Porous Asphalt

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WISCONSIN ASPHALT PAVEMENT ASSOCIATION

Presentation Outline

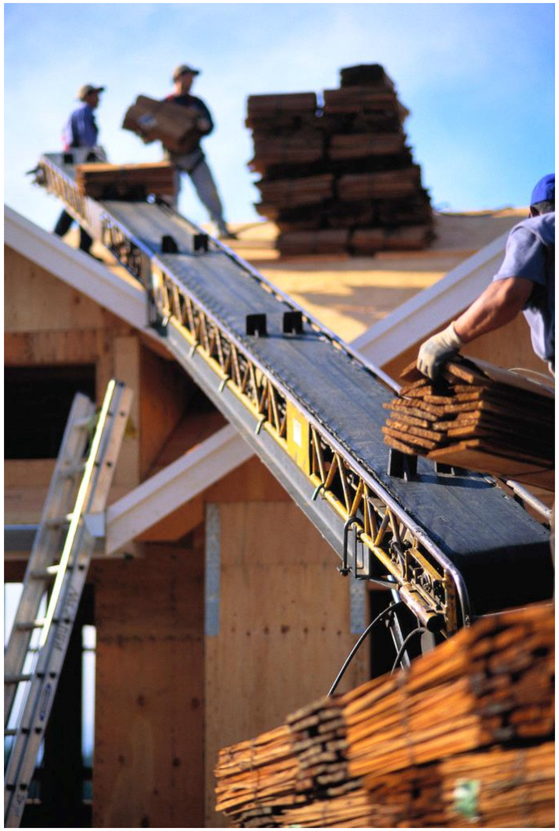
- Concept
- Applications
- Design
- Construction
- Operation
- Costs
- Examples

Porous Asphalt

- Concept

Porous Pavements are Unique

- Conventional pavement philosophy is to build a roof over the pavement
  - Keep the water out
  - Drain water to the edges
- Porous Pavements intentionally allow the water to drain through and be stored below



Porous Pavements are Unique

- **Porous Asphalt Pavement**
  - An open-graded asphalt surface over a stone recharge bed where stormwater is stored

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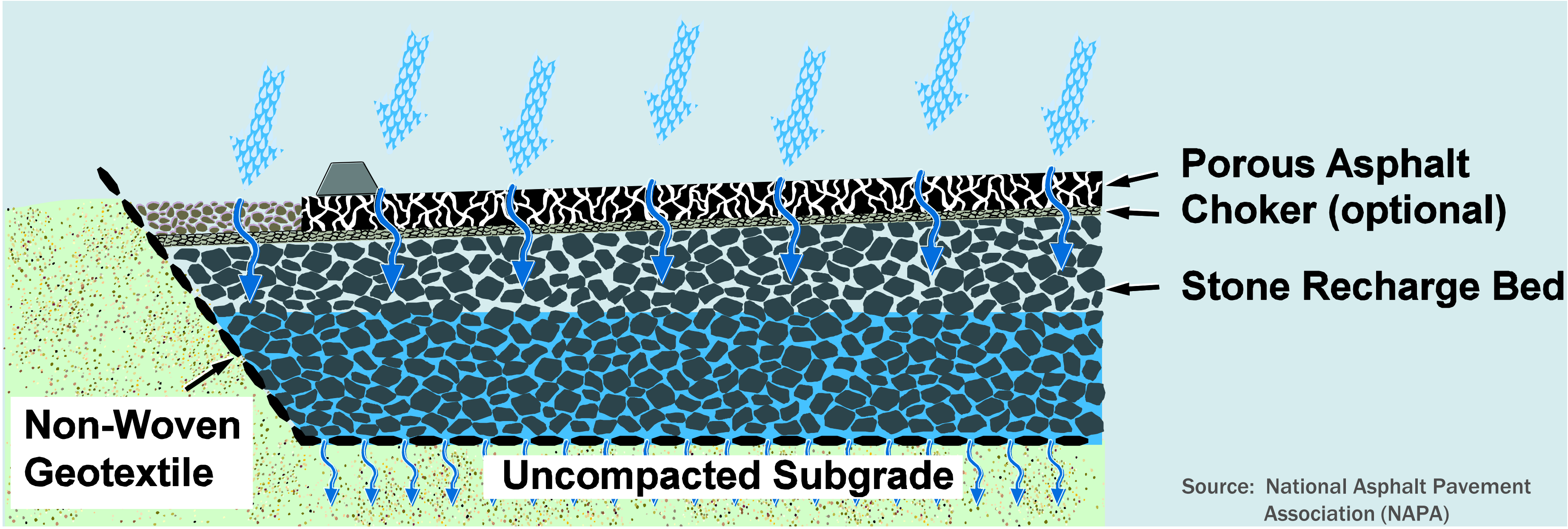
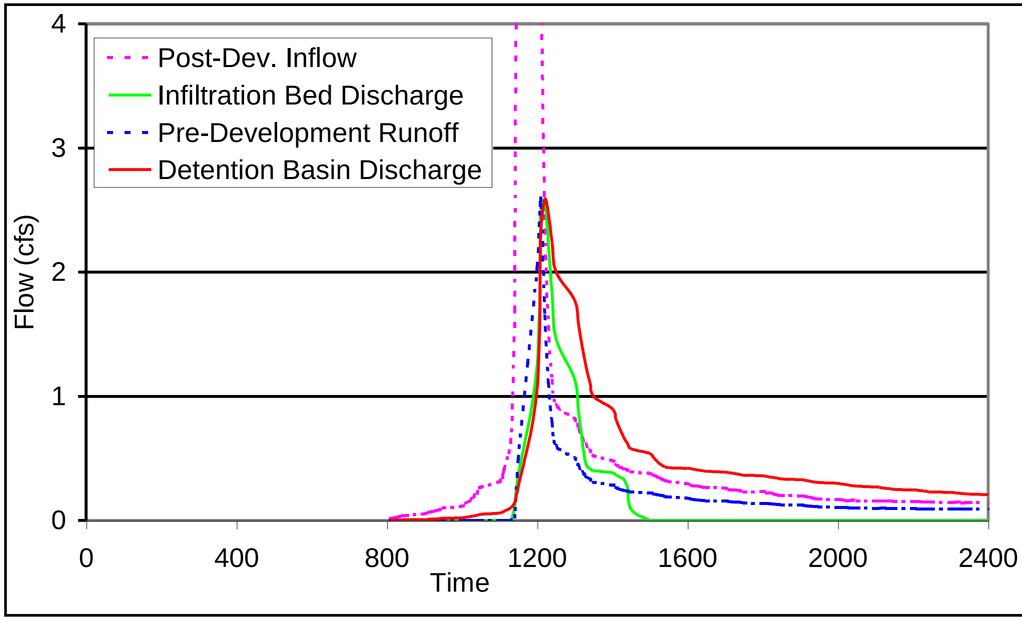
What are Porous Pavements?



Why are they needed?

- New stormwater regulations
  - Reduce volumes
  - Limit the impervious area
  - Stormwater tax
- Sustainability
- LEED Credit



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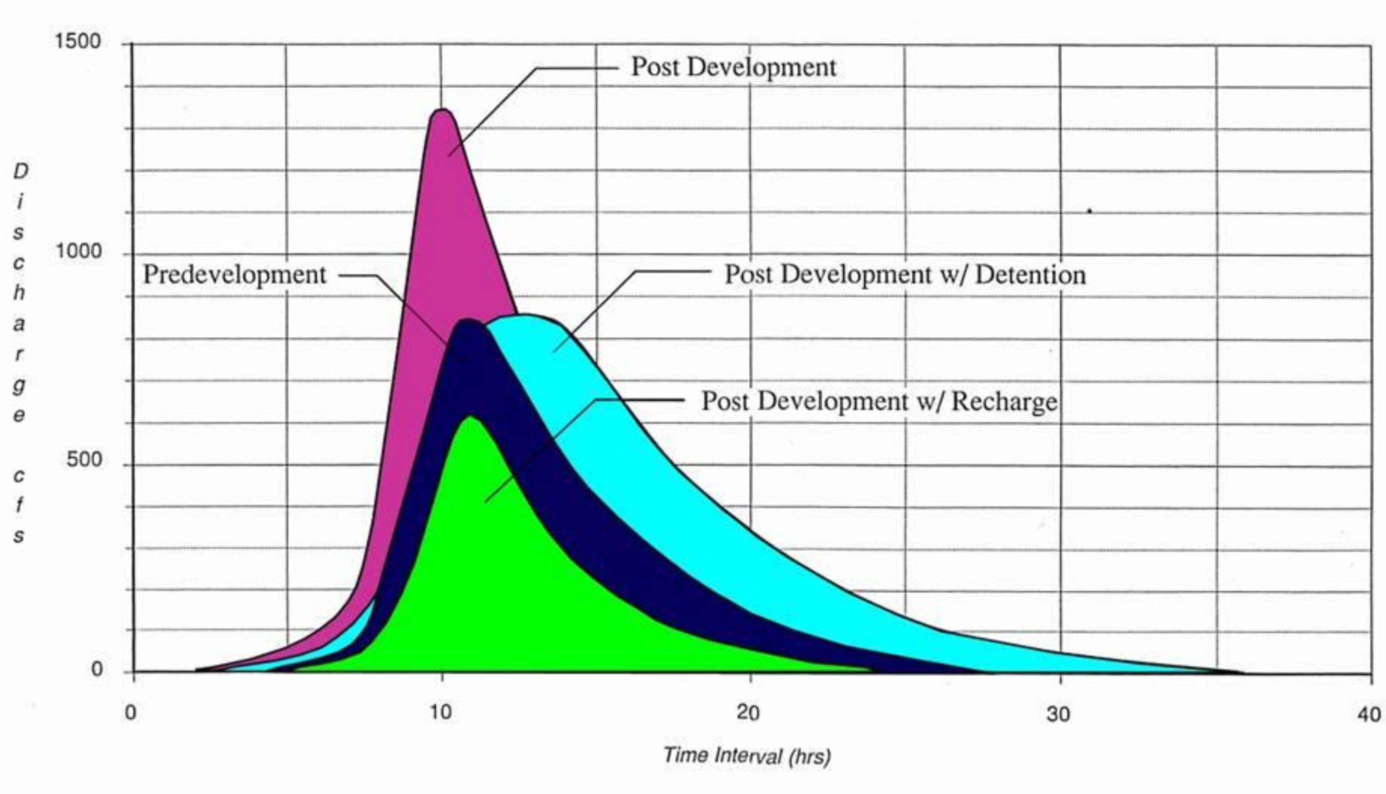
Stormwater Management

- Decreases runoff and increases infiltration



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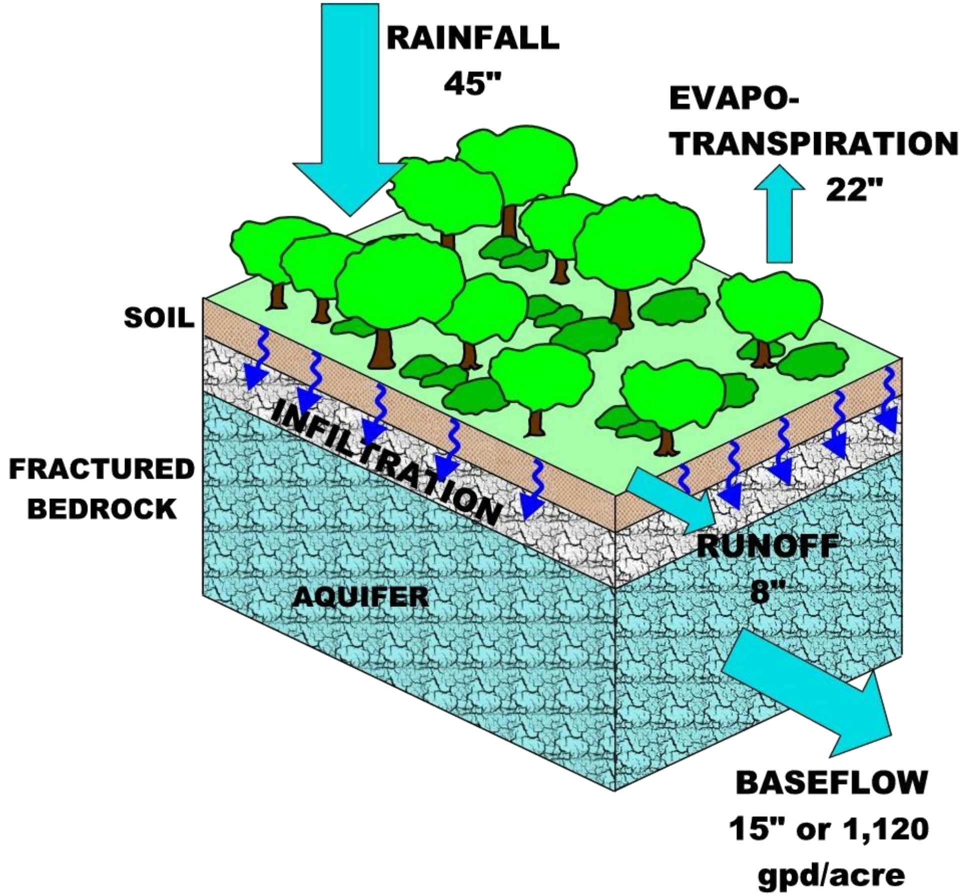
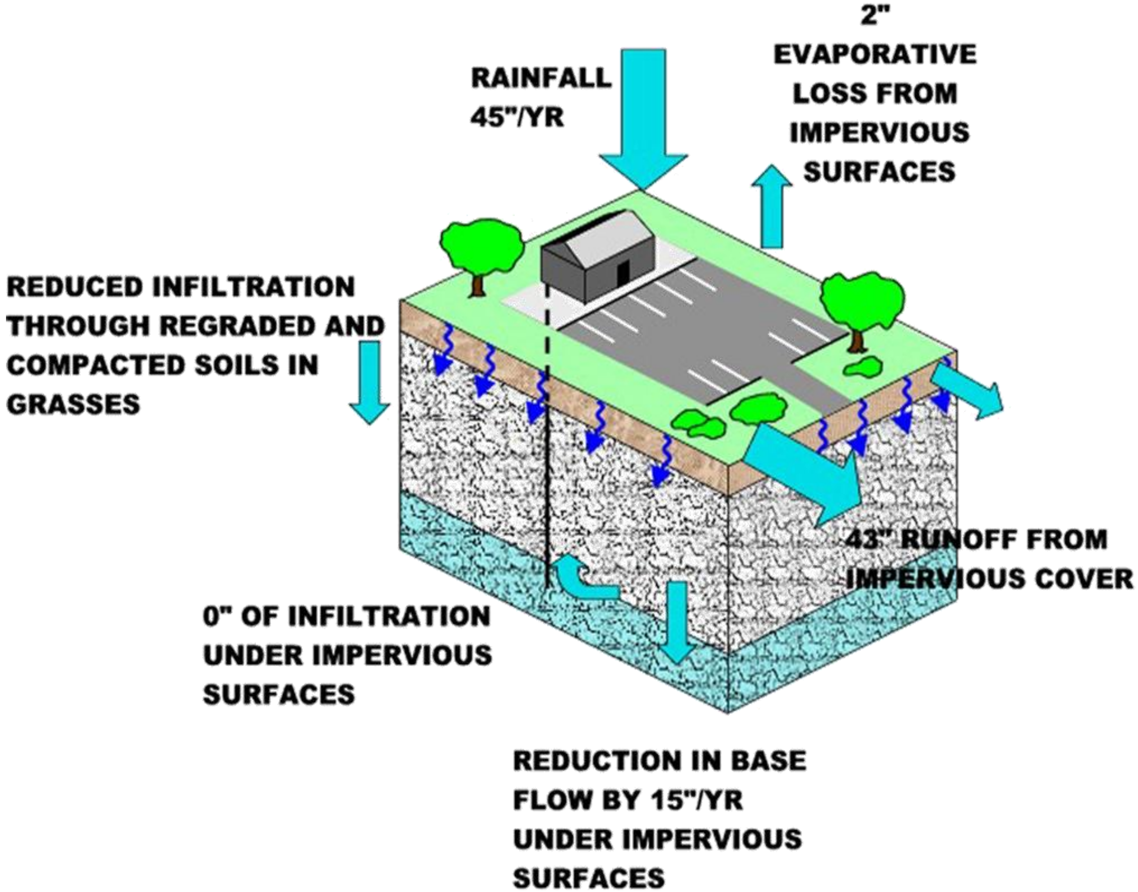
Undeveloped Site



After Development



Challenges

- More Development
  - More Impervious Area
  - More Runoff
- Detention Basins and Retention Ponds
- Flash Flooding
- Suspended solids and chemicals entering our streams

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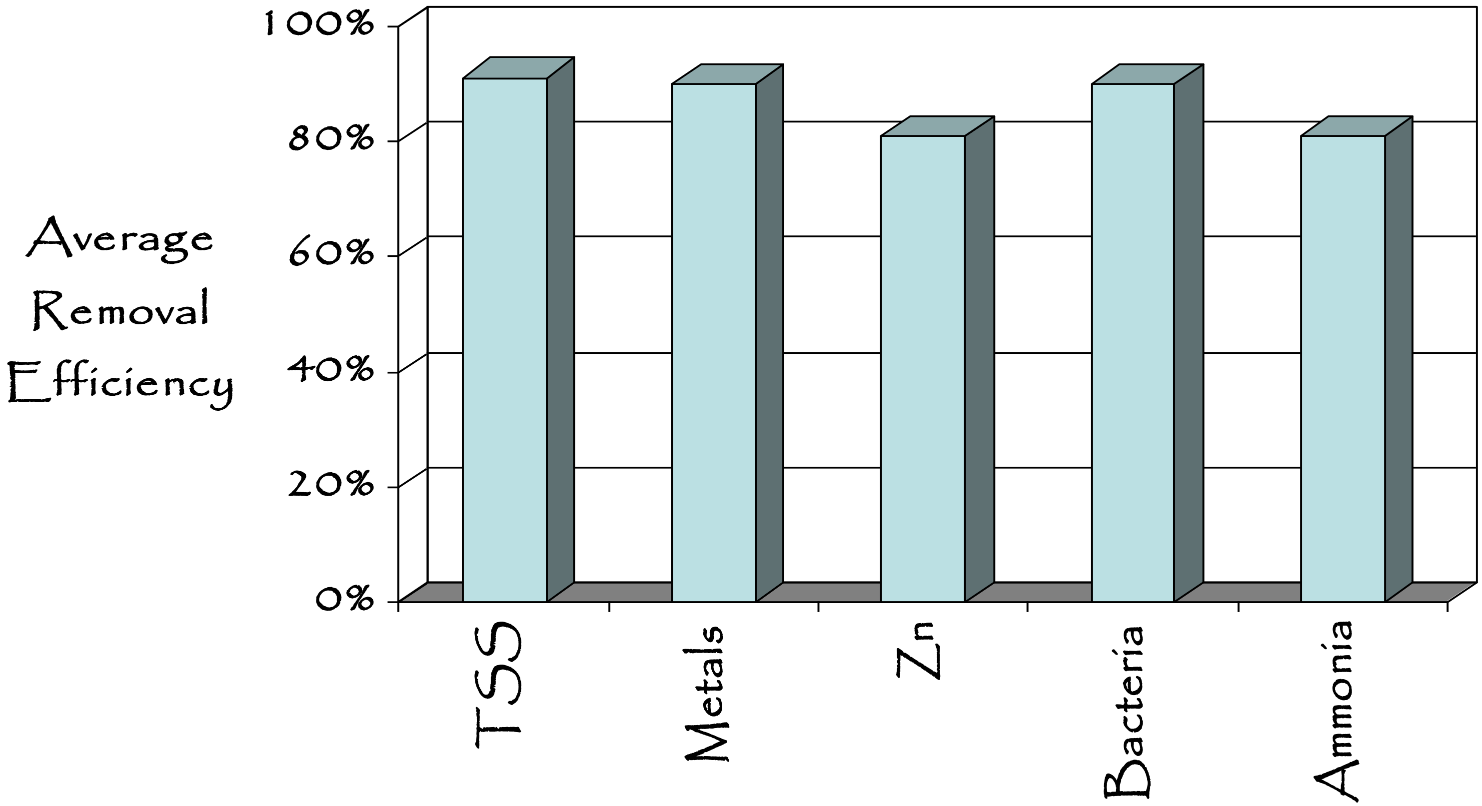
Water Quality Benefits



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Water Quality Benefits

Median Pollutant Removal (%) of Stormwater Treatment Practices

POLLUTANT	INFILTRATION PRACTICES	*Stormwater Wetlands*	*Stormwater Ponds Wet*	*Filtering Practices*	*Water Quality Swales*	*Stormwater Dry Ponds*
Total Phosphorus	70	49	51	59	34	19
Soluble Phosphorus	85	35	66	3	38	-6
Total Nitrogen	51	30	33	38	84	25
Nitrate	82	67	43	-14	31	4
Copper	N/A	40	57	49	51	26
Zinc	99	44	66	88	71	26
TSS	95	76	80	86	81	47

Water quality benefits of porous pavement with infiltration from "National Pollutant Removal Performance Database for Stormwater Treatment Practices" Center for Watershed Protection, June 2000

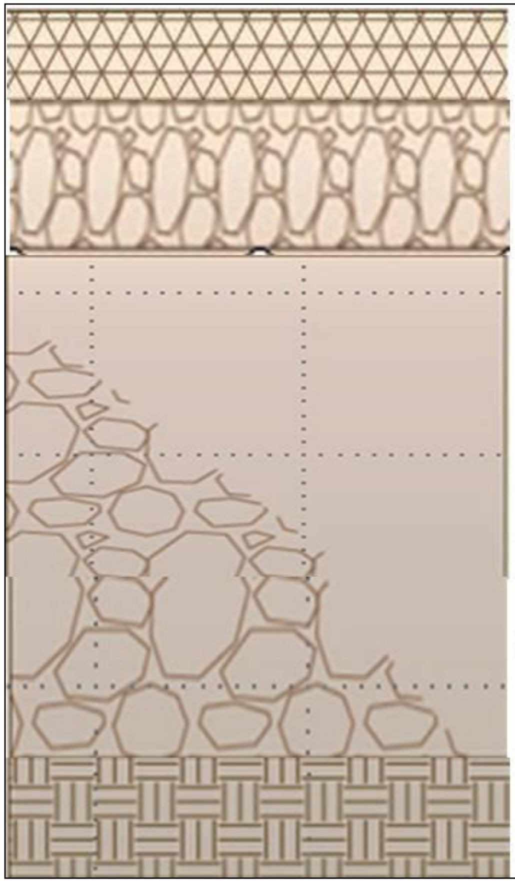
Porous Asphalt

- Applications

Parking Lots

Recreational Facilities

Streets and Roads



1.5" Porous Surface Course
Porous Asphalt Cement Concrete

3.0" ATPB Choker Course
1-2" Provides working surface for construction

10.0" Reservoir Course
Clean uniformly
Graded Crushed Aggregate
Approximately 40% voids

8.0" Pit Run Subbase
4" - 0 Clean

Uncompacted Subgrade
Uncompacted to retain permeability

Porous Asphalt Applications

Non-Desirable:

- Anywhere there's a significant risk of groundwater contamination
  - Truck stops
  - Heavy industrial areas
- Heavy traffic loading situations
- Where smooth surfaces are necessary
  - Roller blading/skating areas
  - Skateboard/Scooter parks

Porous Asphalt

- Design
  - Reservoir
  - Porous Asphalt
    - Thickness
    - Mixture
    - Ancillary Features

Drainable Pavement Structure

The Components:

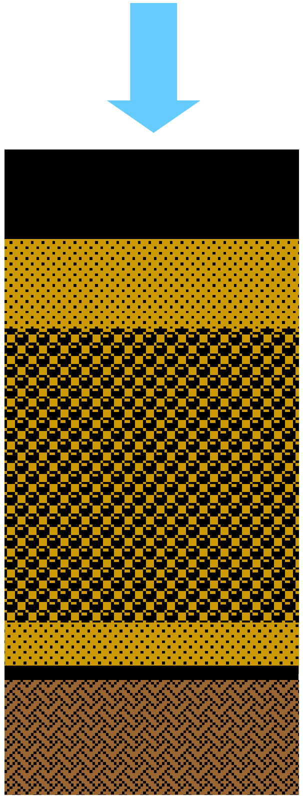
Porous Asphalt Pavement

Paving Platform Layer

Reservoir Layer

Filter Layer

Filter Fabric



Overall Design Concept

- To build a permeable structure that passes water vertically faster than it is supplied to the surface (which eliminates ponding), and has sufficient storage capacity to accommodate the water supplied through the pavement.

Design Methodology

System Functionality

- Site De-watering
- Reduction in impervious area while providing ground water recharge
- Reduction in impervious area & peak rainfall inflow to stormwater systems
- Combinations

Design Methodology

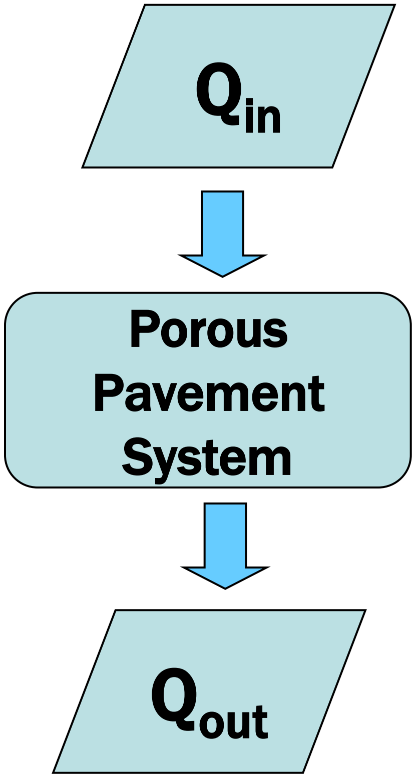
The Steps:

- Determine water inflow
- Determine soil capacities
- Determine structure type
- Determine structure layer thicknesses
- Determine optional drainage feature requirements

Design Methodology

Water Flow

- Calculate rainfall inflow
  - Design Storm event
  - Stormwater inflow calculation method
- Identify site requirements and capabilities
  - Test soil permeability
  - Environmental constraints
  - Land usage



Design Methodology

Soil Design Parameters

Soil Group	Infiltration Rate (in/hr)	Water Storage Capacity (inch of water)
Sand, open-structured	8.27	0.35
Loamy sand	2.41	0.31
Sandy Loam	1.02	0.25
Loam	0.52	0.19
Silty Loam	0.27	
Sandy clay loam	0.17	
Clay loam	0.09	
Silty clay loam	0.06	
Clay	0.02	

Infiltration rates less than 0.2 in/hr are not suitable for infiltration practices. Typically these soils have ~25% or more clay. Soils with a poor drainage capacity are also susceptible to frost heaving and swelling expansion which may cause possible structural instability.

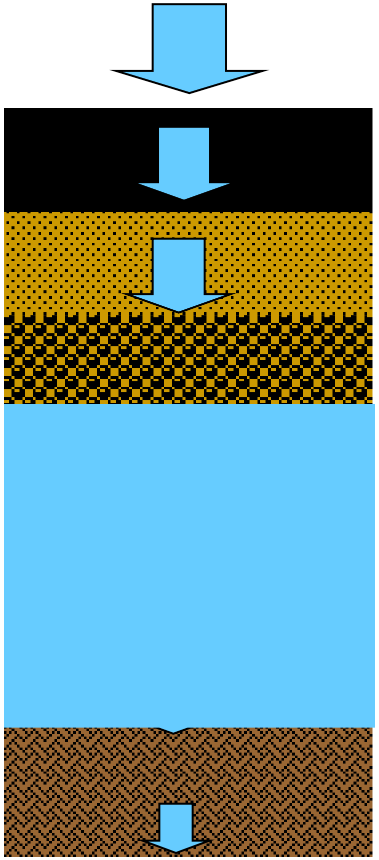
Design Methodology

Structure Type Selection

- If project site soils provide > 0.2 in/hr
  - Total Ground Water recharge is possible (no additional drainage features are needed)
- If project site soils provide < 0.2 in/hr
  - Additional drainage features are required to accommodate rainfall flow (storage tanks, ponds and/or piping systems)

Design Methodology

Pavement Structure Thickness

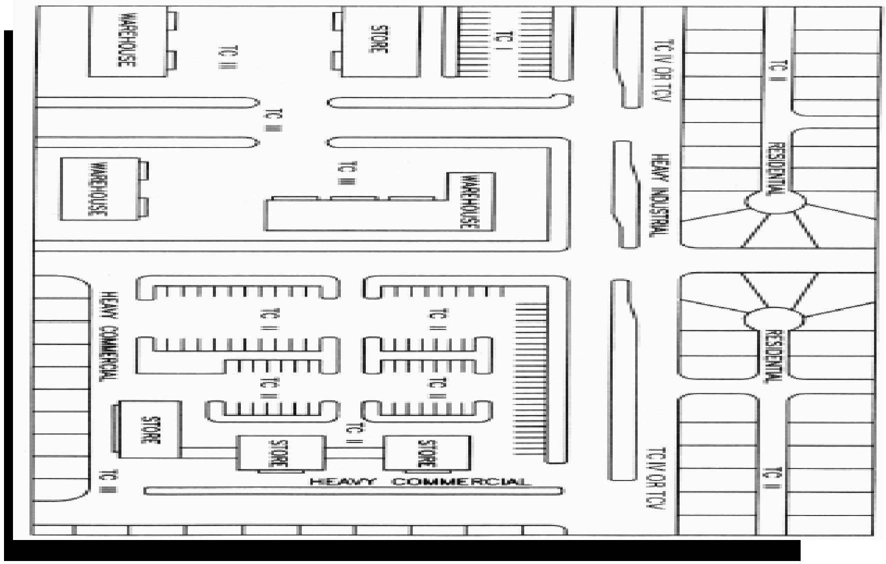


- Calculate drainage system layer thicknesses
  - HMA: structural capacity
  - Reservoir: system's functionality

Design Methodology

Asphalt Structure Thickness

- Recreational Facilities:
    - 3” HMA
- Parking Stall areas:
    - 4” HMA
- Access Roads:
    - 6” HMA (2 Lifts)



(Design based on the WAPA Design Guide)

Design Methodology

Reservoir Structure Thickness

- The type of soil dictates how much volume is needed to "hold" the water before it can leach back into the surrounding soils
  - Layer thickness ranges from 16" to 48"
  - The key is to properly design the structure by knowing the infiltration rates of the soils, the design storm event, and level of expectation

Design Methodology

Reservoir Structure Thickness

- Design Considerations:
  - Rainfall storm intensity, *i* (in/hr)
  - Soil permeability, *k* (in/hr)
  - Additional drainage feature outflow, *q* (in/hr)
  - Rainfall storm duration, *d* (hr)
  - Reservoir aggregate storage capacity (~40% air voids)
  - Frost expansion (~10% increase)

$$t = \frac{[(i - k - q)(d)(1.1)]}{(0.4)}$$

16" min

(Includes filter layers)

Design Methodology

Reservoir Structure Thickness

- The recommended air void content is 40%
  - To find it we ran tests on local 2” & 3” clear stone compacted/uncompacted

	Uncompacted	*Compacted*
2” Clear	50.8%	42.4%
3” Clear	52.3%	45.6%

Compacted level done in lab by rodding, not using compaction equipment

Design Methodology

Additional Considerations

- Average frost level for reservoir depth
  - Approximately 4 feet for this area
- Environmental restrictions
  - Remain 3' above water table
  - Remain 2' above bedrock

Mixture

WAPA Porous Asphalt Mix Design

Mix Properties	12.5 mm Mix	9.5 mm Mix	Test Standard	Footnote
Binder Content	5.5% min	5.5% min		1
Binder Grade	PG 64-22	PG 64-22		2
% Air Voids (V_a @ 50 gyrations)	18 - 20	18 - 20		
Tensile Strength Ratio (TSR @ 5 cycles freeze/thaw)	80% min	80% min	ASTM D4867	3
Draindown at Production Temperature	0.3% max	0.3% max		4

Aggregate Properties	12.5 mm Mix	9.5 mm Mix	Test Standard
LA Abrasion (% Loss)			AASHTO T 96
100 Revolutions	13 max	13 max	
500 Revolutions	45 max	45 max	
Soundness (% Loss) using sodium sulfate	12 max	12 max	AASHTO T 104
Freeze/Thaw (% Loss)	18 max	18 max	AASHTO T 103
Fractured Faces			ASTM D5821
2 Faces	90% min	90% min	
1 Face	100% min	100% min	
Thin or Elongated	5% max 5:1 ratio	5% max 5:1 ratio	ASTM D4791

Mixture Gradation

Sieve	12.5 mm Mix	9.5 mm Mix
3/4"	100	-
1/2"	85 - 100	100
3/8"	55 - 75	90 - 100
#4	10 - 25	30 - 40
#8	5 - 12	10 - 20
#16	-	5 - 15
#30	-	3 - 10
#200	1 - 4	1 - 4
VMA (%)	25 min	25 min

Footnotes

1. 5.75 - 6.0% Recommended
2. min. high temperature of 64 C Recommended
3. following National guidance, we are not including the Cantabro Abrasion test in the mix design guidelines
4. effective measures to reduce draindown include the use of washed manufactured sand in lieu of crusher screenings and fibers. Also a slight reduction in production temperature may also be considered

Unpaved Edges

Porous Asphalt

- Construction

Construction Guidelines

Pre-Construction

- Test materials
  - Measure air voids of reservoir course & compare to design.
- View other projects
  - View examples of existing projects to choose gradation of asphalt.

Construction Guidelines

Site Preparations

- Regulating area during development.
  - Compaction of soils is a large concern
  - Fence off/control traffic
- Construct near the end of the project.
  - Make detailed list of construction sequence
  - Accomplish as many items as possible prior to installation of porous system

Construction Guidelines

Site Preparations

- Final cut to finished grade.
  - It is OK to do rough grading earlier in project, but leave final cut of 6”+ for end of job.
- If equipment must be in affected areas, use tracked vehicles.
  - Do not take for granted, should be few reasons to have any traffic on final subgrade.
- Consider re-testing permeability of soil.
- Bedding area should be as level as possible.

Construction Guidelines

Construction Guidelines

System Placement

- Install Geotextile Non-Woven Fabric
  - Place immediately after excavation.
  - Overlap fabric rolls (1.5’ minimum).
  - Pin to eliminate movement.
  - Excess Fabric (4’ minimum) should be left on edges of area to prevent contamination (much like silt fence).

Construction Guidelines

Construction Guidelines

System Placement

- Place Protective Filter Layer
  - 2 to 3 inch depth of ½" clear stone.
  - Trucks are to dump from the edge and tracked equipment will place the material.
  - Used to protect fabric from larger aggregates.

- Place Reservoir Layer
  - Depth as needed using 1" – 3" clear stone.

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Construction Guidelines

System Placement

- Place Reservoir Layer
  - Place in minimum 8” lifts.
  - No trucks allowed to drive on insufficiently thick stone areas.
  - Test material for air voids.
  - Use a lightweight roller or plate compactor.
  - All equipment must be tracked in order to prevent subsurface compaction (except for finish grading operations)

Construction Guidelines

System Placement

- Place Paving Platform
  - 1 to 2 inch depth of 1/2” clear stone.
  - Installation identical to the filter layer.
  - Used to stabilize the larger aggregates and allow for the paving equipment to get on site.

Construction Guidelines

Construction Guidelines

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Construction Guidelines

Construction Guidelines

System Placement

- Place HMA Porous Pavement
  - Track paver.
  - Hand work.
  - One Layer.

Construction Guidelines

System Placement

- Place HMA Porous Pavement
  - Rolling techniques:
    - Let pavement cool to 200 F before rolling.
    - Use in static mode only 1-2 passes.
    - Roll just enough to “set” the mix.
    - Let cool further to 150 F, final roll 1-2 passes.

Construction Guidelines

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Construction Guidelines

System Placement

- HMA Porous Pavement
  - Keep traffic off for as long as possible (one week minimum).
  - If Striping with epoxy, plan to do it several months later, using cold paint in interim.

Construction Guidelines

Post Construction

- Protect from runoff of unstabilized areas.
  - Confirm vegetation is established before removing temporary storm water measures (filter fabric on edges).
- Inspect for design compliance during storm events.
- Signage for maintenance staff.

Porous Asphalt

- Operation

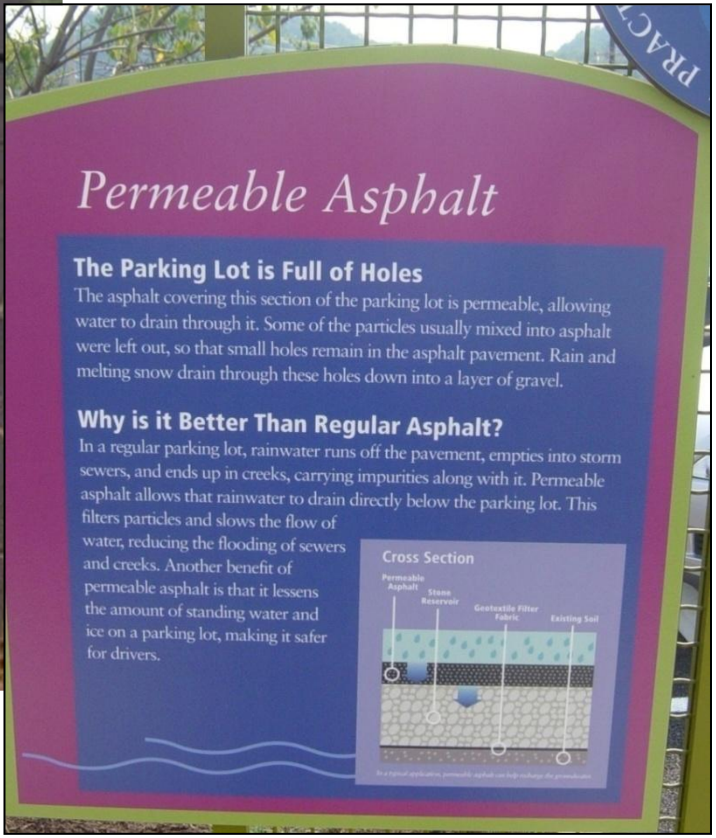
Maintenance Plan

- Inspect the pavement:
  - Once per quarter in year 1
  - Once a year for the pavement life
  - Check for ponding or clogging
- Pavement should be vacuum swept 2 – 4 times a year.
- Patching can be done with conventional HMA up to 10% of the surface area without affecting the pavement infiltration.

Maintenance Plan

- Use liquid de-icing if possible or very light salting, do not use sand.
- Make sure maintenance staff is aware of the "differences" regarding this pavement structure. Keep debris off surface.
  - This would include the selection of adjacent vegetation.
- Do not seal coat pavement or it will no longer be porous.

Educational Signs



Porous Asphalt

- Costs

Porous Asphalt Pavement Costs

- HMA Mix ~40% more than conventional
  - Porous Asphalt (FOB) ~$60/ton
  - WisDOT E-1 (FOB) ~$42/ton
    - Add ~$10/ton if using a polymer modified asphalt
- Reservoir Material ~50% more than CABC
  - Reservoir Base (installed) ~$15 – 18/ton
  - Standard CABC (installed) ~$10 – 12/ton
- Fabric (same as standard usage)
- Additional drainage features ??? (as needed)

Porous Asphalt Pavement Cost Savings

- Reduced usage of sewer fixtures
- Reduced usage of curb and gutters
- Reduced real estate usage
- Reduced environmental effects (fines)

Porous Asphalt

- Examples

Hart Park

Hart Park – 2006

- Environmental Constraints:
  - Soil permeability is wide ranging.
    - Unpredictable from design criteria.
  - 50% of the site is in a flood plane.
    - Backup and clogging of pavement structure hazard.
  - Adjoining facility is used by local senior citizens and there are several walking paths
    - walking hazards must be eliminated.
  - Site topography is not ideal.
    - Terracing was not going to be utilized.
  - Frost depth in area is approximately 2-3'.
    - Stone design will not exceed frost depth.

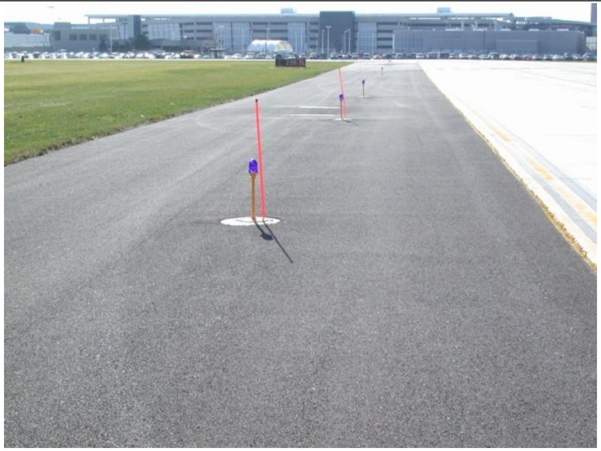
Hart Park – 2006

- 21" of Uniformly Graded 1" Base
- 2-3" paving platform layer
- 4" (one-lift) of 9.5mm porous asphalt
- Dense grade used for curb base (constructability).

Hart Park – 2006

- Redundant storm water system
  - Full storm sewer system
  - Attention to grading plan.
  - Backup system was to mill & overlay with standard asphalt.
  - Draintile system into storm water system at various locations for overflow from stone bed.

Mitchell International Airport



Mitchell International Airport

- Demonstration project July 2004
- Paved shoulder (25’X300’)
  - Fabric
  - 6” perforated underdrain
  - 6” open grade filter layer
  - 12” of ¾” clear stone reservoir
  - 6” of open grade paving platform
  - 6” 12.5mm porous asphalt pavement
    - 2 3” lifts

Mitchell International Airport

- Existing slope of 1.5-5.0%
- PG 64-22 at 4.0% ac
- Air voids of 17%
- Very tight clays with little infiltration (hence the perforated piping)

MSOE

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MSOE

MSOE

MSOE

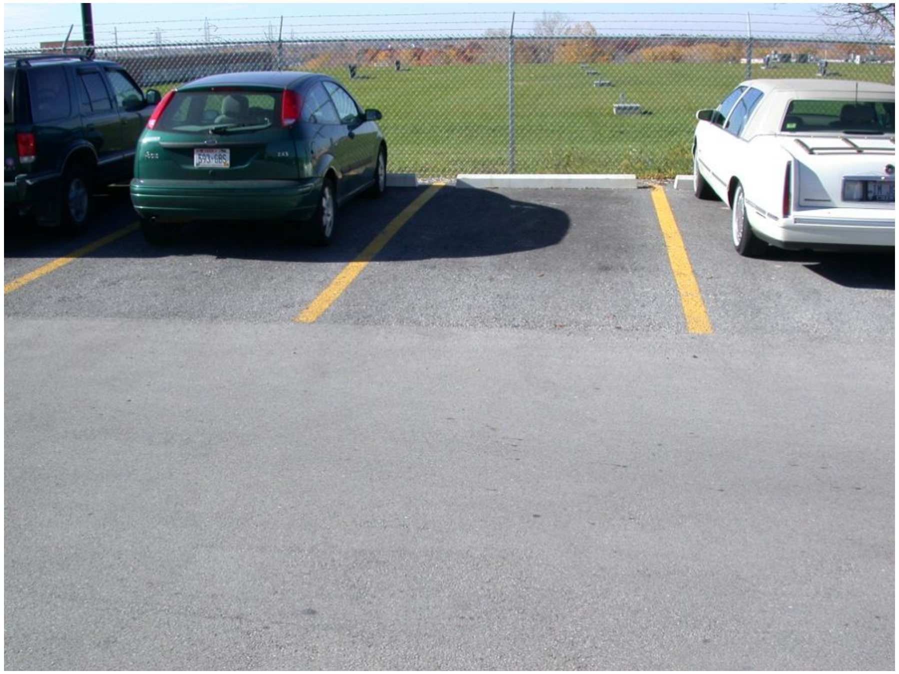
- Constructed August 2005
- 2/3 of job is porous asphalt with 1/3 porous concrete
  - Fabric
  - 12” of 3” clear stone reservoir layer
  - 6” of 2” clear stone reservoir layer
  - 2” of 1½” TB paving platform
  - 4” Porous HMA asphalt

MSOE

- Existing slope of 4-6%
- PG 64-22
- Very good soil, practically beach sand

Robert Anderson Municipal Building

Robert Anderson Municipal Building



Performance

Hart Park Porous Parking Lot (City of Wauwatosa)

Age: ~5 years old
Mixture Gradation: 9.5 mm

Porous Asphalt Pavement Photos:

Wauwatosa Fire Station Parking Lot (April 13, 2011)

Performance

MSOE Porous Pavement Parking Lot (City of Milwaukee)

Age: ~6 years old
Mixture Gradation: 9.5 mm

Covenant Hill Housing (City of Milwaukee)

Age: ~5 years old
Mixture Gradation: 12.5 mm

Middleton Lexus Dealership

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Sauk Trail School

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Performance