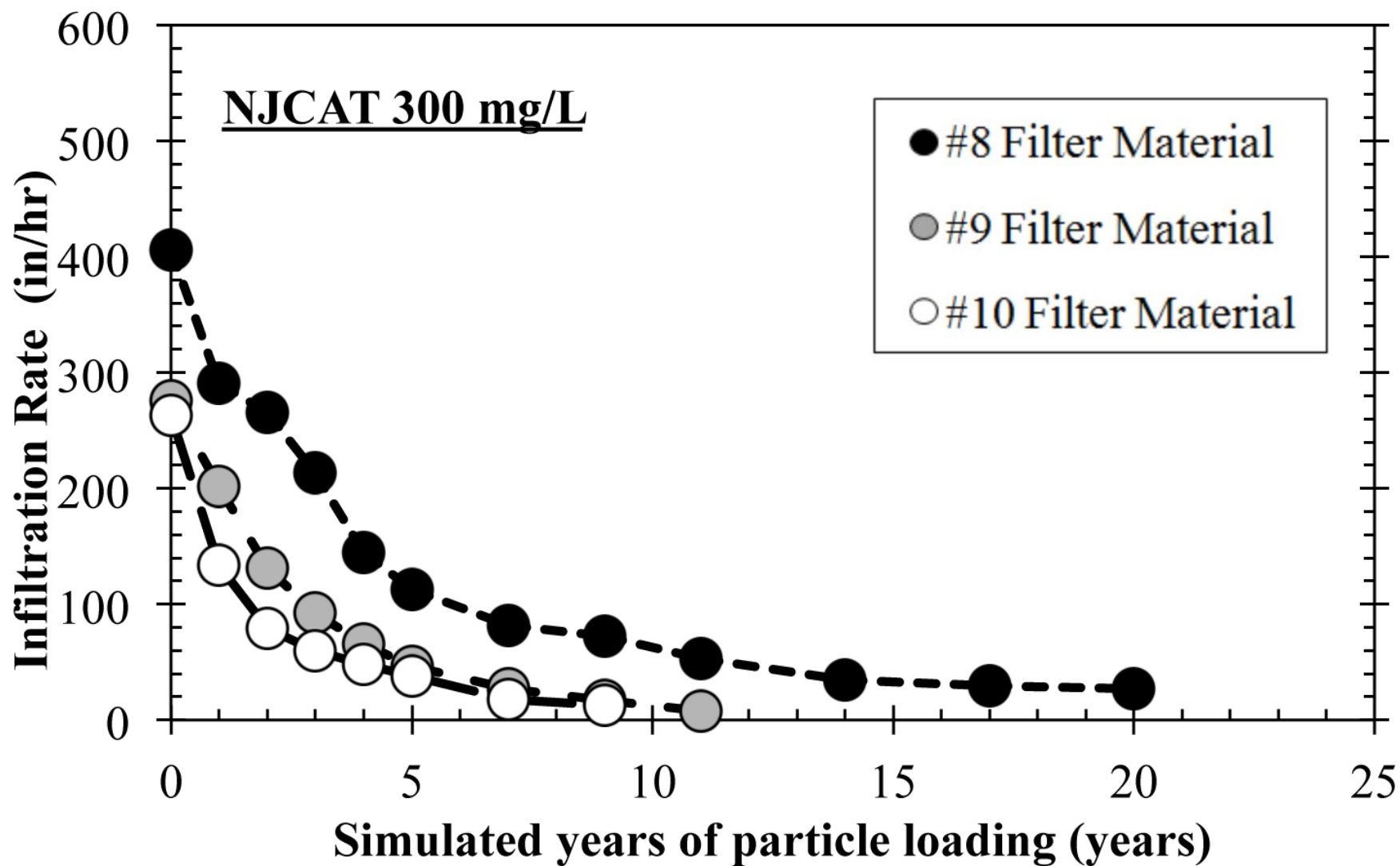


#8NJ300 (After 20-year loading)





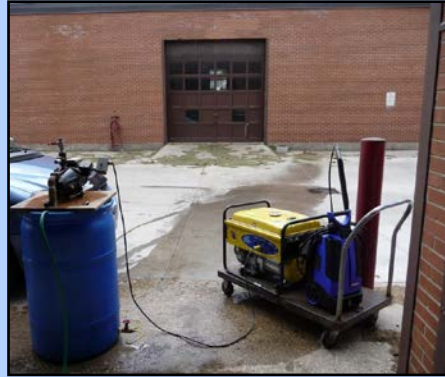




PICP Surface Infiltration Restoration Studies

- Manual removal of soiled jointing stones:
- University of Guelph parking lot – James
- NC State University various sites – Bean
- Vacuum machine removal of jointing stones:
 - University of Central Florida test area – Chopra
True vacuum machine
 - University of New Hampshire parking lot – Roseen
Regenerative air machine
- All studies demonstrated increased infiltration after cleaning – varied with clogging extent

University of Guelph



- Visited 7 mature permeable pavement parking lots in 2010 and 2011
- Tested small-sized equipment
 - pressure-washing
 - shop vacuum
- Tested streetsweepers at 3 mature parking lots in 2011

Statistics	Pre-treatment
Range (cm/hr)	0.4 – 32
Mean (cm/hr)	5.6
σ (mm/hr)	6.6
Median (mm/hr)	3.6

Sweeper Effectiveness

Least effective



Regenerative air vacuum sweeper

- Use 1-2 times/year



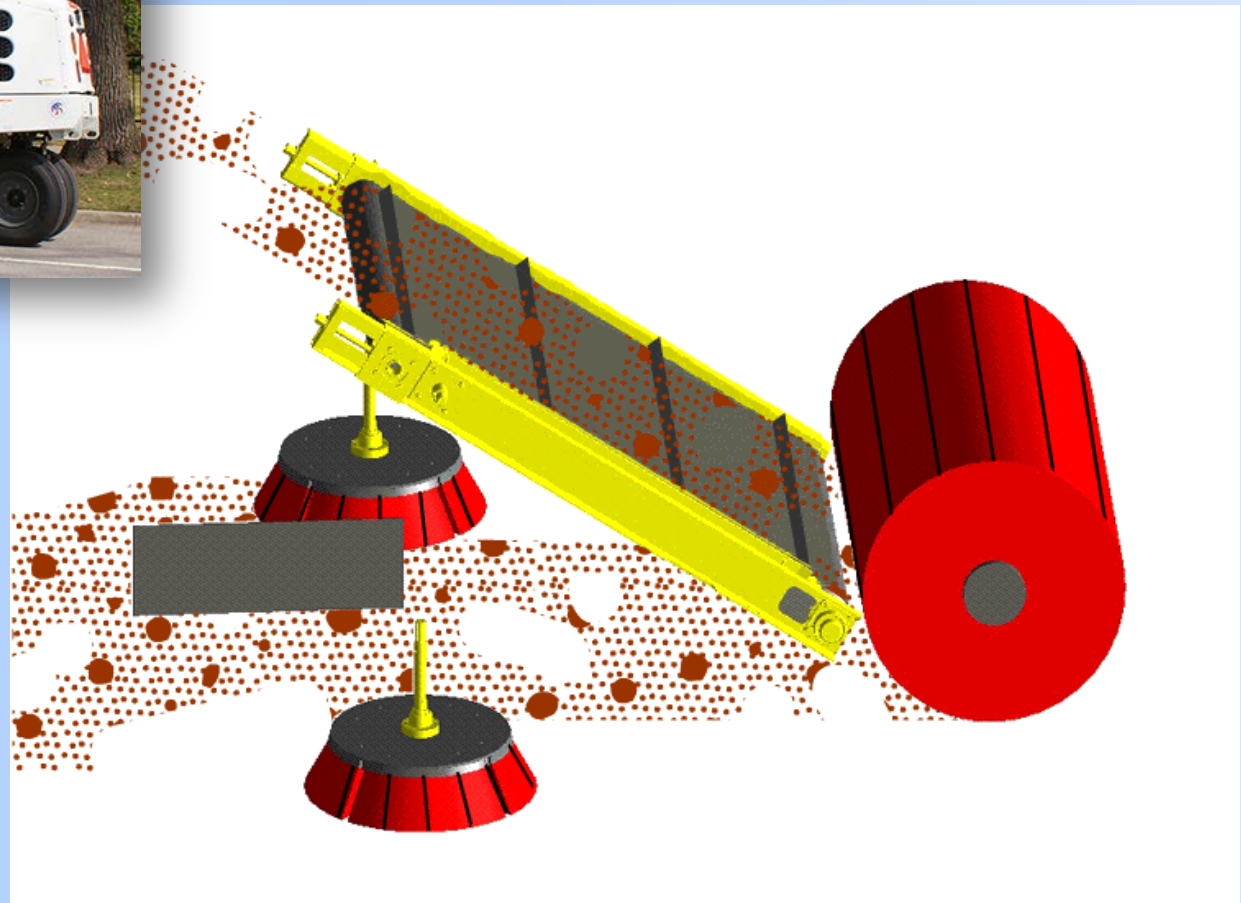
True vacuum sweeper

- Very powerful
- Restores highly clogged surfaces

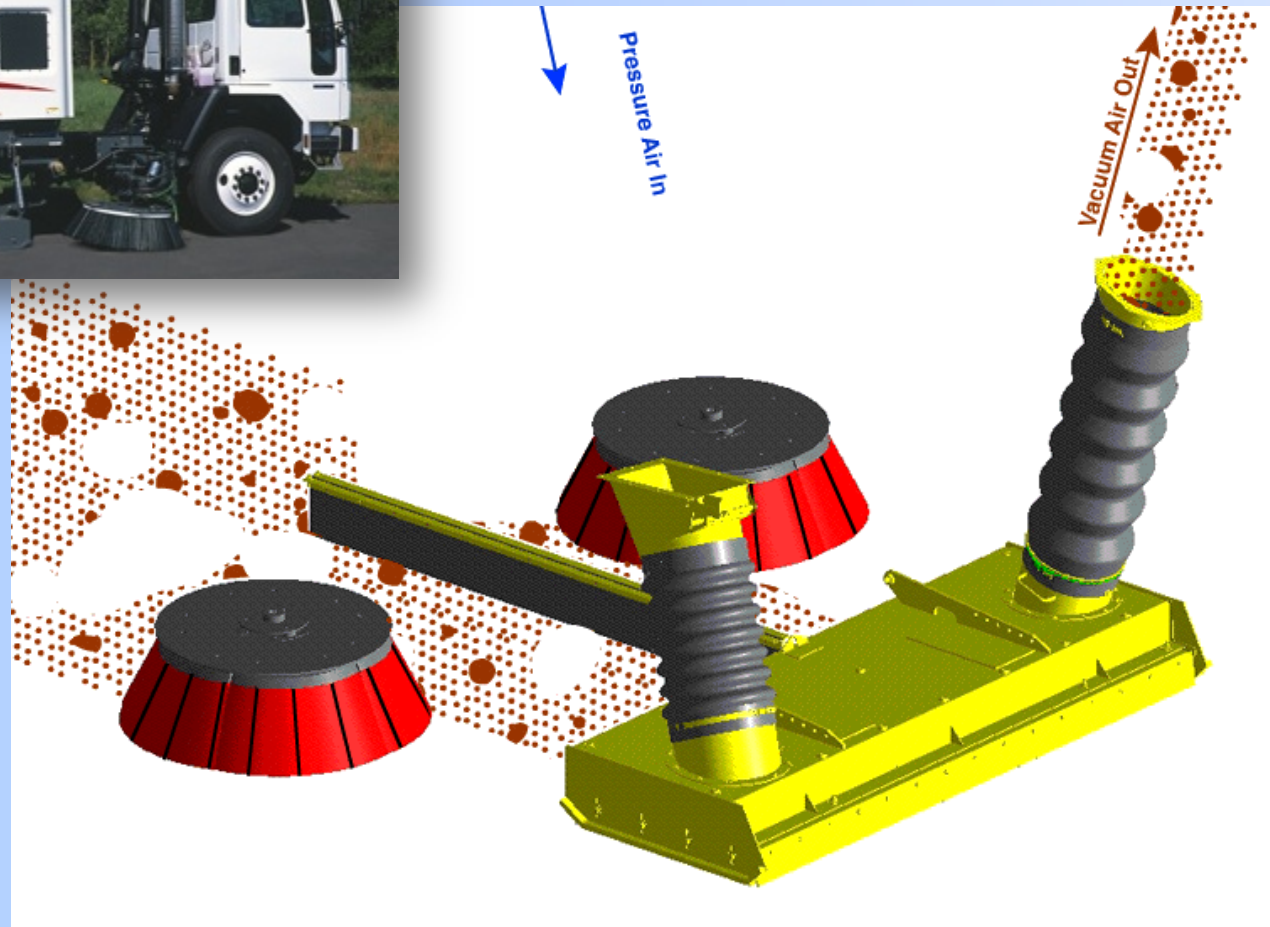


Most effective

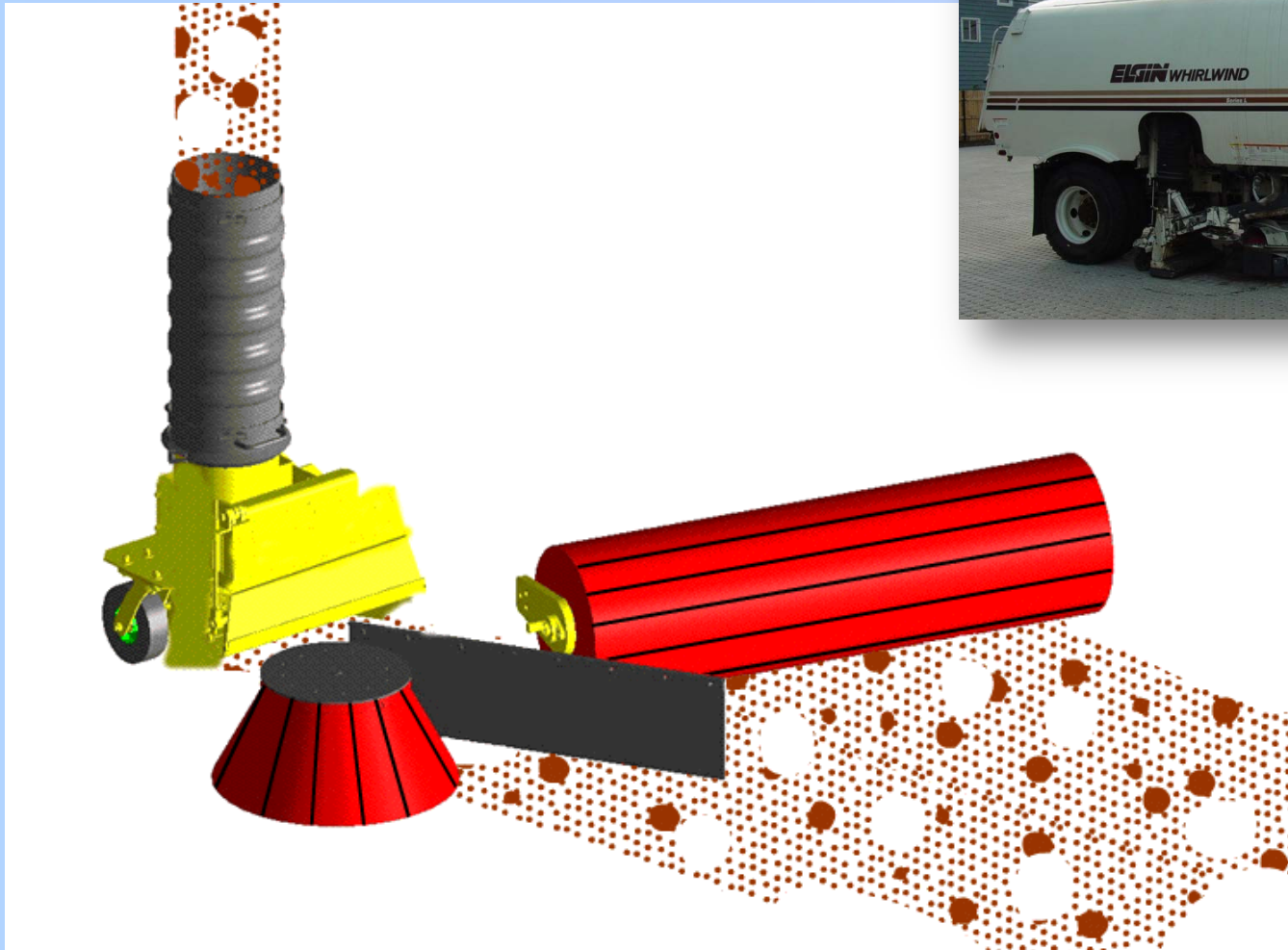
Mechanical Sweeper



Regenerative Air Sweeper



Vacuum Sweeper



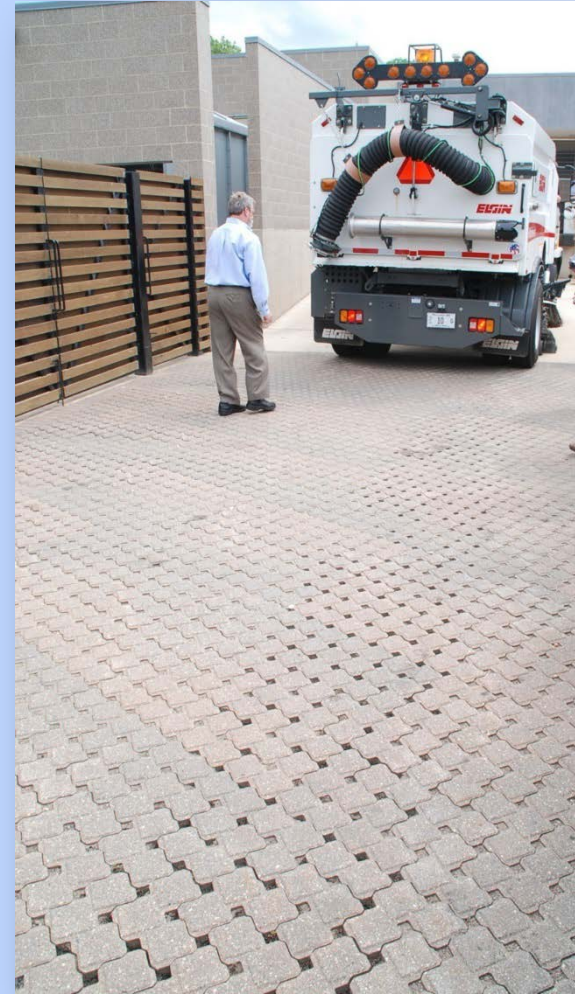
True Vacuum Sweeper



True Vacuum Sweeper



- Sediment collects in top ½ - 1 in.
- cleans out clogged stone & restores surface infiltration – refill with clean stone



University of Guelph - Maintenance Testing

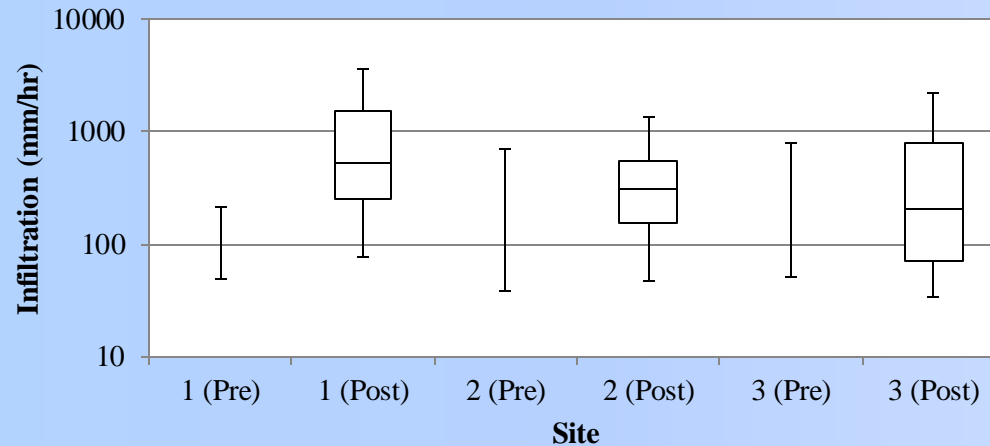
Full-sized equipment

- Tymco-DST 6 and Elgin Whirlwind
- 3 established parking lots (rehabilitation)
- Kortright PP (prevention)
- ASTM C1701 (single ring)

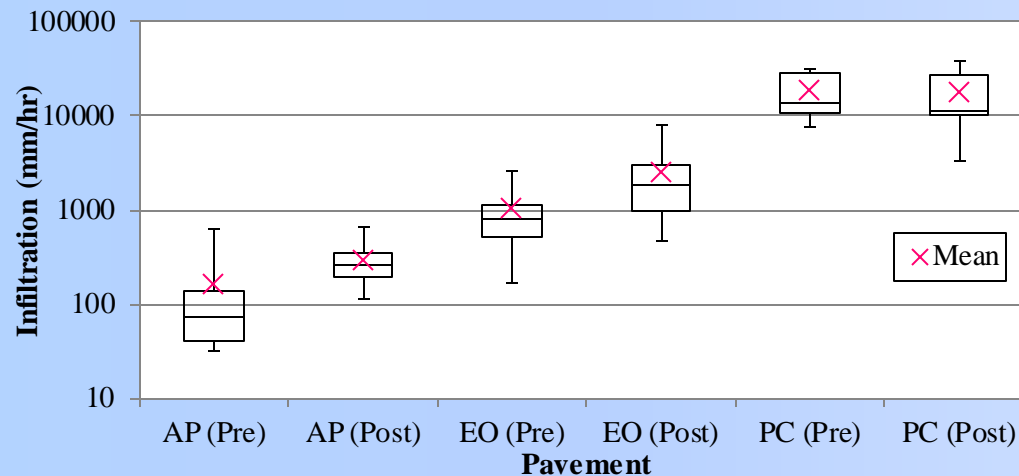


University of Guelph - Maintenance Operations

Rehabilitation Maintenance



Preventative Maintenance



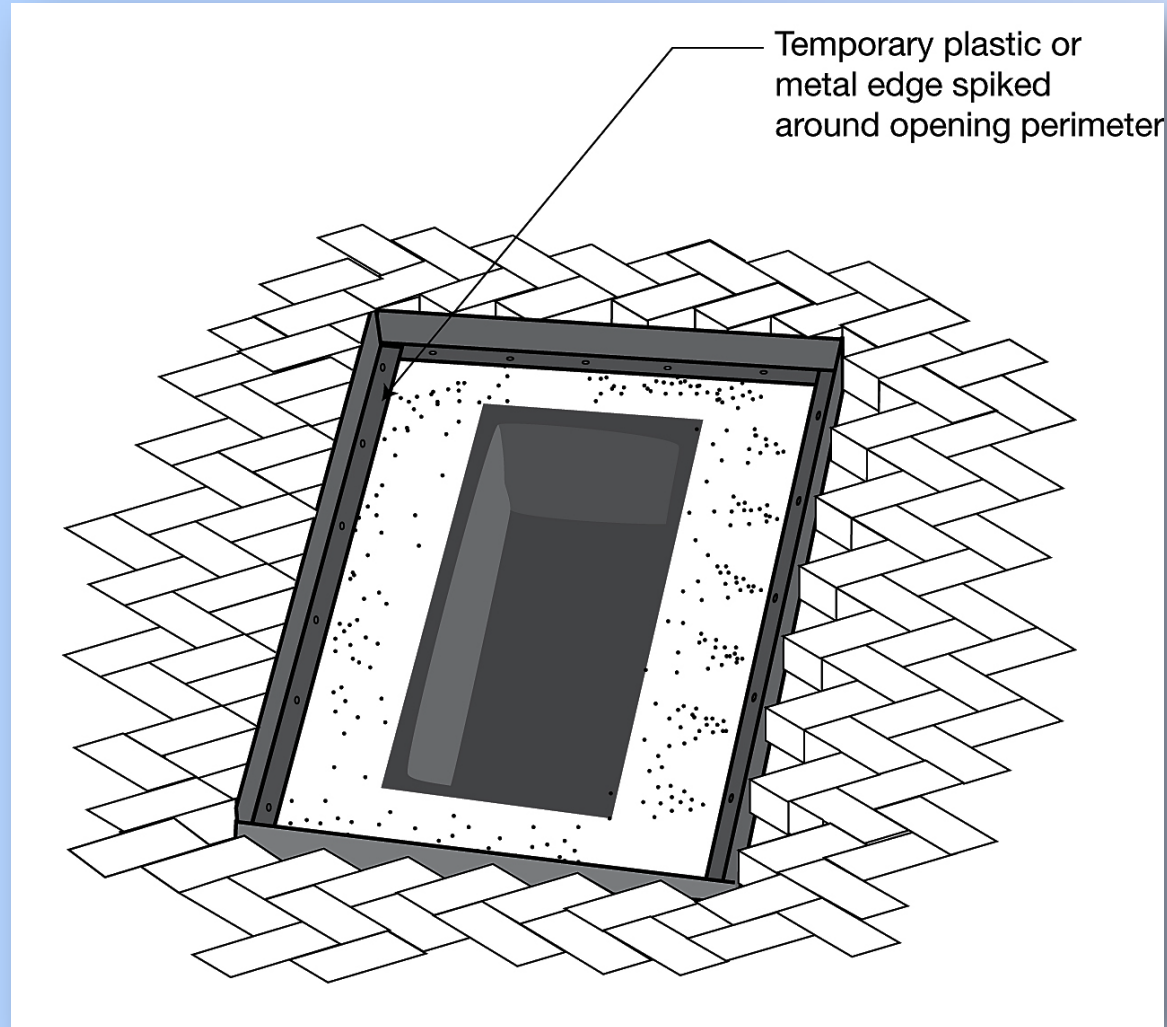
Restoring Surface Infiltration Video



Reinstated surface without damage or reduced service life

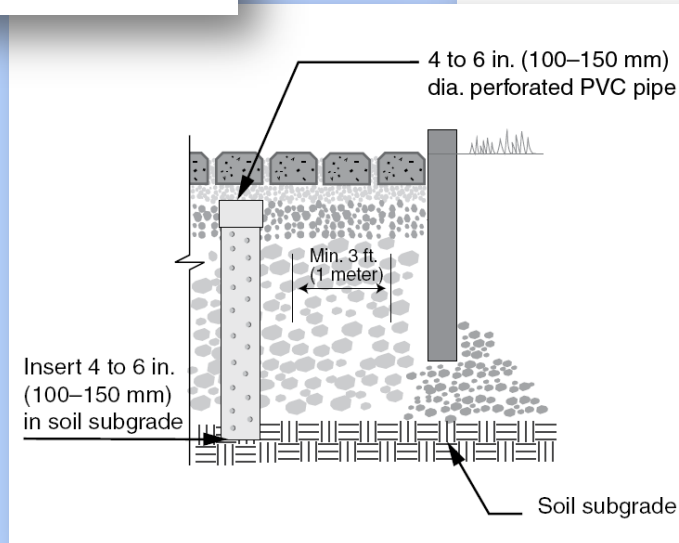
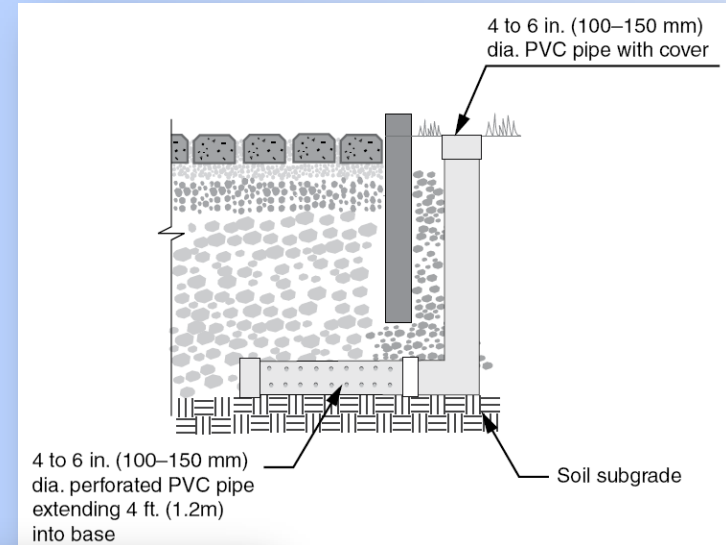
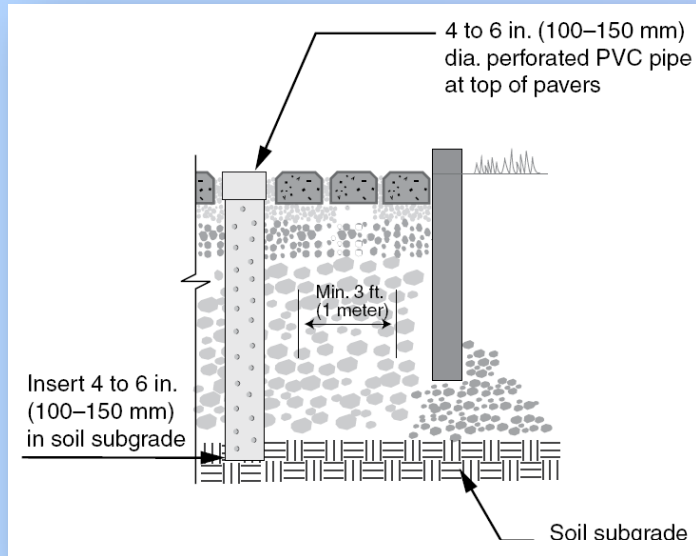


Stabilizing pavers around pavement openings



from ICPI Tech Spec 6 on reinstatement

Observation Well Options





Exposed cap
US Army Ft. Stewart, Georgia

Winter Maintenance

- Snow melts faster – lower risk of ice
- Surface does not heave when frozen
- Use normal plows - dirty snow piles clog surface
- Deicing salts okay
- Sand will clog system – use jointing material for traction



Managing dirty snow



10 years street – winter sand accumulation



Managing dirty snow



No.

Must vacuum winter sand /
sediment accumulation



PICP Inspection Checklist

from ICPI PICP manual

Vacuum surface	1 to 2 times annually, adjust per sediment loading
Replenish aggregate in joints	As needed
Inspect vegetation around PICP perimeter for cover & soil stability	Annually, repair/replant as needed
Repair all deformations exceeding 1/2 in. (13 mm)	Annually, repair as needed
Repair pavers offset by more than 1/4 in. (6 mm) above/below adjacent units	Annually, repair as needed
Replace broken units impairing surface structural integrity	Annually
Check drain outfalls for free flow of water & outflow from observation well	Annually, after a major storm

Maintenance Costs (Rough estimate)

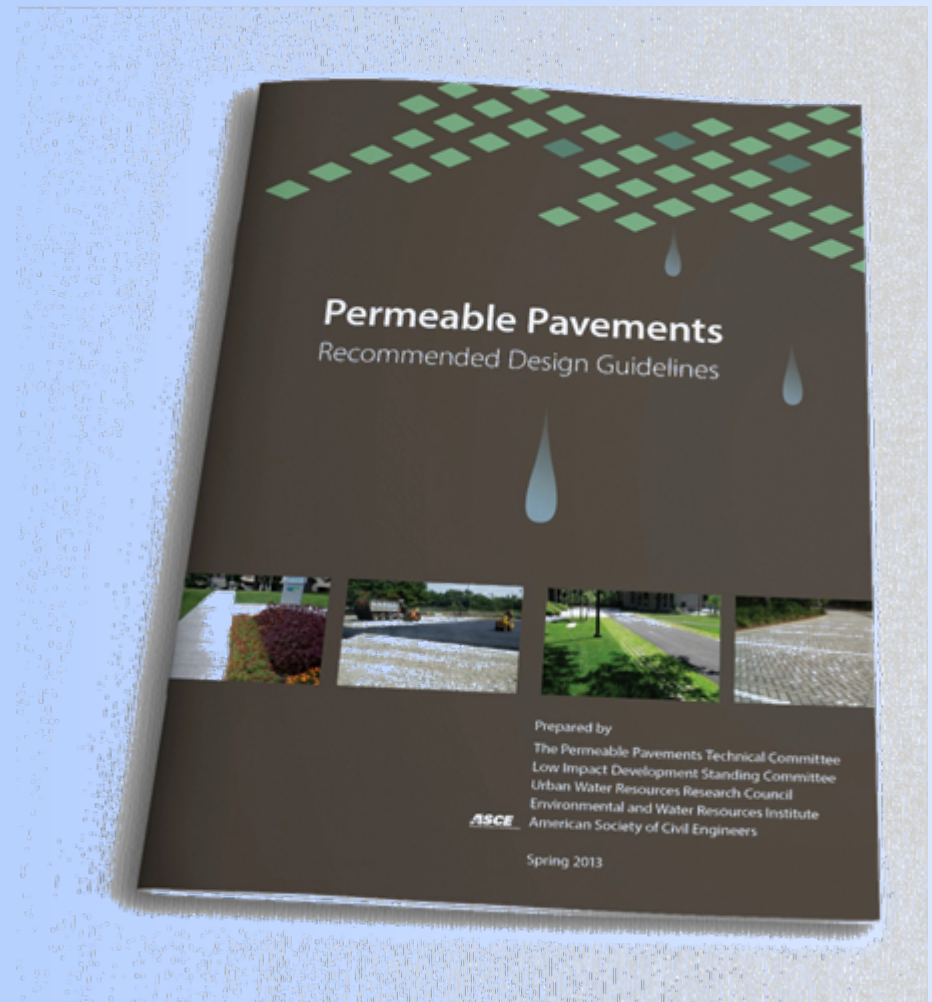
- Vacuuming with a regenerative air machine:
800-\$1000/acre
- Top up jointing stones & re-compact:
\$3000-4000/acre
- Rehabilitative/restorative true vacuuming & replenish jointing stone:
\$8000-\$10,000/acre
- Remove & reinstate pavers, jointing & 2 in. bedding stone:
\$5-\$6/sf
- ***Costs vary with project size, geographic region, labor rates & aggregates prices***

Cleaning sidewalks & residential driveways



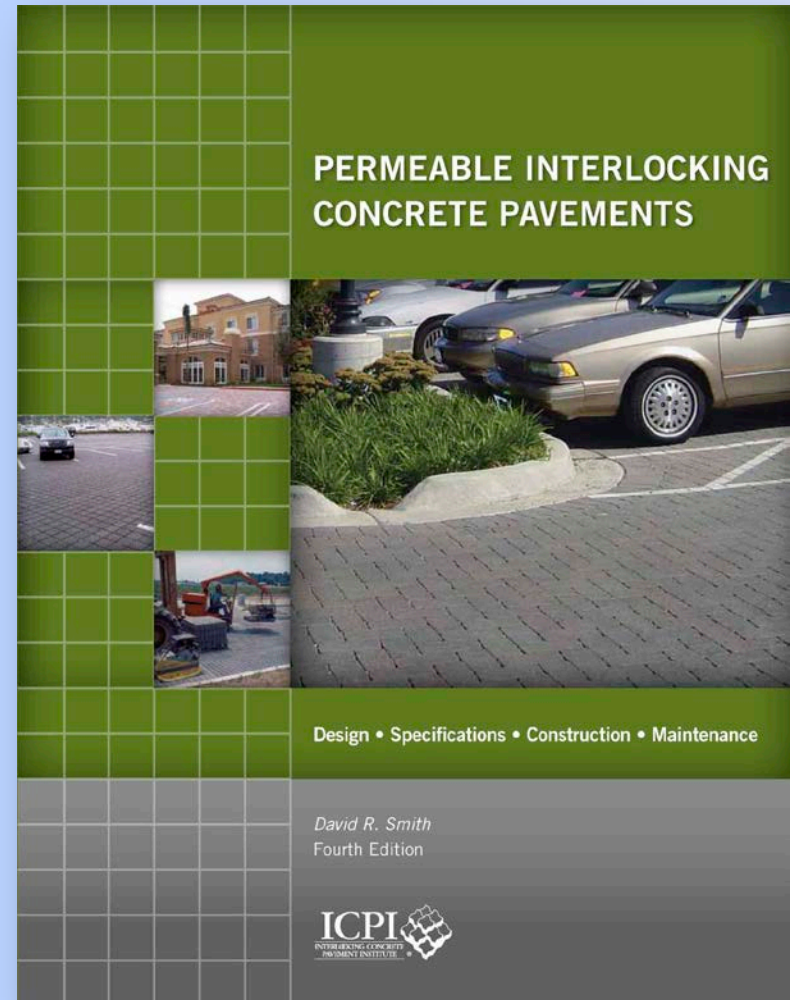
Permeable Pavements Recommended Design Guidelines

- ASCE EWRI Committee Report – online only
- Spring 2014
- Fact sheets
- Checklists
- Design information
- **Maintenance**
- Standards, guide specs & modeling methods
- Research needs
- Establishes common terms for all permeable pavements



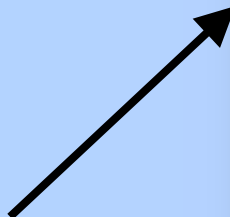
ICPI: PICP Guidance

- 4th Edition PICP Manual
- 100+ pages with 60+ figures
- Industry consensus
- Hydrologic design
- Structural design: Follows Permeable Design Pro software
- Guide specs
- Construction guidelines
- Promotes using contractors with ICPI PICP course certificate
- Certificate appearing in specs Maintenance guidelines



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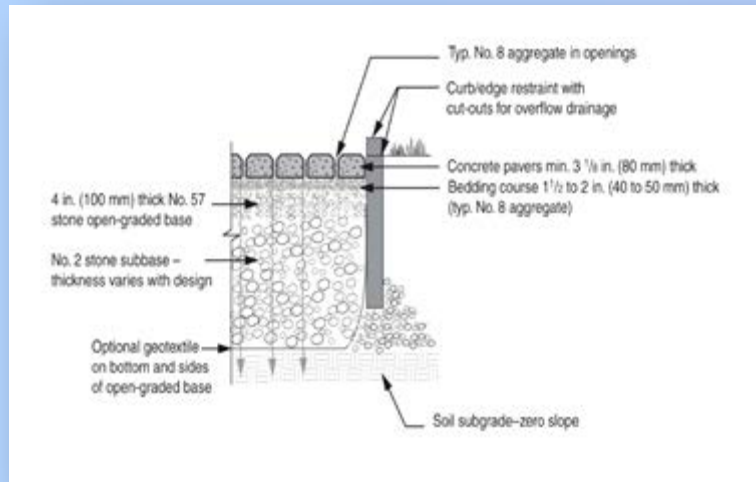
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Sustainable Design

INDUSTRY PROFESSIONALS SAY

"From day one, the Board wanted a permeable lot, a view heightened by the long-term drought in the southeast which

Detail Drawings / Guide specs



SECTION 02795 CONCRETE GRID PAVEMENTS

Note: This guide specification for the U.S. is for concrete grid pavers placed on a sand bedding course over a compacted dense-graded aggregate base. The text allows an option of grass or open-graded aggregate in the grid openings. This specification is for light-duty vehicular applications such as access roads and emergency fire lanes, as well as intermittently used overflow parking areas. Additional design guidance is provided in Tech Spec 8, Concrete Grid Pavements.

If the area is exposed to recurring vehicular traffic and additional stormwater control is desired, the specifier should consider using permeable interlocking concrete pavements, as they provide additional structural support to vehicles. In such cases, the specifier should refer to the ICP manual, Permeable Interlocking Concrete Pavements. This text must be edited to suit specific project requirements for projects. This Section includes the term "Architect." Edit this term as necessary to identify the design professional in the General Conditions of the Contract.

PART 1 GENERAL

1.01 SUMMARY

- A. Section includes:
 - 1. Concrete grid units.
 - 2. Bedding sand.
 - 3. Edge restraints.
 - 4. Geotextiles.
 - 5. [Topsoil and grass for the grid openings.]
 - 6. [Open-graded aggregate for the grid openings.]
 - 7. [Open-graded aggregate bedding course].
- B. Related Sections:
 - 1. Section []: Curbs and drains.

- Interlocking concrete pavements
- Permeable interlocking concrete pavements
- Concrete grid pavements
- Precast concrete paving slabs

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Civil Engineering
UNIVERSITY OF TORONTO

