# PROJECT CONTRIBUTORS

<table>
<thead>
<tr>
<th>Company</th>
<th>Role</th>
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<td>Geotechnical Investigation</td>
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<td>Phillips Construction, LLC</td>
<td>Prime Contractor</td>
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<td>Procon, Inc.</td>
<td>Concrete Sub-contractor</td>
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<td>PER, Inc.</td>
<td>Sub-contractor for Conveyance of Concrete</td>
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<td>Virginia Transportation Research Council</td>
<td>Technical Support</td>
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PERVIOUS CONCRETE
Making the Impossible Possible

Construction of the I-81 Exit 140 Park-n-Ride in Salem, VA

Travis Higgs, P.E.
VDOT Salem Materials
Exit 140 Park-n-Ride location
The Impossible

- Existing Exit 140 Park-n-Ride surrounded by two secondaries, a primary and the interstate
- Already over crowded
- <100 parking spaces
- No room for expansion
The Possible

- **Exit 140 Park-n-Ride**
  - Pervious Concrete
    - Approx. 250 spaces
    - Approx. 2.5 acres
- **Exit 118 Park-n-Ride**
  - Conventional Asphalt
    - Approx. 250 spaces
    - Approx. 4 acres
Why Pervious Concrete?
**Green Eggs and Pervious Concrete**

- **Dr. Celik:** Do you like Pervious Concrete?
  - I do not like it Celik I am!
- **Dr. Celik:** Would you, could you try it on an interstate?
  - I would not, could not try it on an interstate!
- **Dr. Celik:** Would you could you try it on a secondary?
  - I would not could not try it on an interstate or a secondary!
- **Dr. Celik:** Would you could you try it on a shoulder?
  - I would not could not try it on an interstate or a secondary or a shoulder!
- **Dr. Celik:** Would you could you try it on a parking lot?
  - Okay! I will try it on a parking lot!
  - Wow! I do like it in a parking lot!
  - I like it in a parking lot, I would like it on a ..............
- **NOT SO FAST!**
Pervious Concrete Test Slab Acceptance Criteria

- Fresh Density and Void Content (ASTM C 1688)
  - Density: 125 pcf to 140 pcf
  - Voids: 15% to 25%

- Infiltration Rate (ASTM C 1701)
  - Greater than 100 inches per hour

- Hardened Density and Void Content (ASTM C 1754)
  - Density: +/- 5 pcf of Approved Mix Design
  - Voids: +/- 4% of Approved Mix Design

- Core Length (ASTM C 174)
  - -3/8 in. to + 1.5 in. of Design Thickness

- Average Compressive Strength at 28 days (ASTM C 39)
  - Greater than 2,000 psi
Fresh Pervious Concrete Test

- ASTM C 1688 – Fresh Density and Voids Test was performed on every truck load
- This was the only fresh test performed on the pervious concrete for acceptance
- Fresh density was very sensitive to moisture content
Fresh Pervious Concrete Test

- Inverted slump cone test was attempted, but found to not be as practical as the squeeze test
Infiltration Rate Test

- ASTM C 1747
- Infiltration Rate was never a problem as the minimum 100 in./hr. established for the project was easily attained and may have actually been too high on occasion as some measured values exceeded 1,000 in./hr.
Evaluation of Cores for Strength, Hardened Density and Voids

- Cores were taken to evaluate the strength, in-place density, void content and thickness of the pervious concrete.
- In-place density and voids were a challenge throughout the project. There was a slight variation between the density and voids measured using ASTM C 1754 Method A versus Method B. Method A (slow drying) was generally used for the project as the ASTM recognizes that Method B (fast drying) may produce lower density and higher void content.
- Strength (min. 2,000 psi) was generally achieved on average after 28-days of field curing. Cores checked for density and voids by use of Method A (slow drying) can be used for strength testing; however, we found 30% reduction in strength for oven dried cores vs. field cured.
Test Slab

- Forms on No. 57 Stone
- 14 ft x 19 ft w/ joint to test joint rolling, resulting in 12.5 ft x 19 ft slab for shrinkage crack evaluation
- Tried three variations of cross-rolling
  - No Weight
  - One Plate Weight – 35 lbs
  - Two Plate ‘Weights – 70 lbs
Test Slab

- Concrete Placement
- Motorized Screed
- Cross-Rollers
Test Slab

- “Pizza Cutter” for Joints
- 0.5-inch strips were placed on forms for initial screed pass and then removed for weighted rolling
- Variations in weight of cross-roller did not make an impact on density
Test Slab Results

- **Fresh Density and Void Content (ASTM C 1688)**
  - Density: 128.4 pcf : 125 pcf to 140 pcf  **PASS**
  - Voids: 19.6% : 15% to 25%  **PASS**

- **Infiltration Rate (ASTM C 1701)**
  - Average = 343 in/hr. : Greater than 100 inches per hour  **PASS**

- **Hardened Density and Void Content (ASTM C 1754)**
  - Density: 121.4 pcf : +/- 5 pcf of Approved Mix Design (122.8 – 132.8 pcf)  **FAIL**
  - Voids: 25.6% : +/- 4% of Approved Mix Design (16 – 24%)  **FAIL**

- **Core Length (ASTM C 174)**
  - Average Length = 6.07 in. : -3/8 in. to + 1.5 in. of Design Thickness  **PASS**

- **Average Compressive Strength at 28 days (ASTM C 39)**
  - 7-day Average = 1,067 psi : Greater than 2,000 psi  **FAIL**
  - 28-day Average = 2,590 psi : Greater than 2,000 psi  **PASS**
Preparations for Production Slabs

- Forms are set and No. 57 Aggregate has been graded.
First Production Slabs / Test Slab No. 2

- Due to lack of density on Test Slab, cross-rollers were replaced with “heavy roller”
- On the test slab 0.5-inch strips were used for initial motorized screed pass; however, due to difficulty with getting the concrete to compact down and fear of slab to slab roughness, contractor switched to 0.375-inch strips.
Telebelt conveyor was used to distribute concrete from the trucks to the forms.

Despite concerns of pervious concrete being exposed to air too long, the telebelt conveyor proved to be a valuable tool to distribute concrete quickly and without segregation.
First Production Slabs / Test Slab No. 2

- Procon had a lot of workers ready to go and kept a very tight operation with concrete being covered with plastic in 10 – 15 minutes after discharge
Test Slab No. 2 Results

- **Fresh Density and Void Content (ASTM C 1688)**
  - Density: 130.3 pcf : 125 pcf to 140 pcf   | PASS
  - Voids: 18.5% : 15% to 25%                 | PASS

- **Infiltration Rate (ASTM C 1701)**
  - Average = 620 in/hr. : Greater than 100 inches per hour | PASS

- **Hardened Density and Void Content (ASTM C 1754)**
  - Density: 122.6 pcf : +/- 5 pcf of Approved Mix Design (122.8 – 132.8 pcf) | FAIL
  - Voids: 23.0% : +/- 4% of Approved Mix Design (16 – 24%) | PASS

- **Core Length (ASTM C 174)**
  - Average Length = 5.1 in. : -3/8 in. to + 1.5 in. of Design Thickness | PASS

- **Average Compressive Strength at 28 days (ASTM C 39)**
  - 28-day Average = 2,001 psi : Greater than 2,000 psi | PASS
In an attempt to achieve more in-place density, the contractor switched to 0.5-inch strips on top of the forms and followed the mechanical screed with the heavy roller and weighted cross-rolling.

The mix-design was slightly altered to allow more sand and 0.5% less voids (new target 19.5%).

These steps were taken as the success of the pervious concrete is dependent upon the ability to effectively balance permeability, strength and stability.
Next Production Slabs / Test Slab No. 3

- Contractor performed a small test section using only a pan float for compaction and finishing of the pervious concrete to see if it could achieve the necessary targets.
- The ability to use a pan float would have allowed the contractor to not have to form up 12-feet widths/lanes when they poured thus allowing them to place the pervious concrete more like a floor slab than concrete pavement which would in turn mean more production.
- Pan float compacted areas showed less density and less permeability than rolled locations.
Test Slab No. 3 Results

- **Fresh Density and Void Content (ASTM C 1688)**
  - Density: 130.3 pcf : 125 pcf to 140 pcf  
    - PASS
  - Voids: 18.5% : 15% to 25%  
    - PASS

- **Infiltration Rate (ASTM C 1701)**
  - Average = 540 in/hr. : Greater than 100 inches per hour  
    - PASS

- **Hardened Density and Void Content (ASTM C 1754)**
  - Density: 119.6 pcf : +/- 5 pcf of Approved Mix Design (122.8 – 132.8 pcf) 
    - FAIL
  - Voids: 26.6% : +/- 4% of Approved Mix Design (16 – 24%)  
    - FAIL

- **Core Length (ASTM C 174)**
  - Average Length = 5.1 in. : -3/8 in. to + 1.5 in. of Design Thickness  
    - PASS

- **Average Compressive Strength at 28 days (ASTM C 39)**
  - 7-day Average = 1,413 psi : Greater than 2,000 psi  
    - FAIL
  - 28-day Average = 1,875 psi : Greater than 2,000 psi  
    - FAIL
Test Slab No. 3 Results

- Although the acceptance criteria were not all met for the test slab, we finally had a mix design and placement plan that achieved the optimum balance of durability and permeability.
- Although not a specification test, as a check for durability, we performed ASTM C 1747.
  - Test on cylinders produced 34% mass loss.
  - Tests were run on cores
  - Cores with low density had > 40% mass loss
  - Cores with higher density had < 40% mass loss
Overall Results - Density

Density of Cylinders Compared to Cores Correlated Well

Density Specification

- Average Fresh Density (pcf)
- 5 pcf of Avg. Cyl. Density (pcf)
- Average Hardened Density (pcf)
- Average Cylinder Density (pcf)
Overall Results - Strength

Only a few sections failed to meet 2,000 psi and generally those sections were over 1,500 psi.
Overall Results – Infiltration Rate

Highest three infiltration rates correspond to lowest three strengths

All sections met the minimum infiltration rate with some sections having permeabilities that were too high.

Virginia Department of Transportation
The Goal

Strength, Durability and Permeability
QUESTIONS?