Masoud Kayhanian, PhD

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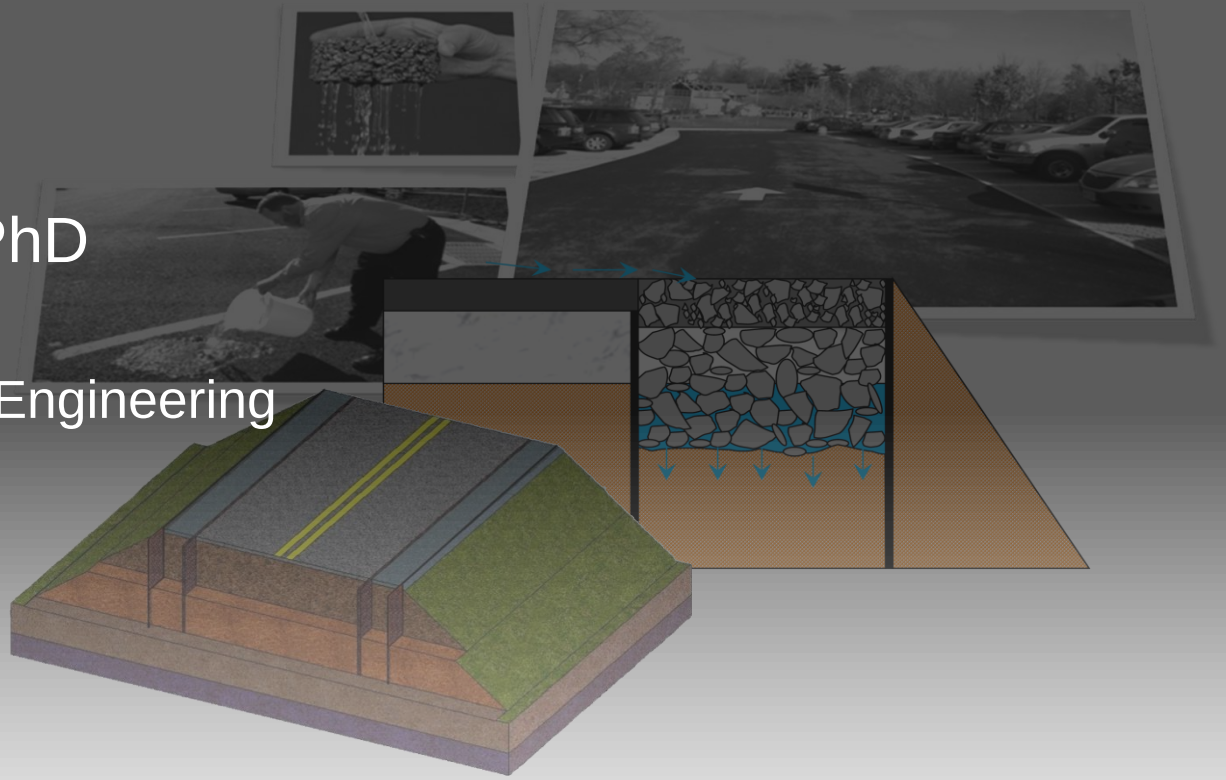

Role of Permeable Pavement in Highway Stormwater Runoff Management: California Research Experience

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Special Thanks to:

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And

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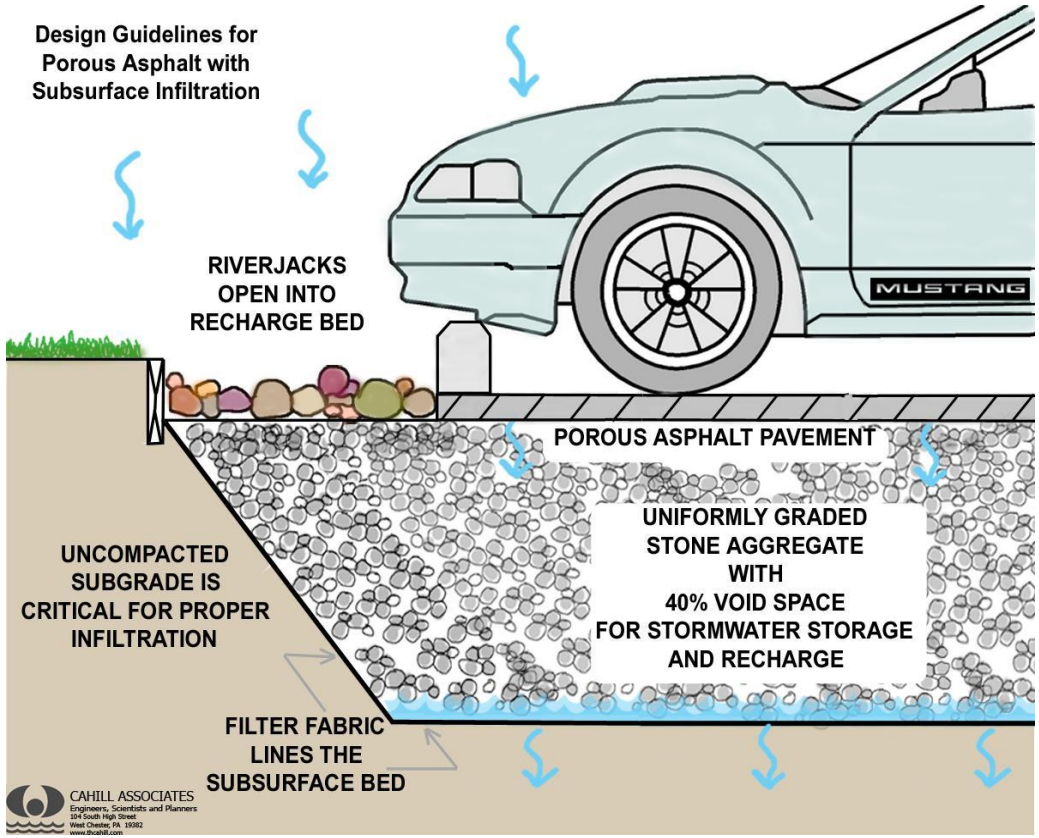
Permeable Pavement Design Concept



Source: CAHILL Associates 2003

- Sustain load and speed
- Surface remain permeable
- Surface remain unclogged
- Subgrade aggregate must retain the required design storm runoff volume
- Subgrade soil permeable enough to infiltrate the captured runoff volume
- Provide adequate water quality benefit and won't harm the underground water

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Additional Expected Benefits

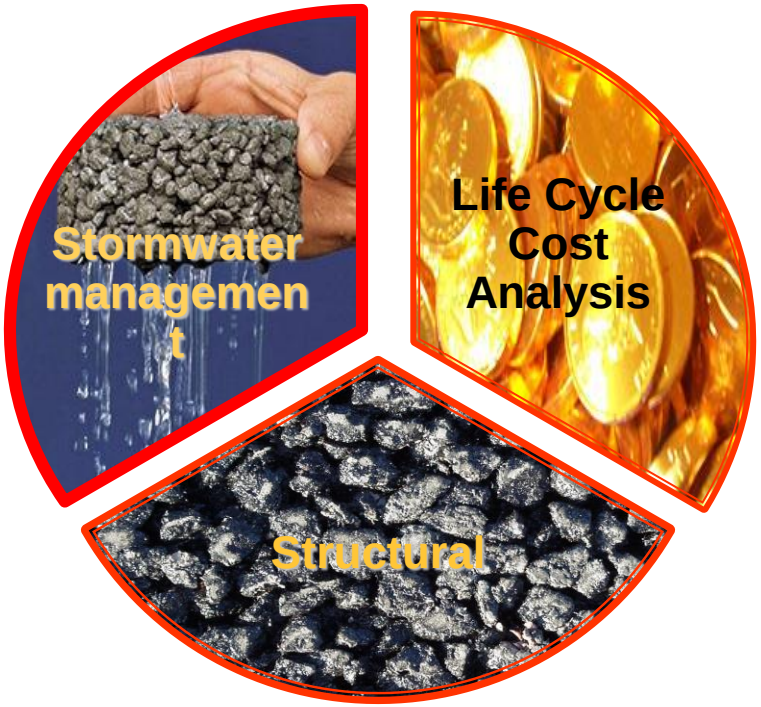
- Improve receiving water quality
- Decrease flood frequency
- Increase groundwater reservoir capacity
- Decrease pavement temperature (cool pavement)
- Low impact development (LID) design in urban areas
- Decrease stormwater management cost?

Application for Highway?

- Currently most permeable pavement design applied to parking lots and commercial areas with light load and slow speed
- Is it feasible to apply in highways with:
  - Heavy load, and
  - Medium to High speed?

UCPRC Laboratory, Simulations, and Field Studies

- Stormwater management studies:
  - Hydraulic performance evaluation
  - Permeability measurement
  - Clogging investigation
  - Water quality evaluation



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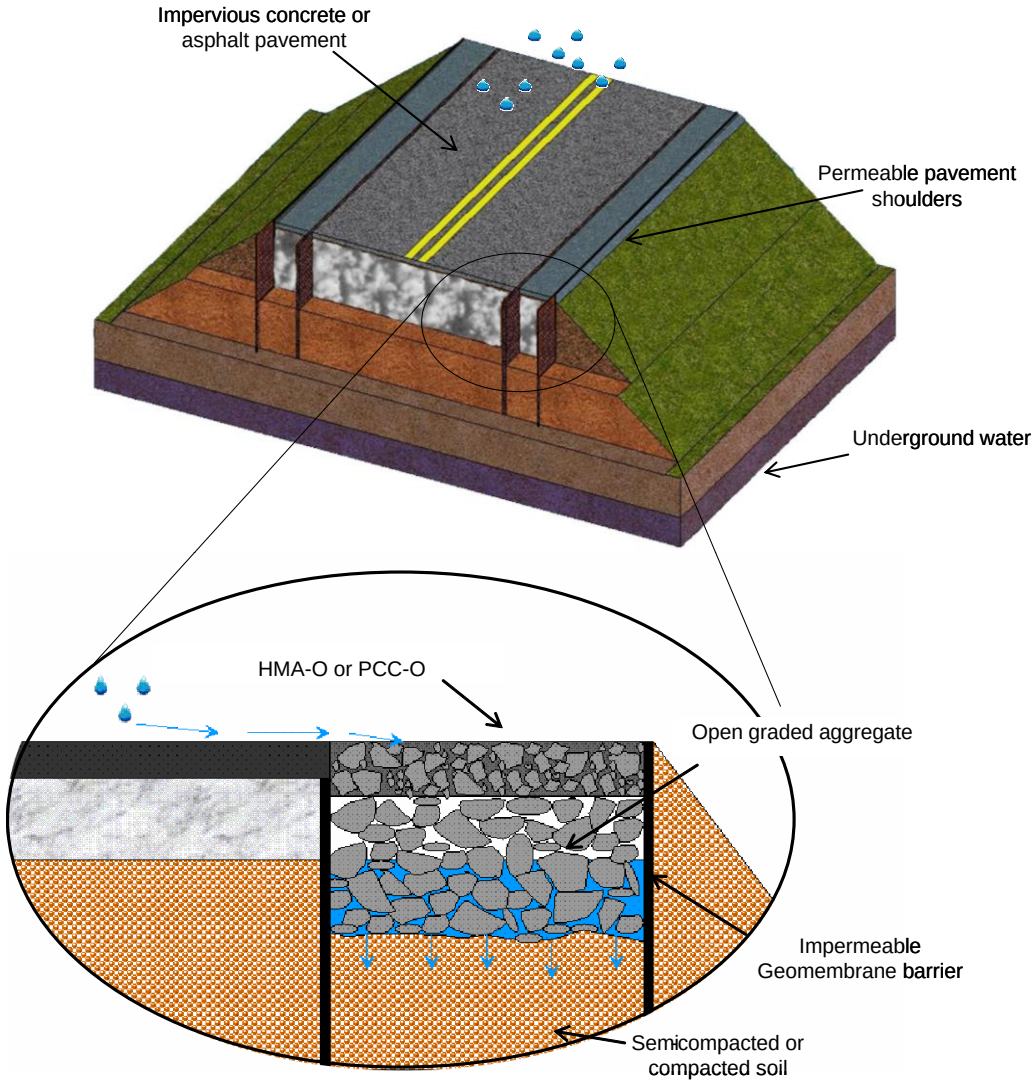
Full Depth Permeable Pavement Shoulder Design: Hydraulic Simulations Study



Under this design approach, stormwater runoff from highway lanes are captured through fully permeable shoulder and allow it to infiltrate into underground water

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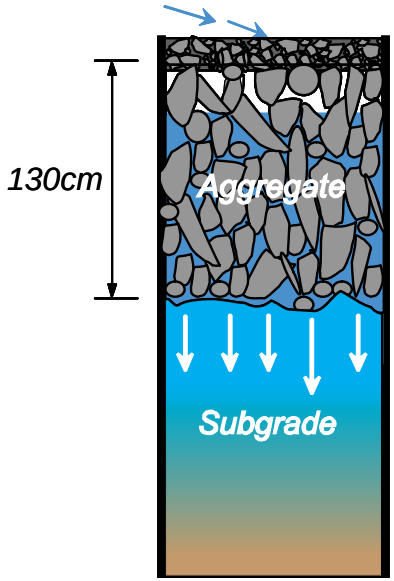
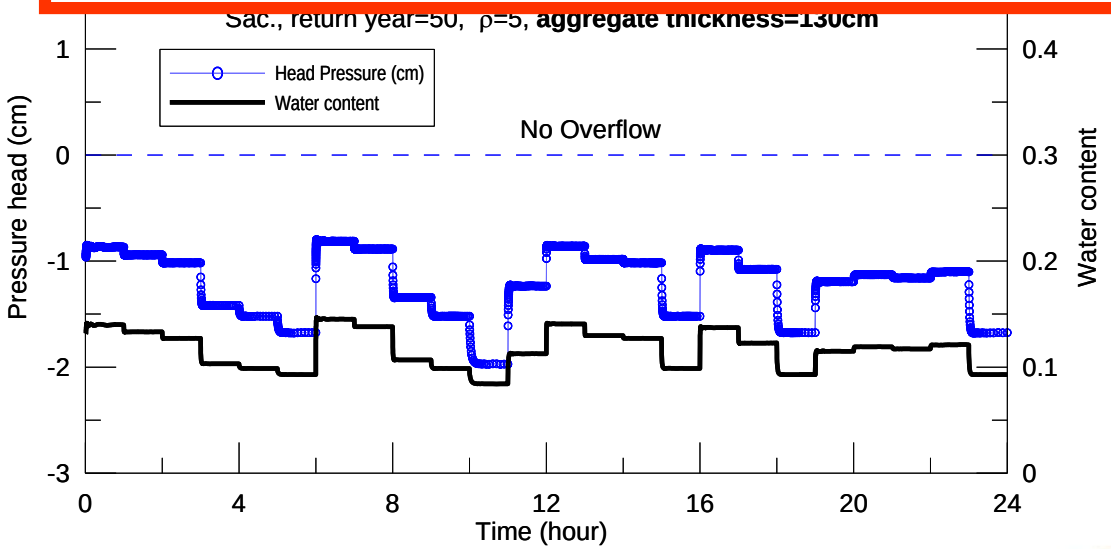
Principal Objective of the Hydraulic Simulations Study

- Determine critical aggregate thickness without overflow

Critical aggregate thickness ≈125cm





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Major Findings of the Study

- Full permeable highway shoulder retrofit can be used as an alternative BMP method to capture the highway surface runoff.
- On average, the aggregate depth in the range of 0.4 to 3 m is sufficient to capture runoff from most rainfalls for highways with 2-4 lanes.
- Subgrade soil hydraulic conductivity (K_s) is the most sensitive factor and for full depth permeable pavement shoulder design to be effective without overflow, K_s value should not be lower than 10^{-5} cm/sec (3.6 m/hr).
- Clogging is possible, but over 90% of pore space need to be clogged in order for surface overflow to occur.

Permeability Measurement Study

- **NCAT method**
- **Standard method C1701**

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Major Findings of the Permeability Measurement Study

- Both methods can be used for permeability measurements, regardless of type of paved surfaces
- Accurate measurements required proof of adequate sealant of permeameters with the paved surfaces to prevent water leakage, but the recommended plumbing putty was insufficient.
- The permeability measured through standard method 1701C was more conservative and usually about 50% lower than NCAT method. A better correlation was found when the permeameter ring sized in ASTM 1701C was reduced to half, which was closer to the lower ring diameter of NSAT permeameter.
- the permeability values after HVS operation were 27 to 92% lower compared to the pre HVS testing and the reduction.
- The reduction in permeability after HVS occurred within early loading repetition (500 to 2000) and was mostly due to rutting.
- The reduction in permeability in parking lots was mostly affected by particles less than 38 mm and age of the parking lots.

Clogging Investigation Studies

- **Technique to obtain core samples from**
  - Parking lots
  - HVS operation of test sections
  - Rainfall simulations test section
- **CT scan imaging of core samples**
- **Imaging analysis for preparing porosity profile**
- **Evaluation of porosity profile to assess clogging**

Core Sampling Test Procedures (Cont.)

- Core sampling using air cooling instead of water

Core Sampling Test Procedures (Cont.)

- X-ray CT scanning of core samples

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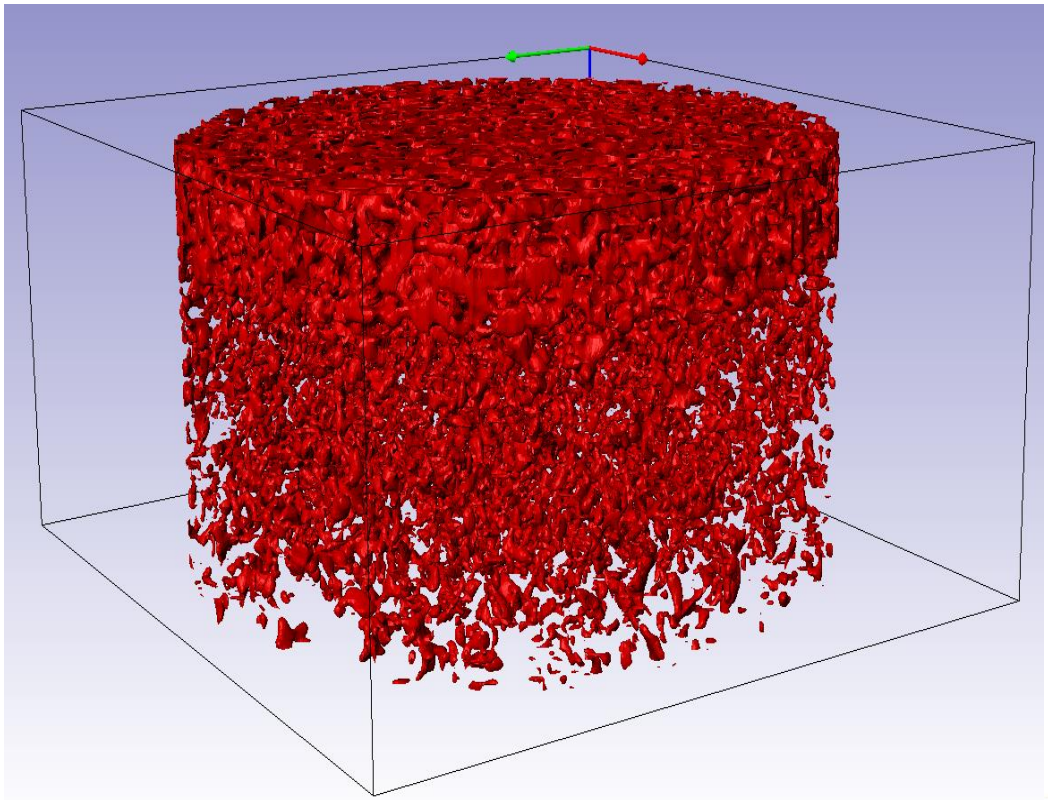
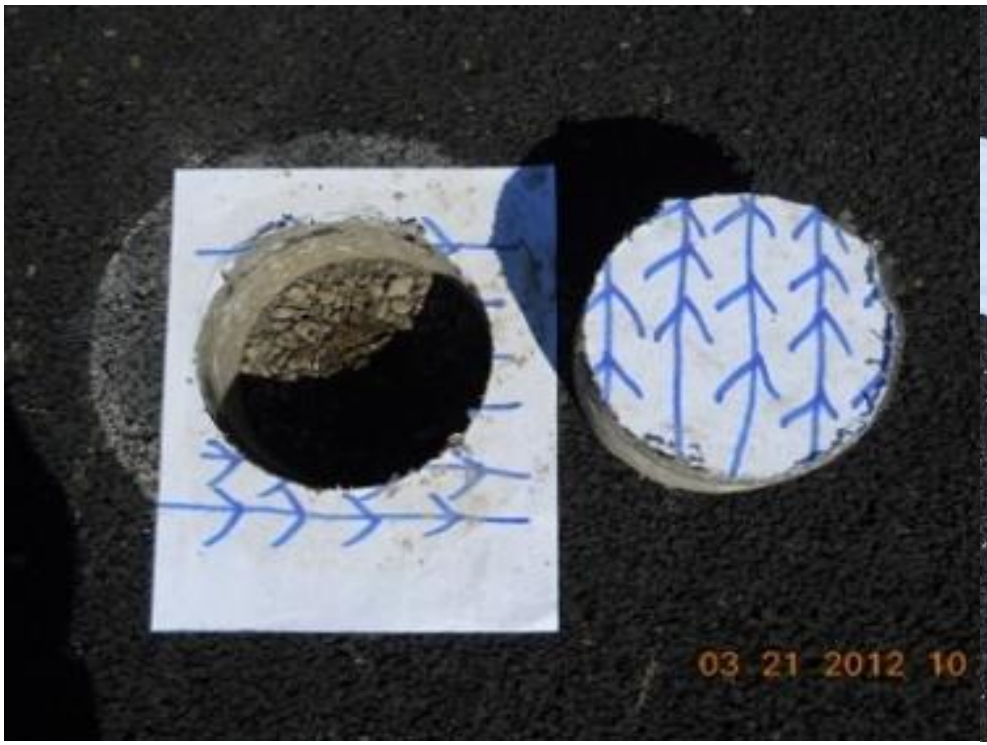
Core Sampling Test Procedures (Cont.)

- 3D images to determine the distributions of air-voids in cores



Core Sampling Test Procedures (Cont.)

- Replace scanned core sample on pavement section to be subjected under rainfall simulation and HVS operation for clogging evaluation

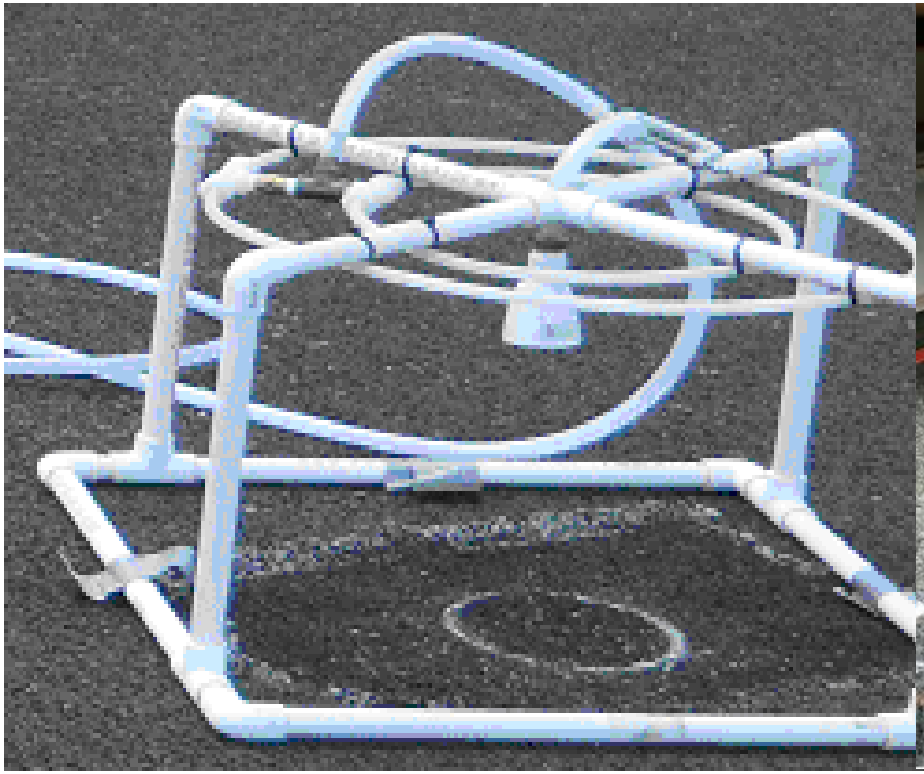


Core Sampling Test Procedures (Cont.)

- Apply epoxy glue to the bottom half of the scanned core sample

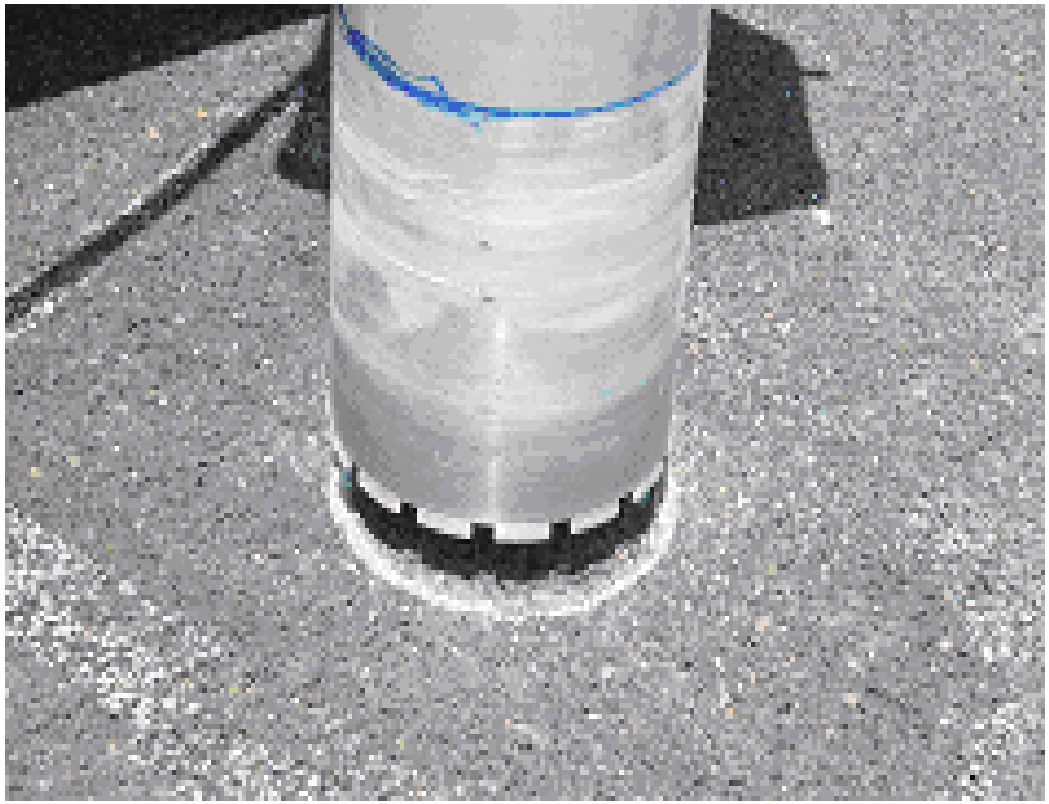
Core Sampling Test Procedures (Cont.)

- Initiate rainfall simulation and HVS testing over the reinstalled core to simulate particle or rutting related clogging



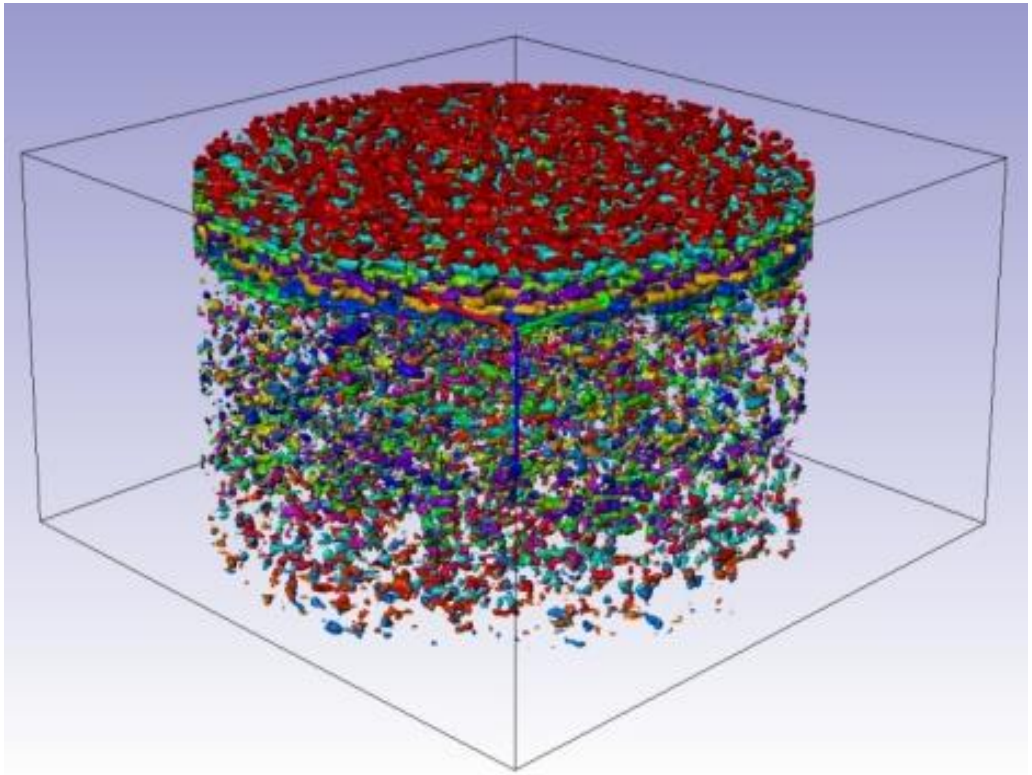
Core Sampling Test Procedures (Cont.)

- Re-core the specimens by repeating steps

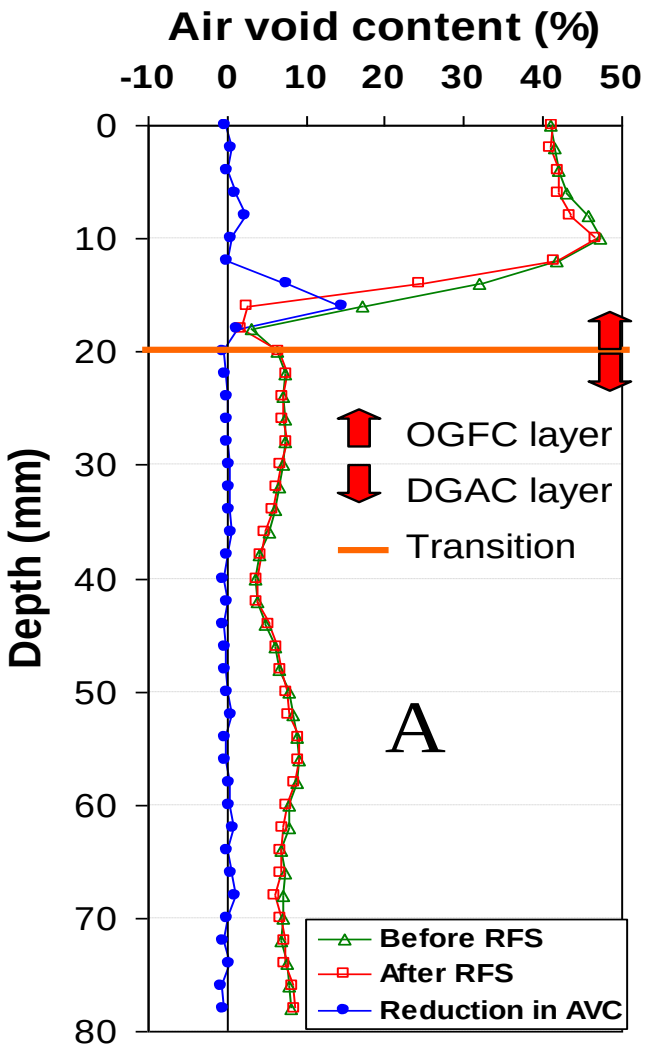


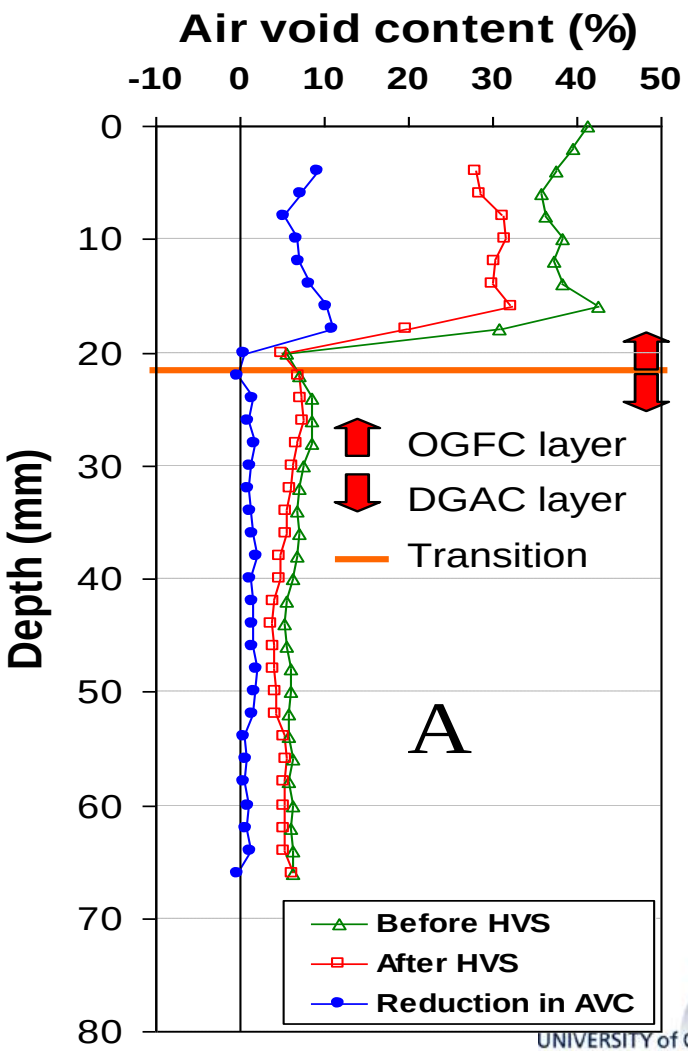
Core Sampling Test Procedures (Cont.)

- Re-scan the re-cored sample



Porosity Profiles before and after HVS or rainfall simulations





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Major Findings of Clogging Study

- Permeability measurement can be used to evaluate clogging, but to show the clogging it may be necessary to perform scan image analysis.
- The porosity of the top surface was generally lower and there may be an indication of clogging.
- While clogging generally appeared to be limited to the top layer (50 mm), in a few core samples the evidence of clogging has been noticed in the mid layer.
- HVS testing showed that not all reduction in void space in surface pavement (porosity) is due to particles, but also can happen from load and rutting effect.
- The fact that particles related clogging is usually on the upper surface layer of the pavement, that is a good news as they may be removed by vacuuming.

Water Quality Evaluation Study

Control laboratory WQ study

Statewide stormwater runoff characterization

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Water Quality Comparison: Metals

Metals (total)	Pavement only (µg/L)	highway stormwater runoff (µg/L)
Arsenic	<RL	0.5-70
Cadmium	<RL	0.2-30
Chromium	<RL-100*	1-94
Copper	<RL	1.2-270
Lead	<RL	1-2600
Nickel	<RL	1-130
Zinc	<RL	5.5-1680

RL = reporting limit
* Related to concrete pavements

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Major Findings of WQ Study

- The concentration of most organic and inorganic chemical constituents generated from the leachate of specimens was below or within the reporting limit (detection limit).
- Temperature and pavement age did not significantly change the leachate pollutant concentration.
- Compared with the actual highway runoff, it is clear that the majority or pollutants measured from storm drains (except chromium) in highways are attributed by anthropogenic activities (i.e., transportation, air deposition, agriculture, industry, etc…).
- The concentration of Cr measured in controlled laboratory was from concrete pavements and the concentration was higher at the early part of the experiment and generally the concentration reduced to below detection limit toward the end of the experiment.

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Thank you for your participation and attention

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