

Designing and Specifying Pervious Concrete



What is Pervious Concrete?

A No-Fines Concrete Mix
Coarse Aggregate
Portland Cement
Water

Intended for use as an
open-graded drainage
material



Pervious Concrete Properties

15% to 35% air void content

Field studies show 18-25% average

100 to 125 lbs/ft³ unit weight

2000 to 3000 psi strength*

compressive strength typically not used as acceptance criteria.

Air void structure and unit weight are used instead.

Pervious Concrete Properties

Drainage rate

3-5 gal/min/ft²

Equivalent of 275" to 450"
of rain per hour!

*More than half of all
annual rainfall is provided
in rain events that total
one inch or less.*

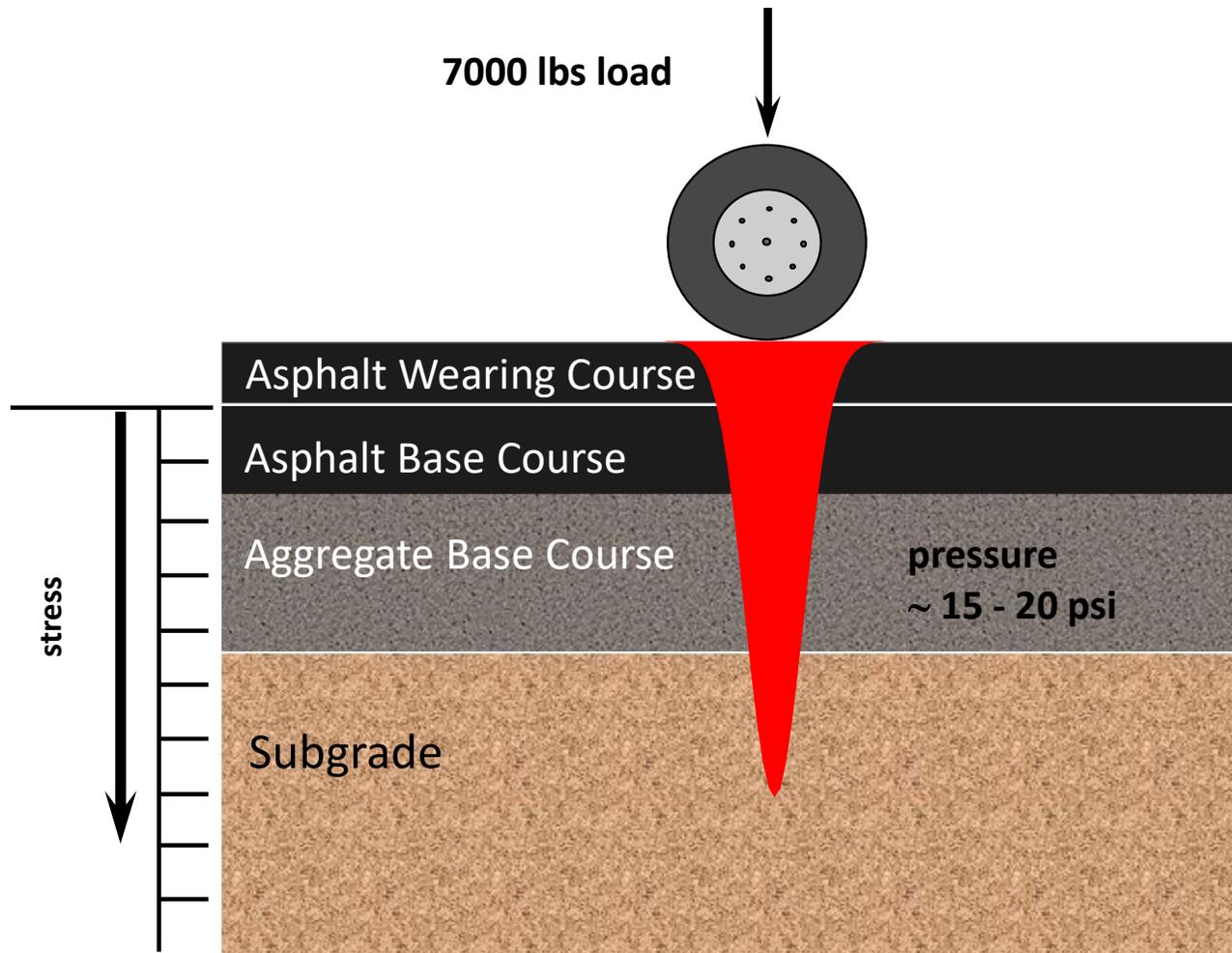


Pervious Concrete Design Guidelines

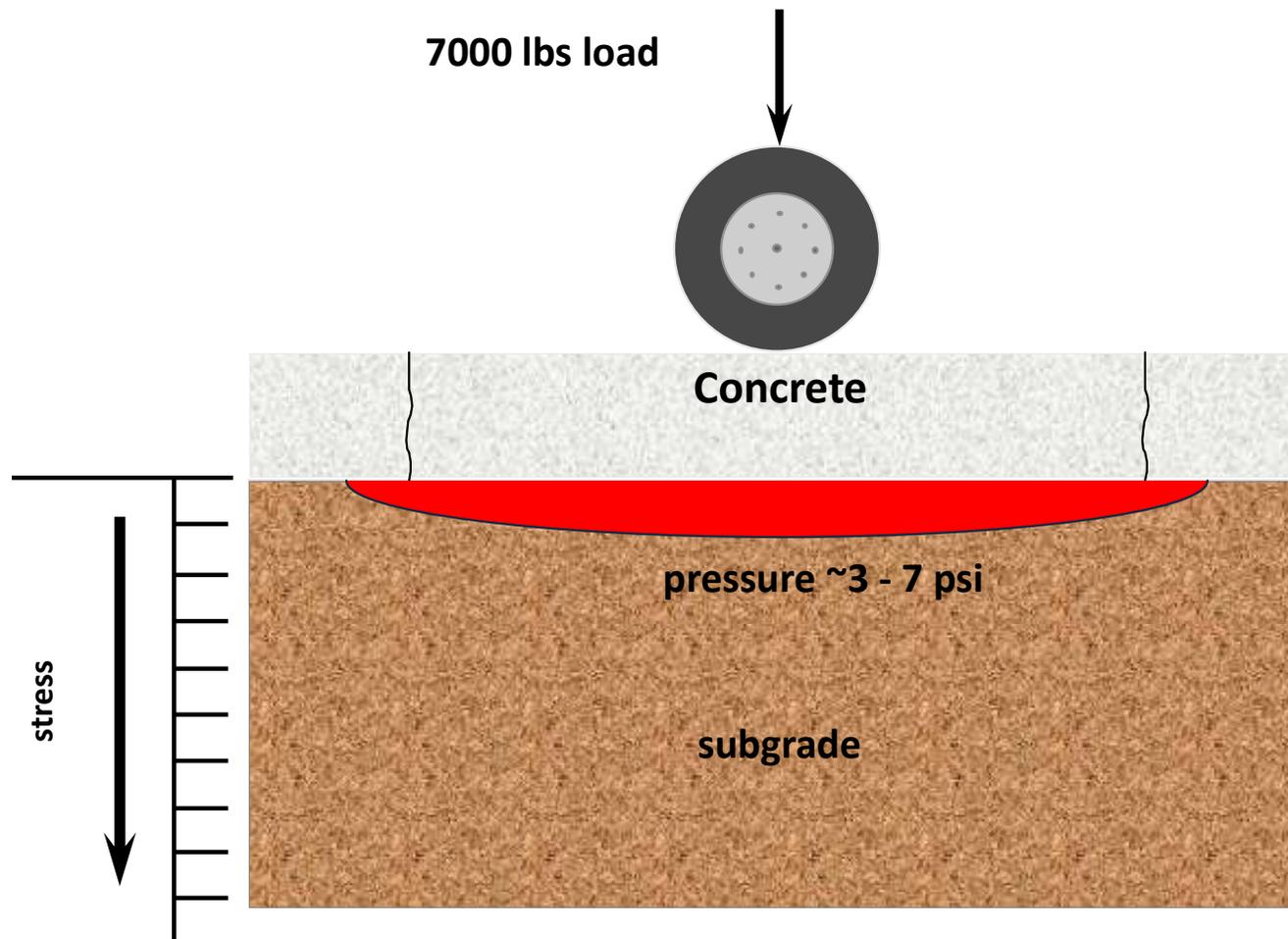
Structural Design



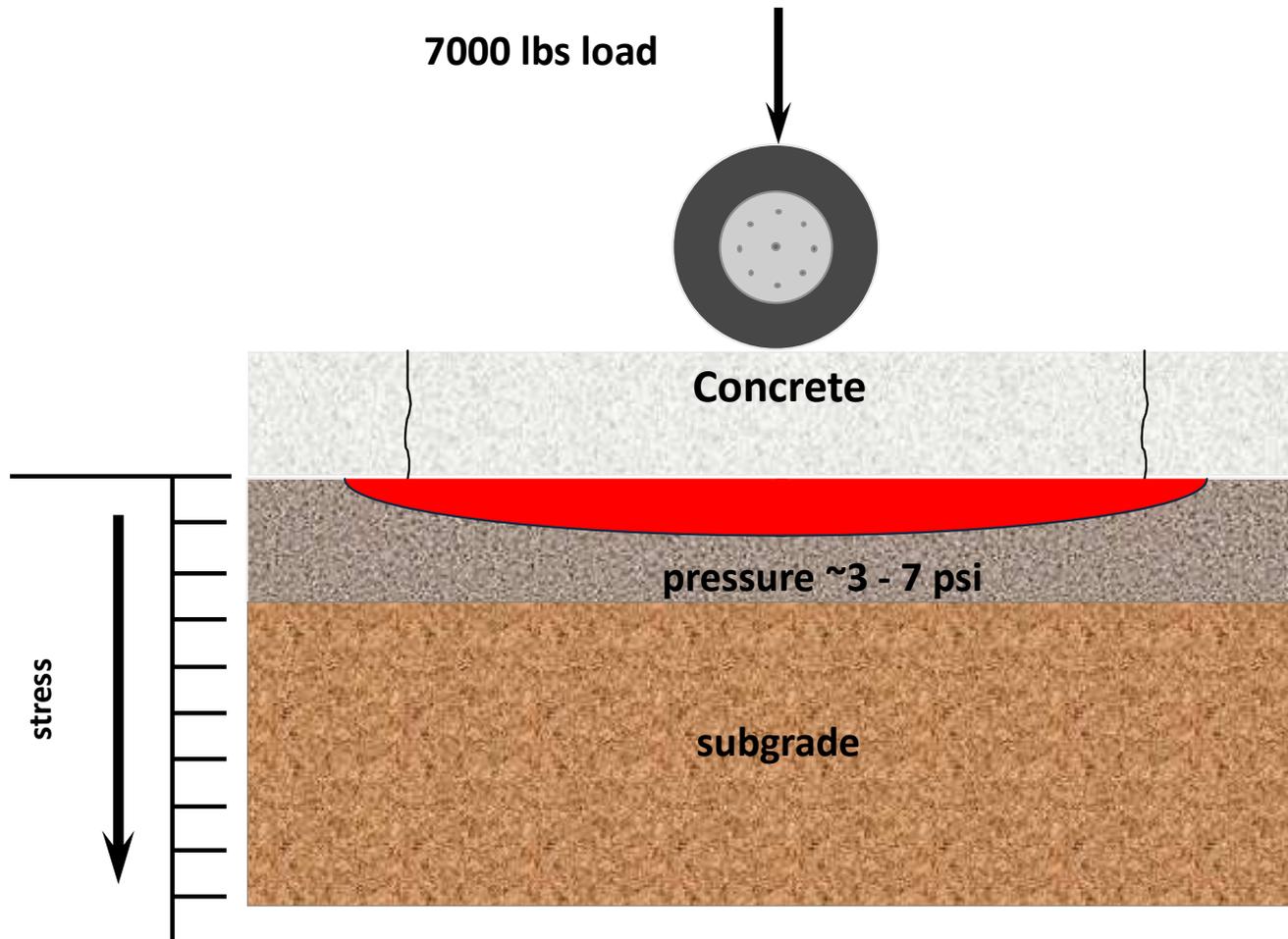
Load-Carrying Structure for Flexible Pavement



Load-Carrying Structure for Rigid Pavement



Load-Carrying Structure for Rigid Pavement



Strength vs. Thickness

Section strength – proportionate to:

Material Strength

Square of the thickness

For a stronger pavement,

Use a stronger concrete

Use a little more concrete

If the concrete has to be weaker (e.g., pervious),
you can make the section stronger by making it thicker

Structural Design – Example

- Design Life = 30 years
- Average Daily Traffic
 - 200 vehicles/day
 - 1% trucks
- Compare f'_c
 - 4000 psi
 - 2000 psi
- Assume 6" gravel base
 - CBR = 2

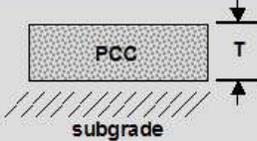
StreetPave

File Global Settings About

Project Traffic Pavement Properties Existing Pavement Analysis **New Pavement Analysis** Life Cycle Cost

Previous Step 6. Analysis results and additional reports are now available.

CONCRETE PAVEMENT



PCC
T
subgrade

Run Analysis

$f'c = 4000$ psi
ADT = 200
1% Trucks

Composite Modulus of Subgrade Reaction (k) = 161 pci Resilient Modulus of the Subgrade:

MRSG [user-entered] = 3120 psi
MRSG [design] = 1891.2 psi

Base =
Flexible ESALs =

Design Concrete Thickness = 4.62 in. Design Asphalt Thickness = in.

Concrete Recommendations:

Concrete Thickness = 5.00 in.

Maximum Transverse Joint Spacing = 10 ft.

Dowel Bars: Dowel bars not chosen and not recommended.

Fatigue/Erosion Table
Rounding Considerations

View and Print Reports

Design and Analysis Summary

Sensitivity Analysis of:

k-value Reliability
 Concrete Strength % Slabs Cracked
 Design Life View

Progress Bar

Fatigue/Erosion Table
Rounding Considerations

start Inbox - Microsoft Out... Microsoft PowerPoint StreetPave 12:19 PM

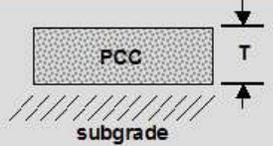
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CONCRETE PAVEMENT



Run Analysis

f'c = 2000 psi
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Composite Modulus of Subgrade Reaction (k) = 161 pci

Resilient Modulus of the Subgrade:
MRSG [user-entered] = 3120 psi
MRSG [design] = 1891.2 psi

Base =
Flexible ESALs =

Design Concrete Thickness = 5.98 in. Design Asphalt Thickness = in.

Concrete Recommendations

Concrete Thickness = 6.00 in.

Maximum Transverse Joint Spacing = 12 ft.

Dowel Bars: Dowel bars not chosen and not recommended.

Fatigue/Erosion Table Rounding Considerations

View and Print Reports

Design and Analysis Summary

Sensitivity Analysis of:

- k-value
- Reliability
- Concrete Strength
- % Slabs Cracked
- Design Life

View

Progress Bar

Structural Design – Experience

4" Sidewalks/Pathways

6" Parking Lots

6" Residential Driveways

8" Residential Streets

8" Commercial Parking Lots

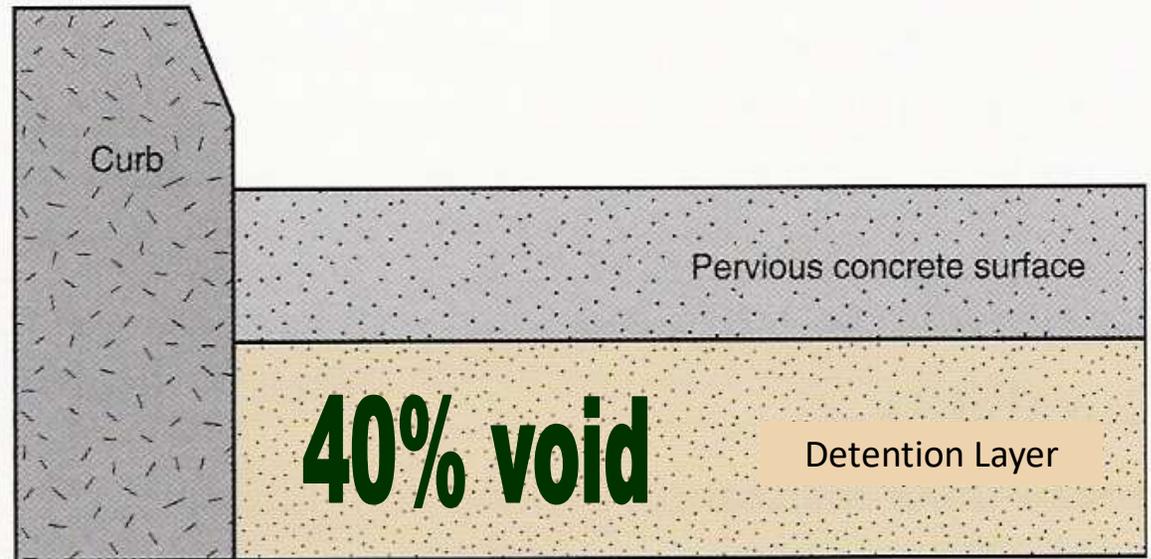
Pervious Concrete Design Guidelines

Hydrologic Design



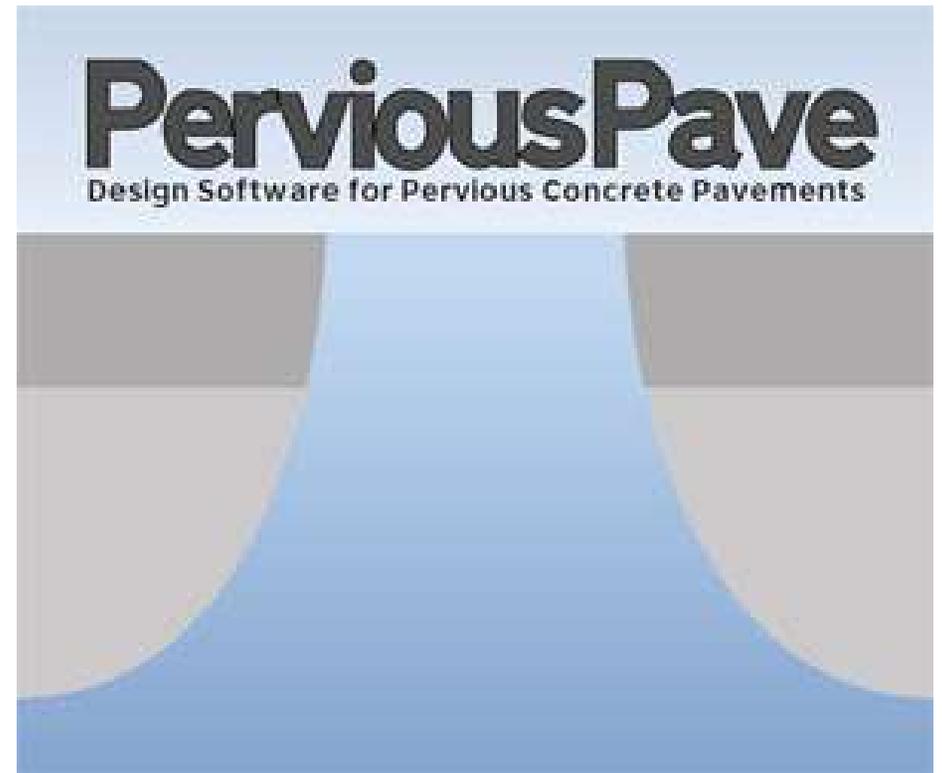
Open-graded stone subbase

- Determined by local hydrologic conditions
 - Filter Bed
 - Storage Bed
 - Detention Layer



ACPA PerviousPave Design Software

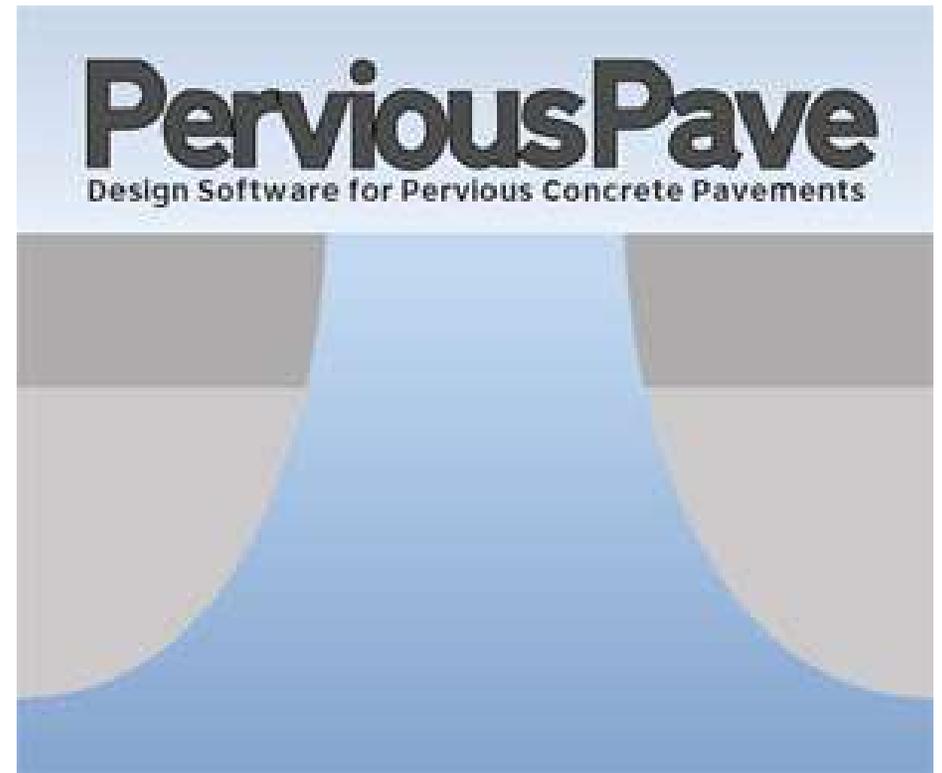
- Structural and Hydrologic design



www.acpa.org/perviouspave/

Hydrologic Design

- User inputs
 - Pervious pavement thickness
 - Pervious surface area
 - Detention layer thickness
 - Soil exfiltration rate
 - Stormwater volume
 - Desired (allowed) runoff



KNOW YOUR LIMITATION



Applications for Pervious Concrete

GOOD

- Parking Lots
- Driveways
- Residential Streets
- Roadway Base

AVOID

- Truck Areas*
- Industrial Facilities*
- Airports
- Gas Stations
- Areas with high water table
- Areas needing frequent maintenance



Pervious Concrete Design Guidelines Specification



Mix Design – The Old Way

- 550-650 lbs. Portland Cement
- 27 ft³ Coarse Aggregate
- 0.25 – 0.30 W/C Ratio
- Admixtures
 - High Range Water Reducer
 - Viscosity Modifier
 - Hydration Stabilizer



Mix Design – What We've Learned

- Typically 450-500 lbs. Cementitious
 - Maximum 550 lbs.
- 27 ft³ Coarse Aggregate
 - Aggregate size will affect drainage rate
- 0.34 – 0.41 W/C Ratio
 - Sufficient water to display a wet, metallic sheen on the aggregate
- Admixtures



ACI 522.1-20

Performance specification
Provides Guidelines for
Quality Assurance
Materials
Acceptance Testing
Placement
Does not provide recipe for
pervious concrete mix design

An ACI Standard

Specification for Pervious
Concrete Pavement

Reported by ACI Committee 522

ACI 522.1 - 20



American Concrete Institute
Always advancing

Specification Recommendations

- Fresh density of pervious concrete shall be within 5 lbs. (+/-) of the fresh density of the specified fresh density (approved mix design)

Specification Recommendations

*Target void content of 15% to 25% as measured by ASTM C1688**

****Suggested text - Not taken from ACI 522.1-20***

Section 1.6: Quality Assurance

1.6.1.1 *Contractor Qualification*

NRMCA Pervious Concrete
Contractor Certification Program

- One Certified Craftsman
- Three Certified Installers



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Section 1.6; Quality Control

1.6.2.2 Test panels - Place two test panels on the project site, on a subgrade and subbase prepared as specified, using the material and construction requirements for pavement in this Specification. Each panel must have an area of at least 225 ft², and a width and thickness as specified for the pavement in the Contract Documents.

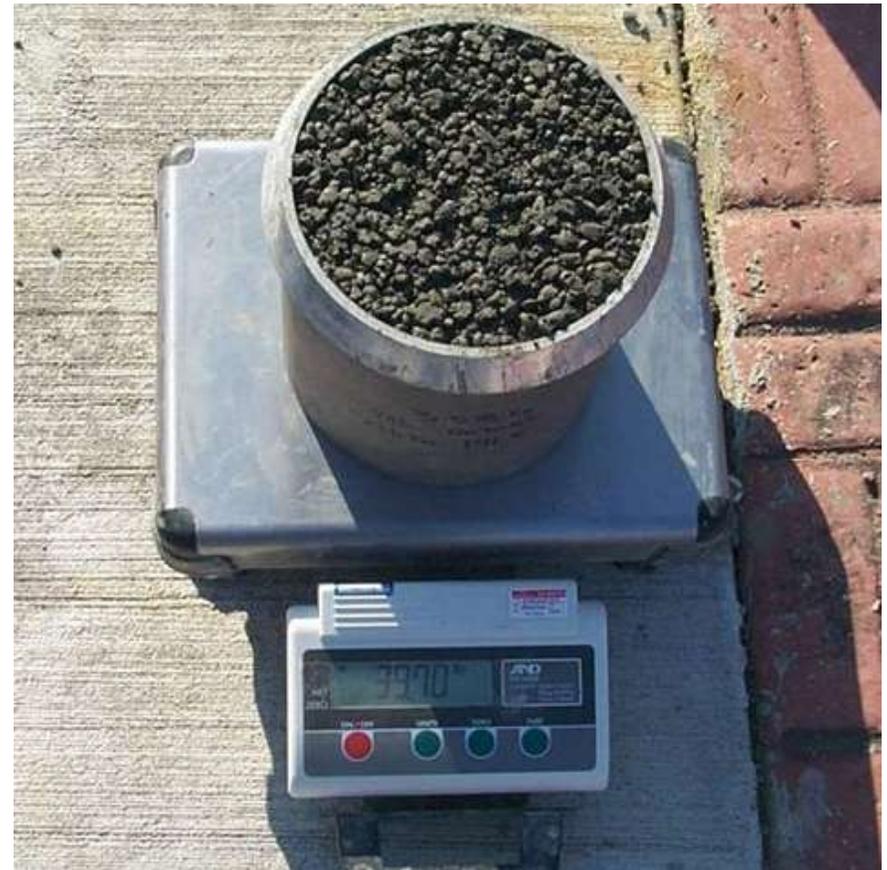
Pervious Concrete Acceptance Testing



ASTM Test Procedures

- Fresh Concrete Density and Voids Content
 - ASTM C1688-12: Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete
- Field Permeability (Infiltration Rate)
 - ASTM C1701-09: Standard Test Method for Infiltration Rate of In-Place Pervious Concrete
- Hardened Concrete Density and Porosity
 - ASTM C1754-12: Density and Void Content of Hardened Pervious Concrete
- Surface Durability (Impact and Abrasion)
 - ASTM C1747-11: Determining Potential Resistance to Degradation of Pervious Concrete by Impact and Abrasion

ASTM C1688-12:
Standard Test
Method for Density
& Void Content of
Freshly Mixed
Pervious Concrete



ASTM C1701-09:
Standard Test
Method for Infiltration
Rate of In-Place
Pervious Concrete



Pervious Concrete Cores

ASTM C42

ASTM C174

Measure thickness

Compressive strength test
not recommended
for acceptance

Dry Density/Void

ASTM C140 replaced by
ASTM C1754



The Importance of Maintenance



Freeze-Thaw Resistance

- Depends on saturation level
- Avoid critical saturation
 - Design
 - Infiltration System
 - Secret of success is to provide the water a place to go
 - Maintenance
 - Cleaning, as needed, in severe climates

Frequency of Cleaning

- Depends on amount of sediment
- Inspect pavement regularly
- Drainage during a storm event
- Trash, leaves or paper, may degrade into small particles and migrate into the voids

Even if 100%
clogged with dirt,
pervious concrete
will still be
permeable

Cleaning can
restore 90+% of
original
permeability



Routine Maintenance

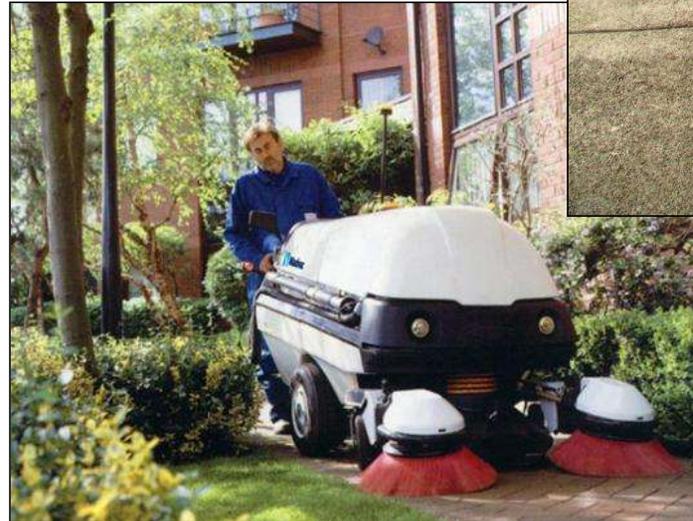
- Visual Inspection
- Leaf blowing or vacuuming
- Can reduce infiltration of materials into pavement



Periodic Maintenance

Water flushing
removes debris

Dislodged sediment
vacuumed



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Vacuum Sweeping

Regenerative vacuum/sweeper is preferred

Conventional pavement sweeper/vacuum equipment can also be used



Deep Cleaning/ Unclogging

For severely clogged pavement, pressure washer/vacuum may be necessary.



Deicing Chemicals

- Use sparingly
- Never on concrete less than one year old
- Calcium Chloride impregnated sand after first year
- Never ammonium sulfate or ammonium nitrate



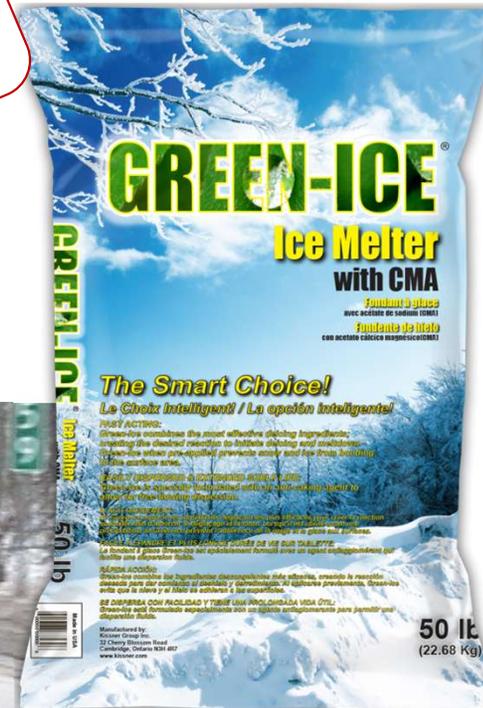
Coarse Sand

- Larger than a No. 8 sieve
- Broadcast on pervious pavement
- Thoroughly clean surface by vacuuming after winter season
- Maintain the system permeability

Deicing Chemicals

Magnesium Chloride
Calcium Chloride
Potassium Acetate

NEVER!



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“An ounce of prevention is worth a pound of cure.”



Develop Maintenance Plan

- Establish baseline infiltration rate
- Identify procedure and frequency
- Transfer with change in ownership





Pervious Concrete Pavement Maintenance and Operations Guide

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ACTIVITY	SCHEDULE
Avoid sealing or repaving with impervious materials. In particular, never use asphalt or other tar-type sealers on pervious concrete.	N/A
Visually inspect pervious pavement area to ensure that it: <ul style="list-style-type: none"> • is clean of debris • de-waters between storms • is clean of sediments 	Monthly
<ul style="list-style-type: none"> • Maintain upland and adjacent grassy areas. • Seed upland and adjacent bare areas. • Keep the pervious pavement surface free of sediment by blowing, sweeping or vacuuming. • Excessive water flow carrying debris toward the pavement should be diverted. 	As needed
Inspect the pervious pavement surface for deterioration or spalling.	Annually

Pervious Concrete Maintenance Log

Site Name and Location: _____

Initial ASTM C 1701 Test Results: _____ Inches / Hour

Date of Inspection	Observations/ Pavement Condition	ASTM C1701 Performed?	ASTM C 1701 Results	Type of Maintenance Performed	Type and Amount of Debris/Sediment Removed	Maintenance Performed By:	Name/Signature of Inspector
		Yes <input type="checkbox"/> No <input type="checkbox"/>	Before Maintenance <input type="text"/> IN/HR After Maintenance <input type="text"/> IN/HR				
		Yes <input type="checkbox"/> No <input type="checkbox"/>	Before Maintenance <input type="text"/> IN/HR After Maintenance <input type="text"/> IN/HR				
		Yes <input type="checkbox"/> No <input type="checkbox"/>	Before Maintenance <input type="text"/> IN/HR After Maintenance <input type="text"/> IN/HR				
		Yes <input type="checkbox"/> No <input type="checkbox"/>	Before Maintenance <input type="text"/> IN/HR After Maintenance <input type="text"/> IN/HR				

Resources



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A photograph of construction workers in safety gear (hard hats, high-visibility vests, and boots) working on a concrete slab. They are using long-handled tools to guide the pouring and leveling of concrete. In the background, a concrete mixer truck is visible. The scene is outdoors with trees in the distance.

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Pervious in Practice

- Guide to Specifying Pervious Concrete
- Importance of Using Certified Pervious Concrete Contractors
- Acceptance Testing of Pervious Concrete
- Guide to Pervious Concrete Mix Design



PIP 1 – Guide to Specifying Pervious Concrete

Background

Recommendations and specifications for pervious concrete pavement are published by the American Concrete Institute (ACI) Committee 522. *ACI 522R-10: Report on Pervious Concrete* provides technical information on pervious concrete's application, design methods, materials, properties, mixture proportioning, construction methods, testing and inspection. *ACI 522.1-13: Specification for Pervious Concrete Pavement* covers materials, preparation, forming, placing, finishing, jointing, curing and quality control of pervious concrete pavement. Provisions governing testing, evaluation and acceptance of pervious concrete pavement are included. Besides these documents, a specifier of pervious concrete should pay attention to general concepts and details.

Compressive Strength

Compressive strength is commonly used for acceptance of conventional concrete. It should be recognized that application and characteristics of pervious concrete are different from those of conventional concrete. An important fact is that the main property of pervious concrete—its permeability—is inversely proportional to strength. There are no standardized procedures to make and test strength specimens of pervious concrete. The methods for conventional concrete do not apply. It is, therefore, inappropriate to specify compressive strength requirements for pervious concrete or to use such tests as a basis of acceptance.

Void Content and Density

Considering the primary function of pervious concrete pavements, the important property that should be specified is a target range for void content (such as 15% to 25%). This property is derived from the measured density in accordance with ASTM C 1688: *Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete*. As stated in ACI 522.1-13, the tolerance for the specified void content is $\pm 5\%$. The pervious concrete mix submittal should document the density of the pervious concrete relative to the void content that complies with the specified requirements. It is also important to recognize that the void content of a pervious concrete mixture is

determined in a density measure using standardized compaction methods. This verifies that the mixture is properly designed to achieve the specified void content. It should not be expected that this void content will be obtained in the constructed pavement, since construction methods will not replicate the standardized compaction in the test. For this purpose, the density and associated void content of a core taken from a test slab is used as the basis for the subsequent acceptance of the constructed pavement.

Importance of Aggregate on Pervious Concrete Mixture Proportions

Proportioning pervious concrete mixtures is different compared to procedures used for conventional concrete.

When developing pervious concrete mixtures, the goal is to obtain a target or design void content that will allow for the infiltration of water. The void content of a pervious concrete mixture will depend on the characteristics of the ingredients, how they are proportioned and how the mixture is consolidated.

More so than when proportioning conventional concrete mixtures, coarse aggregate properties affect the proportions of all other materials in a pervious concrete mixture. The first step in proportioning the mixture is to accurately determine the void content of the aggregate, in accordance with ASTM C29, and the aggregate specific gravity. The void content of aggregate that will be used in a pervious concrete mixture will vary, depending on the grading. The density of the aggregate depends on the relative density of the aggregate and the grading. Because of these variations, it is inappropriate to specify the density of a pervious concrete mixture. Rather, the target void content range of the pervious concrete mixture should be specified. Experience shows that the void content of pervious concrete mixtures that have been successfully used in projects falls within a range of 17%-23% voids.

Cementitious Materials Content and w/cm Ratio

It is common to see a minimum or required quantity of cementitious materials for conventional concrete, possibly

Do's and Don'ts of Specifying Pervious Concrete

Do not specify compressive strength as acceptance criteria.

Do not specify a minimum cement content or water-to-cement ratio.

Do specify target range for void content.

Do specify acceptance of concrete based on its density relative to the approved mix as determined by ASTM C1688.



NRMCA Design Assistance Program



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