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Development of a National ASCE Standard for Permeable Interlocking Concrete Pavement

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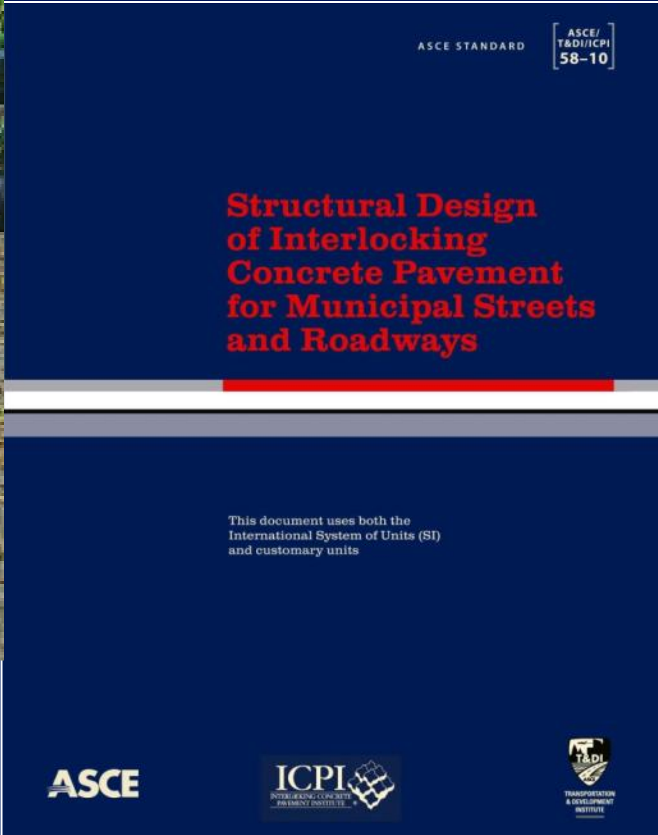
APPLIED RESEARCH ASSOCIATES, INC.

Interlocking Concrete Pavement (ICP) *compared* to PICP

Sand joints & 25 mm bedding typical

ASCE 58-10 ICP AASHTO-based Structural Design Standard (non-permeable)

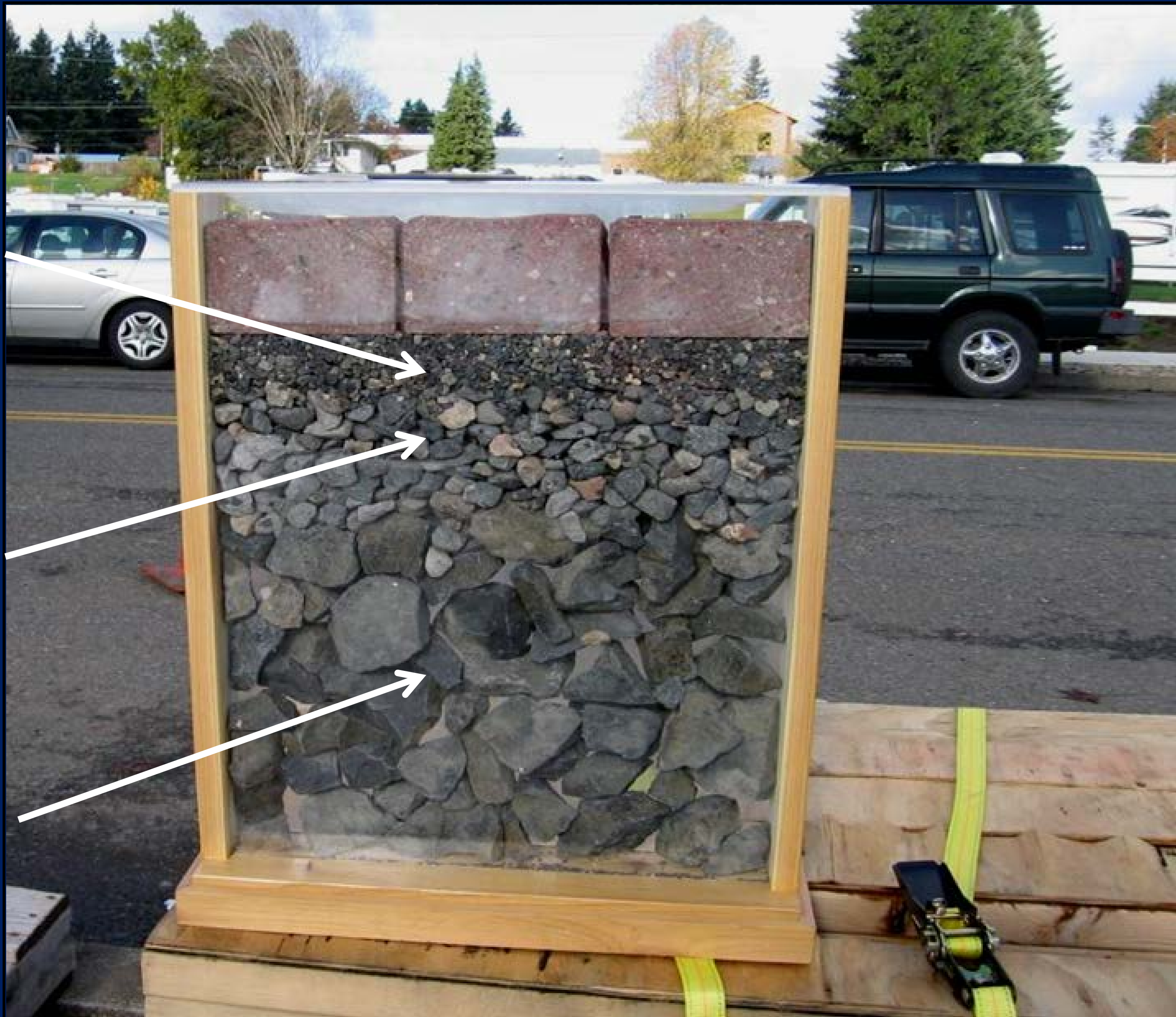


Permeable Interlocking Concrete Pavement (PICP)

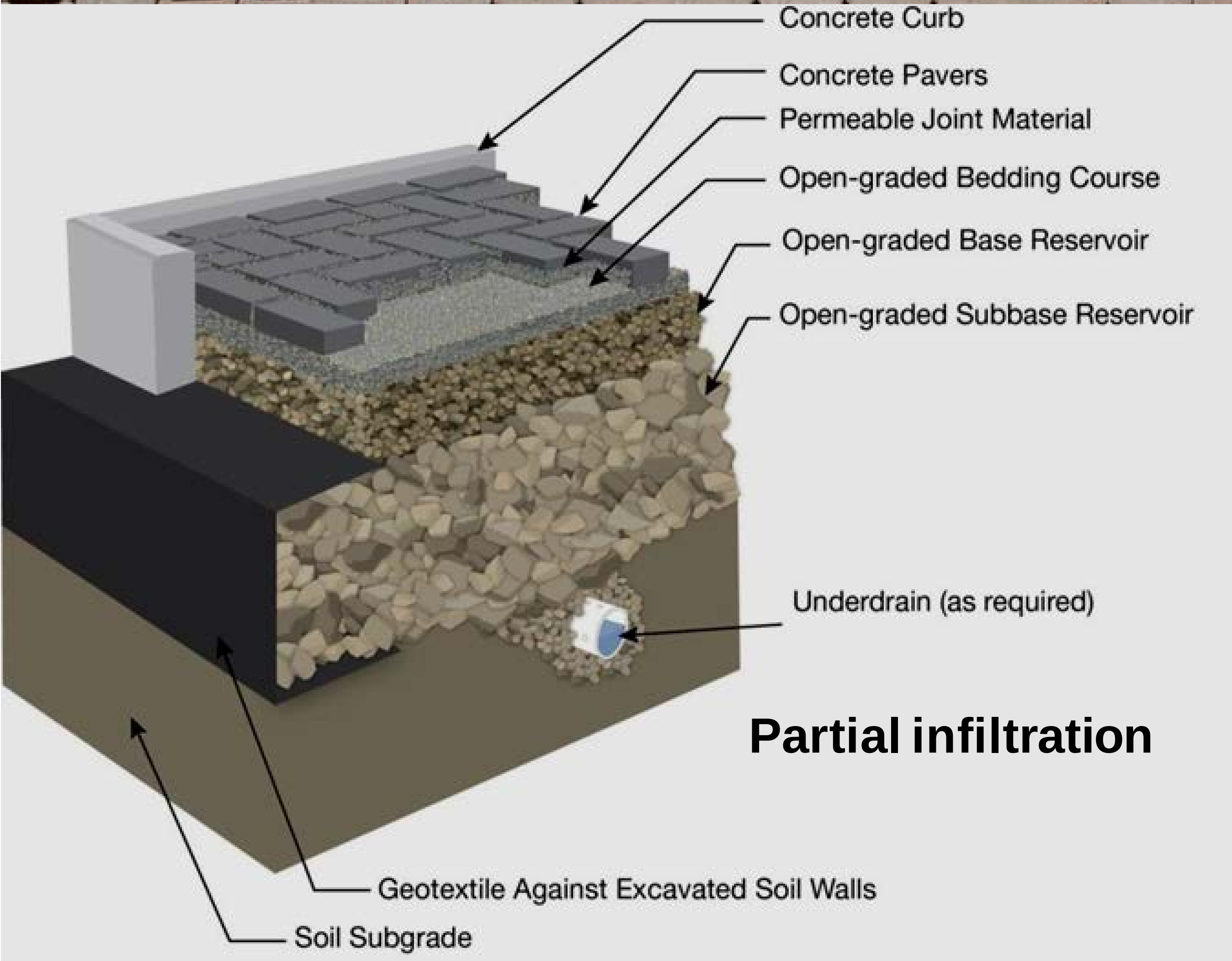
Pavers, bedding & jointing stones

Base reservoir Stone – 100 mm

Subbase stone - thickness varies with water storage & traffic

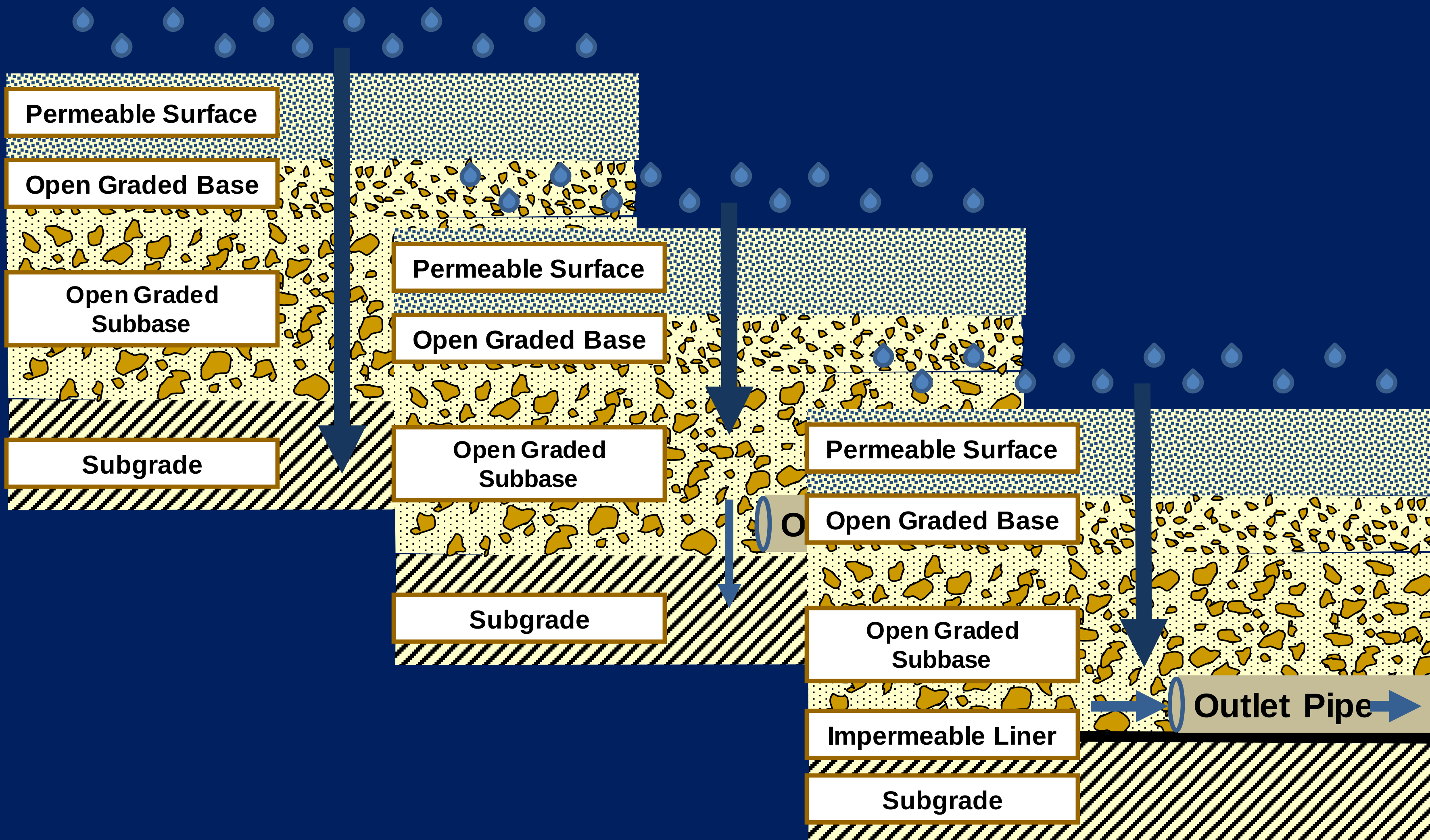


ASCE PICP Design Standard Highlights



- NO sand
- Wider joints
- Permeable aggregates

Permeable Pavement Functions



Key Decision Factors

Considerations	Description
Availability of capital funding	The initial capital construction cost of permeable pavement is typically higher than for conventional pavement. Overall long-term life-cycle costs can be very competitive if consideration is given to stormwater quality and quantity benefits are taken into account.
Status of environmental approval	In some jurisdictions, permeable pavement may not be permitted or may require additional environmental approvals.
Proximity to environmentally sensitive areas	The presence of protected watersheds, cold water streams, marshland, etc. may preclude the use of permeable pavement systems or require more extensive treatments.
Safety	Ability to accommodate safety features such as rumble strips, vegetative growth, areas subjected to rapid icing, etc.
Significant longitudinal grades	Not recommended for grades of more than 5 percent as sheet flow may overload the ability of the permeable shoulder to infiltrate water which may cause localized flooding.
Depth of water table	Permeable pavements should not be used in areas where the water table is within 0.6 m (2ft) of the top of the soil subgrade. It must be possible to drain water entering the subgrade.
Significant use of sand and/or salt for winter maintenance	Melting salt will result in higher concentrations of chlorides in the water which may hinder plant growth. Winter sand may clog permeable pavement systems resulting in reduced system permeability.
Risk of accidental chemical spill	Is the permeable pavement location in an area where hazardous chemical transportation is present.

Key Decision Factors

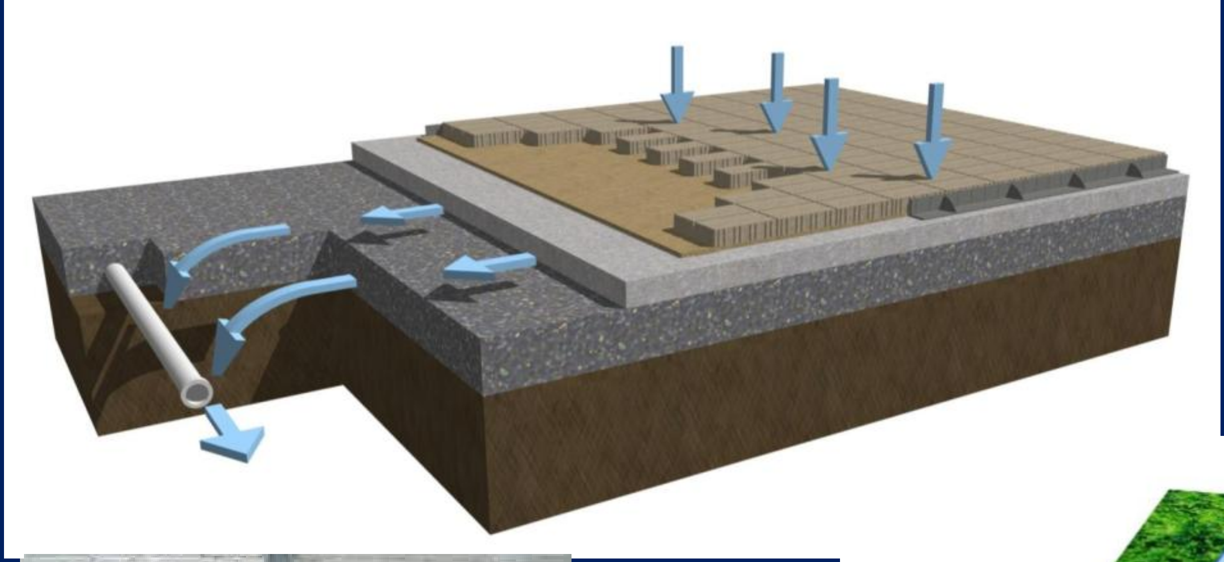
Considerations	Description
Amount and intensity of precipitation	May not be suitable in areas of frequent, high intensity storms.
Presence of utilities	The design and construction of permeable shoulders may be problematic in areas where utilities are present along the roadway shoulders.
Risk of flooding	Areas subject to frequent flooding may require supplemental drainage features to ensure that the roadway surface is properly drained.
Mandates for water quality	Permeable pavements may contribute substantially to water quality improvement.
Mandates for stormwater management	Permeable pavements provide stormwater management alternatives to more costly or complicated practices.
Maintenance protocols	Permeable pavement systems require mandatory non-traditional maintenance practices such as vacuum sweeping.
Shoulder utilization	Some shoulders are used as driving lanes for specification conditions or circumstances, e.g. evacuation routes, rush hour traffic, pullovers for passing, high occupancy vehicle routes, emergency vehicles, etc.
Interest in innovation	Utilizing traditional impermeable surfaces for stormwater management provides opportunities for innovation.
Complexity of geometric conditions	Geometric constraints such as horizontal or vertical grades, presence of bridge structures, curbs, retaining walls, guiderails, etc.
Impact of unknown site conditions	Variability of soil conditions, presence of organics, potential for frost heave, etc. may impact shoulder pavement performance.
Owner experience and resources	The use of permeable pavements for roadway shoulder is very limited a present.

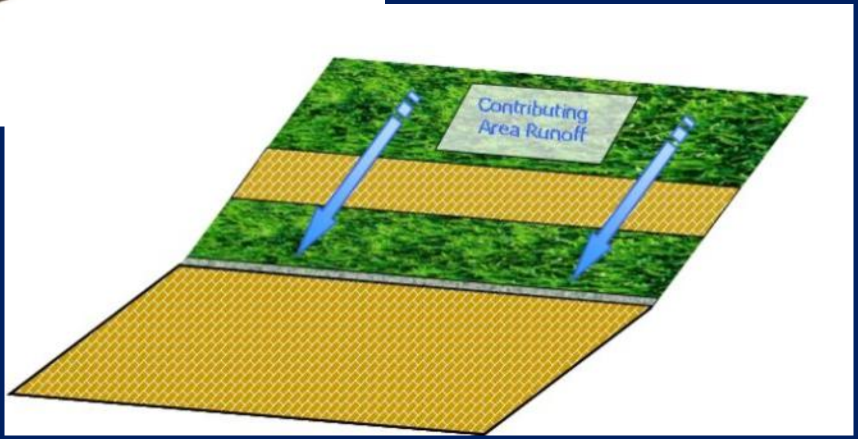
Site Recommendations

- Pedestrian areas, parking lots, low-speed residential roads
- 30 m from wells
- 3 m from building foundations unless waterproofed
- Infiltrating base: Min. 0.6 m to seasonal high water table
- Lined base: Min. 0.3 m to seasonal high water table
- Max. contributing impervious area: PICP = 5:1
- Surface slope: as much as 18%...w/ subgrade check dams
- Subrade slope: >3% - use berms

Key Design Features

- **Site Drainage -** Consider the overall site drainage, rainfall and from surrounding areas





Key Design Features

- **Contaminant Loading -** Consider potential contaminants such as winter sand, biomass (tree leaves and needles, grass clippings, etc.) and sediment

Key Design Features

- **Contaminant Loading –** Do not want to see a complete failure before the pavement has been opened to traffic

Key Design Features

- **Traffic Type and Composition -** Avoid using permeable pavements in high, concentrated traffic areas subjected to many heavy vehicles
- A qualified pavement engineer should be consulted for these specific applications

Key Design Features

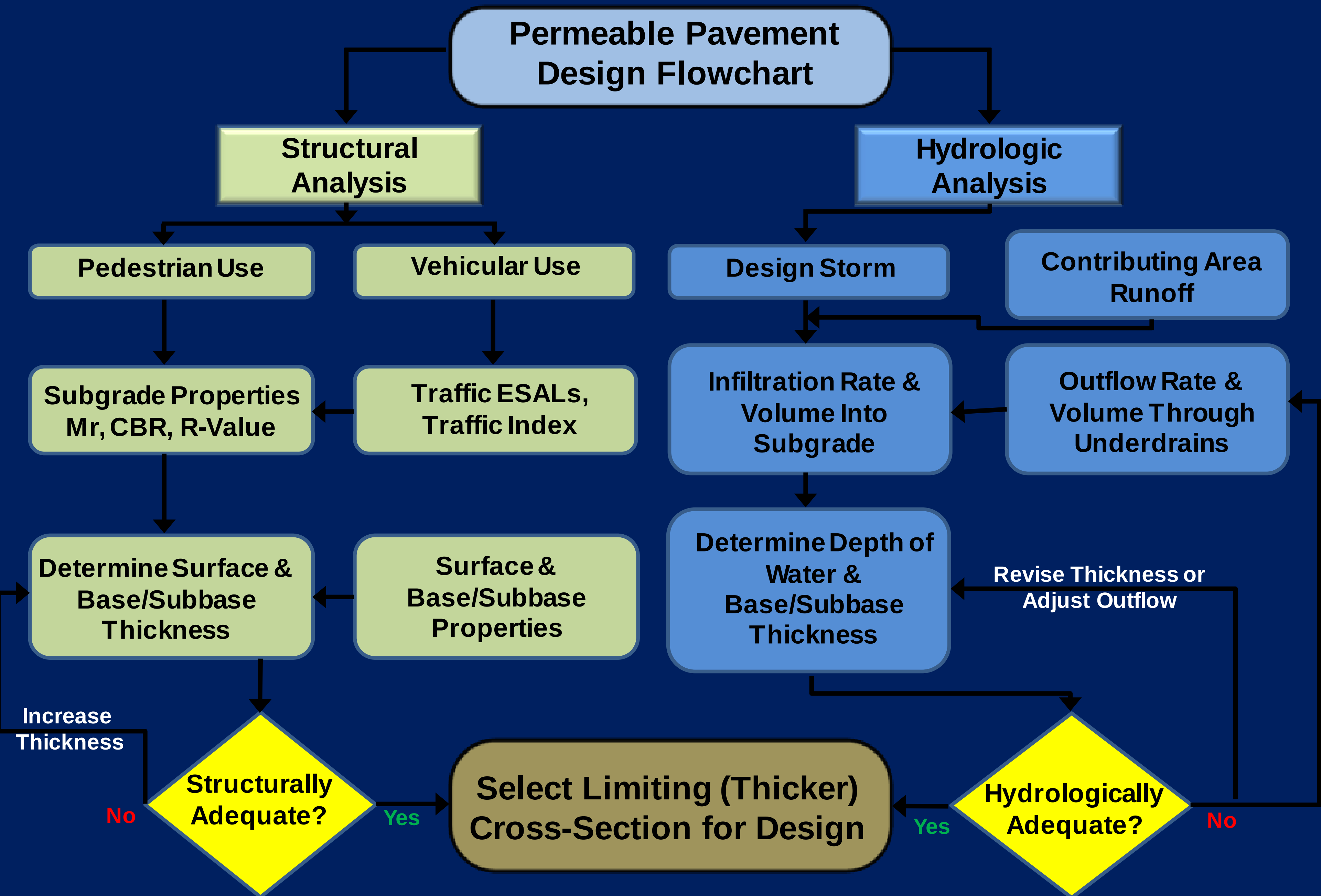
- **Pavement Surface -** Consider the type of surface most appropriate for the traffic and infiltration capacity conditions
- Porous asphalt or pervious concrete may be more appropriate for some slope conditions
- Permeable interlocking concrete pavement may be more suitable for situations where vehicles are turning
- Most permeable pavements should have slopes less than 5 percent

Key Design Features

- **Aggregate Base and Subbase -** Permeable pavements typically utilize open graded aggregate to provide structural and hydraulic capacity
- Aggregates should be hard, durable and have a low percentage of material passing the 75 µm (ASTM No. 200) sieve size.
- It may be necessary to double wash the aggregate to ensure less than 2 percent fines content
- For heavier traffic conditions, a cement- or asphalt-stabilized open-graded aggregate may be more suitable

Key Design Features

- **Subgrade Slope** - Infiltration designs should minimize subgrade slope to promote water infiltration
- Sites with subgrade slopes over 3% often require buffers, weirs, check dams, etc. to control water flow
- Supplementary drainage outlets such as catchbasins, stormwater ponds, should be used to prevent the system from flooding in high rain events
- Determine the need for these geosynthetics for subgrade/ aggregate separation, filtration, containment and reinforcement


Permeable Pavement Design Flowchart
Structural Analysis
Hydrologic Analysis
Pedestrian Use
Vehicular Use
Design Storm
Contributing Area Runoff
Subgrade Properties Mr, CBR, R-Value
Traffic ESALs, Traffic Index
Infiltration Rate & Volume Into Subgrade
Outflow Rate & Volume Through Underdrains
Determine Surface & Base/Subbase Thickness
Surface & Base/Subbase Properties
Determine Depth of Water & Base/Subbase Thickness
Revise Thickness or Adjust Outflow
Increase Thickness
No
Structurally Adequate?
Yes
Select Limiting (Thicker) Cross-Section for Design
Yes
Hydrologically Adequate?
No

Critical Hydrologic Design Factor: Subgrade Infiltration

Double ring infiltrometer test

Use avg. infiltration rate

Apply safety factor for clogging & construction compaction

Portable soil infiltration device

Multiple test holes

Test pit

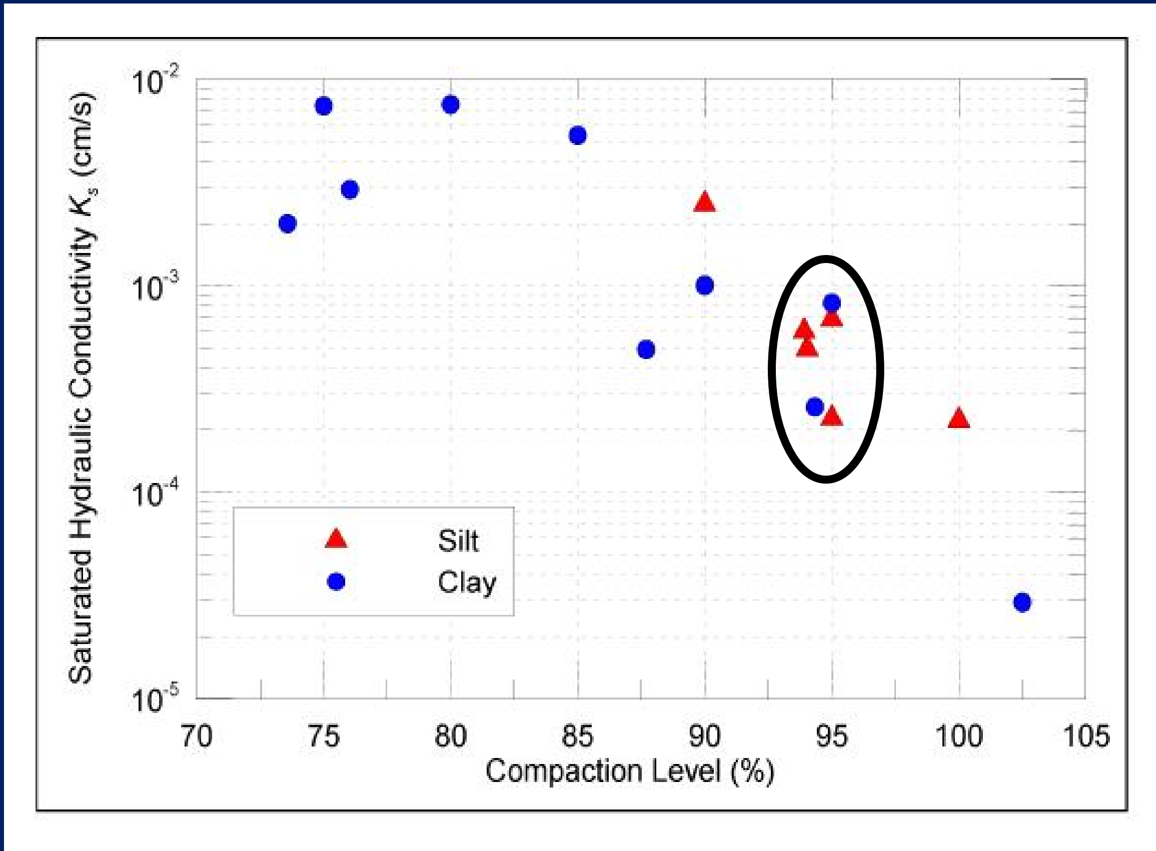
Infiltration vs Compaction

- **Soil classification per ASTM D4287**
- **Laboratory Proctor density per ASTM D698**
- **Density tests on compacted soil**
- **Soil infiltration test on *compacted* soil per ASTM D3385/D5093**

Clay soils have <u>some</u> Infiltration when compacted - Laboratory study by UC Davis, Jones, et al. for Caltrans

10^{-2} cm/sec = 14.2 in./hr
10^{-3} cm/sec = 1.4 in./hr
10^{-4} cm/sec = 0.13 in./hr
10^{-5} cm/sec = 0.014 in./hr

Per AASHTO T-215 constant head test



Critical Structural Design Factors

Uncompacted or compacted soils…

Strength characterization of *saturated* soils via…

California Bearing Ratio (96 hr soaked)

Resilient Modulus M_r or R-value

AASHTO layer coefficients

Paver surface &

Bedding = 0.3 **Base = 0.09** **Subbase = 0.06**

Traffic Loading and Design

Pavement Class	Description	Design ESALs	Design TI
Arterial	Through traffic with access to high-density, regional, commercial and office developments or downtown streets. General traffic mix.	9,000,000	11.5
Major Collector	Traffic with access to low-density, local, commercial and office development or high density, residential sub-divisions. General traffic mix	3,000,000	10
Minor Collector	Through traffic with access to low-density, neighborhood, commercial development or low-density, residential sub-divisions. General traffic mix.	1,000,000	9
Bus Terminal	Public Transport Centralized facility for buses to pick up passengers from other modes of transport, or for parking of city or school buses.	500,000	8.5
Local Commercial	Commercial and limited through traffic with access to commercial premises and multi-family and single-family residential roads. Used by private automobiles, service vehicles and heavy delivery trucks	330,000	8
Residential	No through traffic with access to multi-family and single-family residential properties. Used by private automobiles, service vehicles and light delivery trucks, including limited construction traffic.	110,000	7
Facility Parking	Open parking areas for private automobiles at large facilities with access for emergency vehicles and occasional use by service vehicles or heavy delivery trucks.	90,000	7
Commercial Parking	Restricted parking and drop-off areas associated with business premises, mostly used by private automobiles and occasional light delivery trucks. No construction traffic over finished surface.	30,000	6
Commercial Plaza	Predominantly pedestrian traffic, but with access for occasional heavy maintenance and emergency vehicles. No construction traffic over finished surface.	10,000	5

Structural Design

Pedestrian Only Use	Soaked CBR (%)	3	4	5	6	7	8	9	10
	R-Value	7.5	9	11	12.5	14	15.5	17	18
	Resilient Modulus (MPa)	36	43	49	55	61	67	72	77
	Base	150	150	150	150	150	150	150	150
	Subbase	0	0	0	0	0	0	0	0
50,000 (6.3) Residential Driveways	Base	100	100	100	100	100	100	100	100
	Subbase	175	150	150	150	150	150	150	150
100,000 (6.8)	Base	100	100	100	100	100	100	100	100
	Subbase	275	200	150	150	150	150	150	150
200,000 (7.4)	Base	100	100	100	100	100	100	100	100
	Subbase	425	325	275	225	175	150	150	150
300,000 (7.8)	Base	100	100	100	100	100	100	100	100
	Subbase	500	400	350	300	250	225	200	175
400,000 (8.1)	Base	100	100	100	100	100	100	100	100
	Subbase	550	475	400	350	300	275	250	225
500,000 (8.3)	Base	100	100	100	100	100	100	100	100
	Subbase	600	525	450	400	350	300	275	250
600,000 (8.5)	Base	100	100	100	100	100	100	100	100
	Subbase	650	550	475	425	375	350	300	275
700,000 (8.6)	Base	100	100	100	100	100	100	100	100
	Subbase	700	600	525	450	425	375	350	300
800,000 (8.8)	Base	100	100	100	100	100	100	100	100
	Subbase	725	625	550	500	450	400	375	325
900,000 (8.9)	Base	100	100	100	100	100	100	100	100
	Subbase	750	650	575	525	475	425	400	350
1,000,000 (9)	Base	100	100	100	100	100	100	100	100
	Subbase	775	675	600	525	475	425	400	375

Need: Validated Base Thickness Charts

Design Tables for PICP

Accelerated Pavement Testing

UC Pavement Research Center

Sponsors: CA Paver Manufacturers, ICPI Foundation, CA Cement Assoc.

Key Construction Features

- **General Construction Site Conditions -** A pre-construction site meeting is critical to the success of the permeable pavement installation

Key Construction Features

- **Subgrade Preparation –** Most agency guidelines recommend that the subgrade not be compacted in order to help promote water infiltration
- An uncompacted subgrade tends to consolidate when saturated under vehicular loading, causing settlement and possible rutting of the pavement surface
- Placement of the open-graded aggregate base and subbase should be completed as close in time as possible to minimize risk of sedimentation of the permeable pavement system

Key Construction Features

- **Geotextiles** - Generally placed vertically against the walls of excavated soil to separate the permeable pavement from adjacent soils
- **Geomembranes –** Typically polyvinyl chloride, ethylene propylene diene monomers or high density polyethylene
- Separates the base/subbase from adjacent pavements/buildings
- May enclose the sides and bottom to create a no infiltration design for water storage and flow control

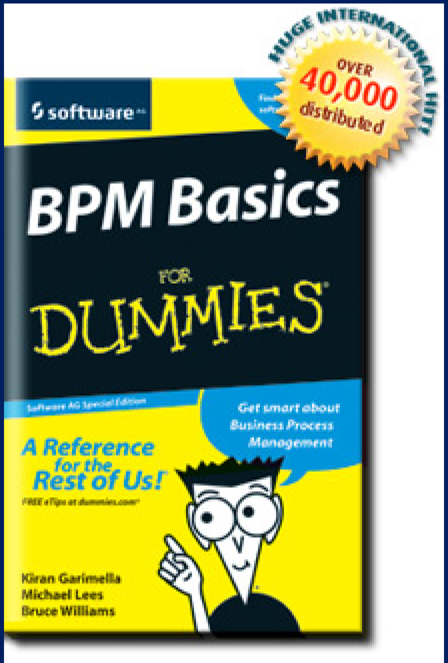
Key Construction Features

- **Underdrains -** These should be installed in a trench the lowest point of the pavement subgrade
- Pipes are surrounded with open-graded aggregate offering protection during construction
- Pipes should be perforated, polyvinyl chloride (PVC), minimum 0.5 percent slope to an outlet
- Pipe spacing and size should be selected to ensure that the pavement does not flood and become completely saturated during storm events

Key Construction Features

- **Contractor Certifications and Experience -** Require more attention to detail to ensure that a durable pavement is produced
- Contractors working at or near the permeable pavement must be cognizant of the need to not contaminate and clog the pavement with particles
- May require installation of cattle guards and/or washing stations to ensure that the construction traffic does not contaminate the pavement
- Trade groups have training and certification courses

ASCE PICP Standard Guidelines



Content

- Overview & benefits
- *PICP for Plan Reviewers – the basics*
- Design context & site review checklist
  - Hydrologic & structural design
- Construction checklist
  - Pre-construction meeting
  - Sediment control
- Maintenance inspection checklist

Goal: end of 2014 Completion

Uses

- Adoption by state, provincal & local agencies
- Design professional & contractor guidance

Key Construction Factors

Minimizing compaction

Maintaining clean aggregates & pavement surface

Mechanical PICP Installation

Warrenville, IL

Marine Market Way
Burnaby, BC
35,000 m^2

PICP receives roof runoff

Critical Maintenance Factors

- Regenerative air vacuum sweeper
  - Routine cleaning
  - Removes loose sediment,
    leaves, etc.
  - More common
  - ~$2000/ha
- True vacuum sweeper
  - 2X more powerful
  - Restores highly clogged surfaces
  - Narrower suction

Winter Maintenance

- Snow melts– lower risk of ice
- 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

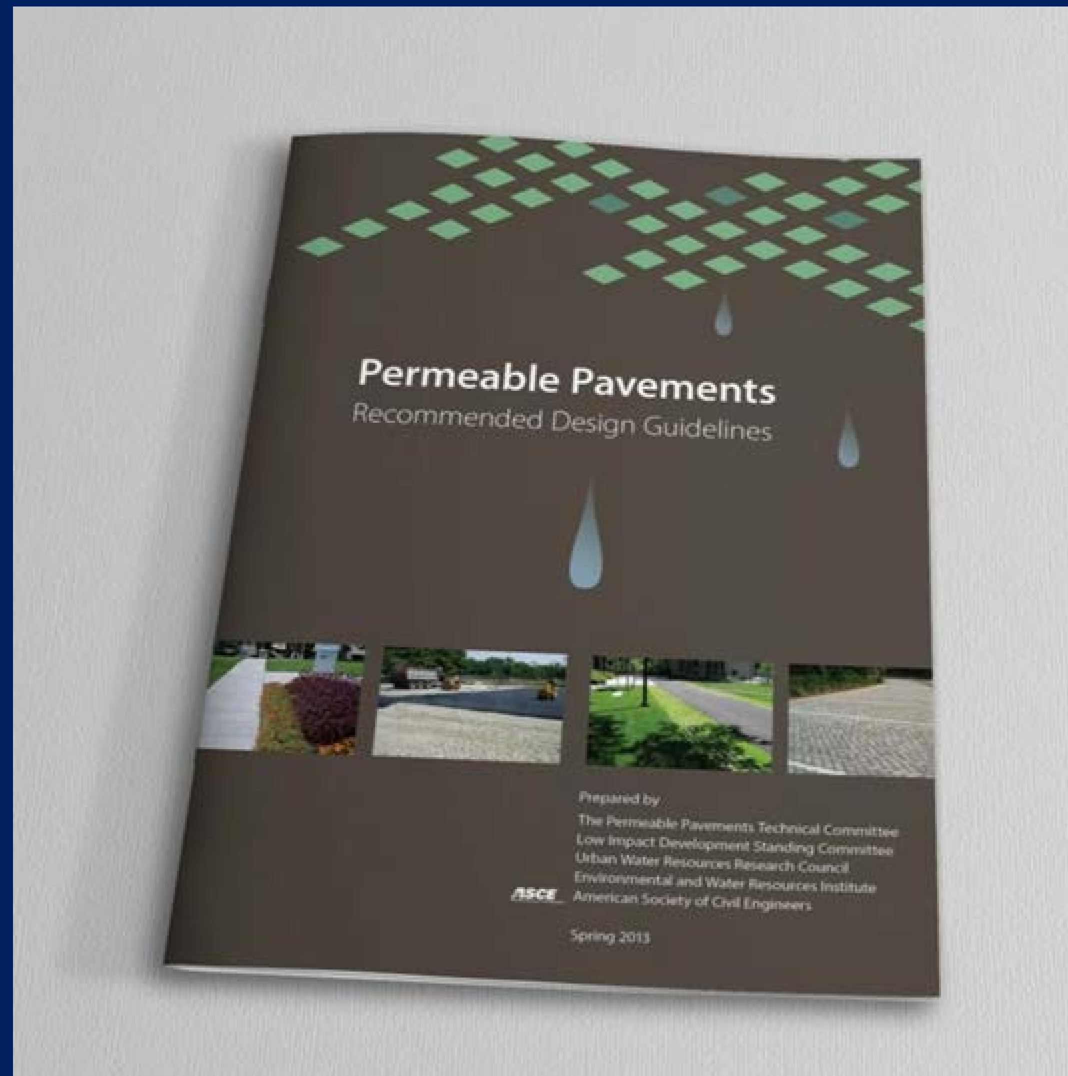
Must vacuum winter sand/sediment accumulation

Spring 2014: Permeable Pavements Recommended Design Guidelines

ASCE EWRI Committee Report – online only

- **Fact sheets**
- **Checklists**
- **Design information**
- **Maintenance**
- **Standards, guide specs & modeling methods**
- **Research needs**

Establishes common terms for all permeable pavements



Status of ASCE Standard Guideline

- Pre-Standard Committee 2012 (3 meetings)
- Standard Committee 2013 (2 meetings)
- Standard Committee 2014 (1 meeting, 2 more)
- Full standard developed, working some details
- Public comment fall 2014
- Publish date, early 2015