
VDOT
Virginia Department of Transportation

PROJECT CONTRIBUTORS

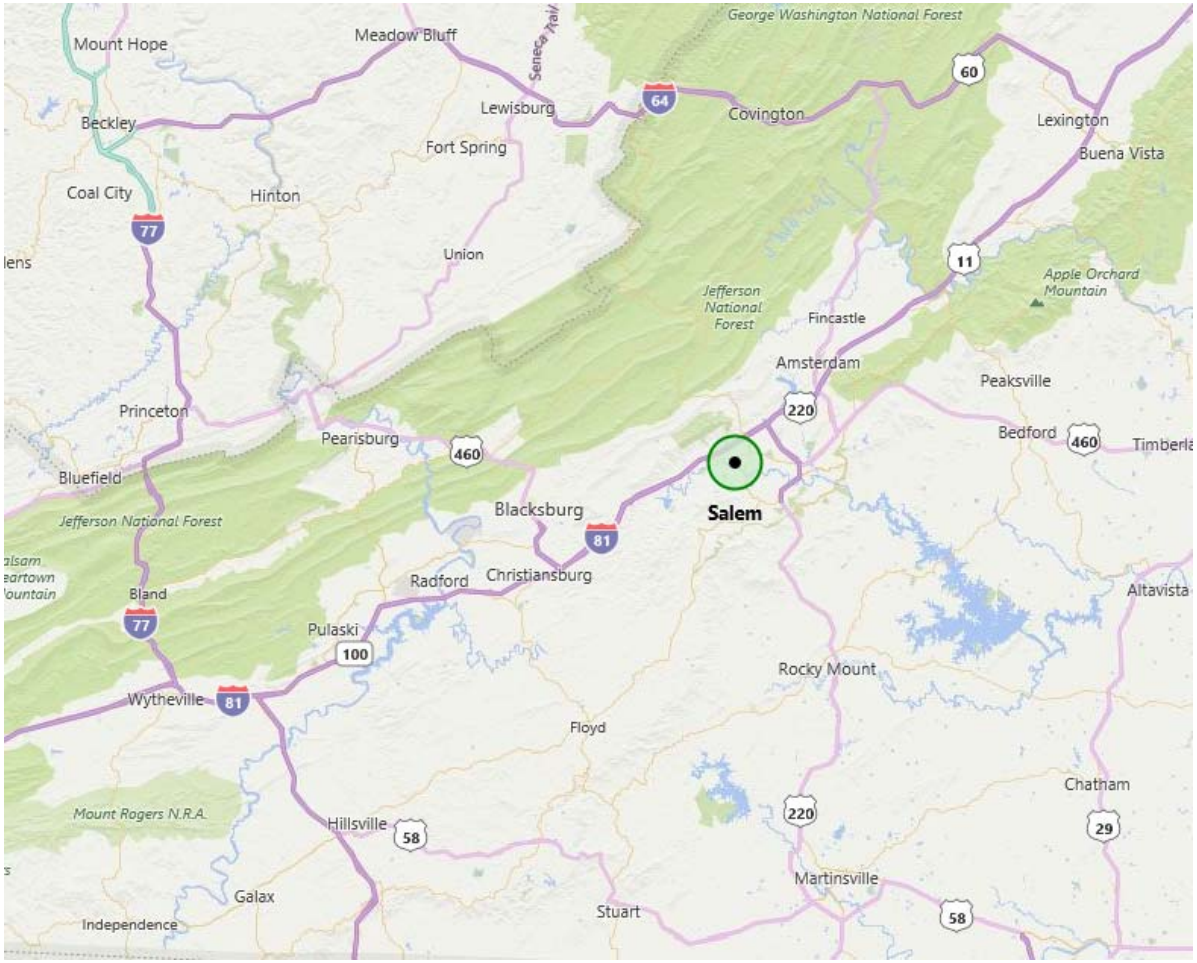
WRA	Whitman, Requardt and Associates, LLP	-	Designer
Schnabel Engineering	Schnabel Engineering, Inc.	-	Geotechnical Investigation
Phillips Construction	Phillips Construction, LLC	-	Prime Contractor
Procon	Procon, Inc.	-	Concrete Sub-contractor
PER	PER, Inc.	-	Sub-contractor for Conveyance of Concrete
Chandler Concrete	Chandler Concrete, Inc.	-	Concrete Supplier
MBP	McDonough Bolyard Peck, Inc.	-	Construction Inspection
VDOT	Virginia Department of Transportation	-	Owner, Project Mgr.
VTRC Virginia Transportation Research Council	Virginia Transportation Research Council	-	Technical Support

PERVIOUS CONCRETE
Making the Impossible Possible

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

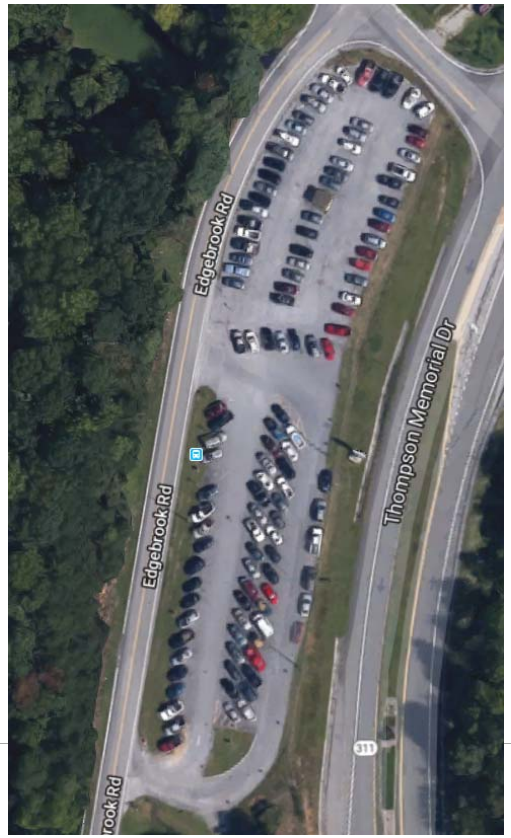
Travis Higgs, P.E.
VDOT Salem Materials

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?

- A permeable pavement alternative was attractive given the lack of space for expansion of park and ride at the Exit 140 interchange.

Why Concrete?

- While VDOT did have permeable asphalt park and ride installations, there are not a comparable amount of pervious concrete installations.
- With this installation, the pros and cons of permeable asphalt and pervious concrete can be evaluated over time.

The Perceptions under Evaluation

- **Permeable Asphalt**
  - More prone to clogging and loss of void space over time due to viscoelasticity of asphalt as a binding agent in an open graded mixture
- **Pervious Concrete**
  - Less prone to clogging and loss of void space over time, potentially more prone to raveling with age

Considering Pervious Pavement as an Option

- **Pros**
  - **Save real estate**
  - **No run off**
- **Cons**
  - **Maintenance**
    - It should be noted that all stormwater management systems require maintenance
  - **Durability?**

Getting Started with a Permeable Pavement

VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 7

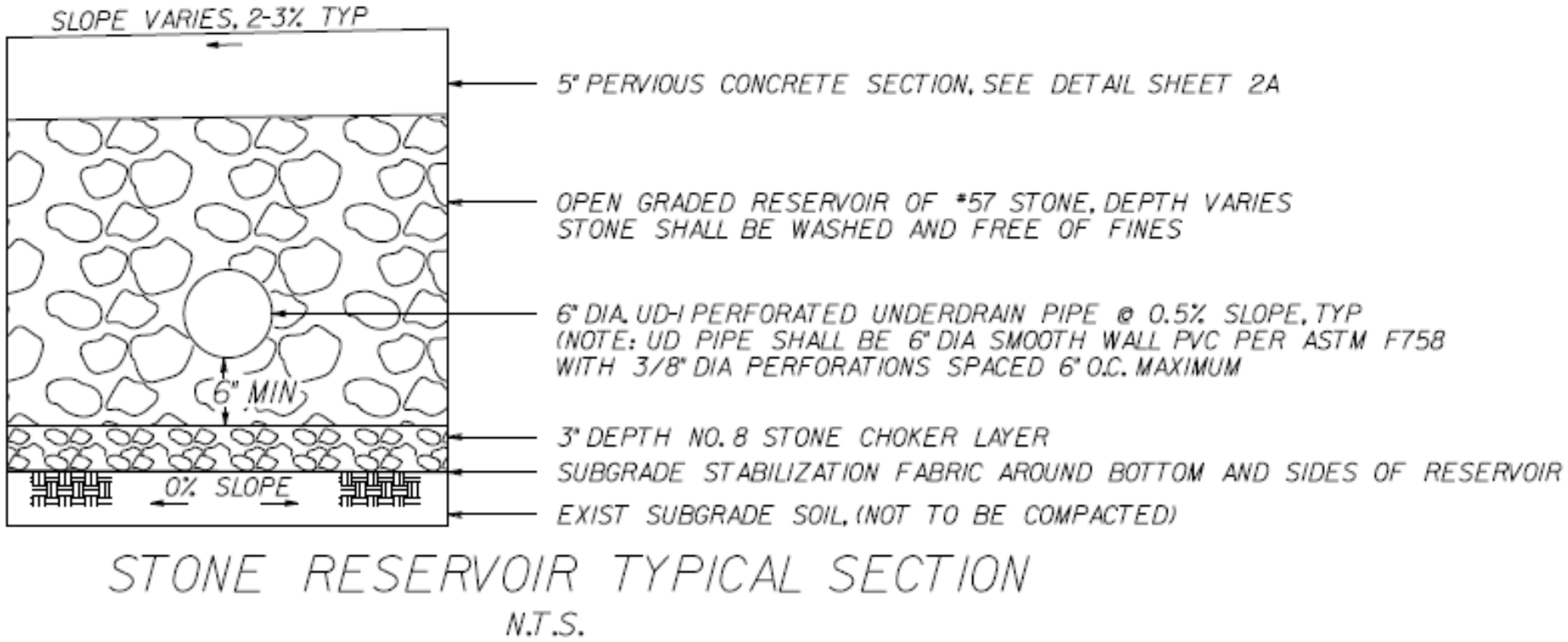
PERMEABLE PAVEMENT

VERSION 1.8
March 1, 2011

Getting Started with a Permeable Pavement

- **Geotechnical Site Evalution**
  - **To design a permeable pavement system with no flow leaving the site (no underdrain) the measured infiltration rate of subsoils must be 0.5-inch per hour or greater.**
- **Exit 140 Evaluation Results**
  - **Minimum Infiltration Rate Measured = 0.88 in./hr.**
  - **Average Infiltration Rate Measured = 2.38 in./hr.**
    - Infiltration Rate Testing completed in accordance with VA DCR Stormwater Design Specification No. 8

Exit 140 Park-n-Ride Typical Section



STONE RESERVOIR TYPICAL SECTION

N.T.S.

Sizing Reservoir Layer

- **Section 6.7 of DEQ Design Specification No. 7**
  - **Thickness of reservoir layer determined by**
    - Runoff storage needs
    - Infiltration Rate of in situ soils
    - Pavement Design structural requirements of subbase
    - Depth of water table and bedrock
- **Exit 140 Park and Ride**
  - **2 – 3 feet of No. 57 Aggregate used primarily as a fill material rather than compacted soil**

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

"Development of a Special Provision on the Use of Pervious Concrete as a Stormwater Management Tool in Parking Lots" – VTRC Nov. 2017

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 1701
- 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.

First Production Slabs / Test Slab No. 2

- 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

Next Production Slabs / Test Slab No. 3

- 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.

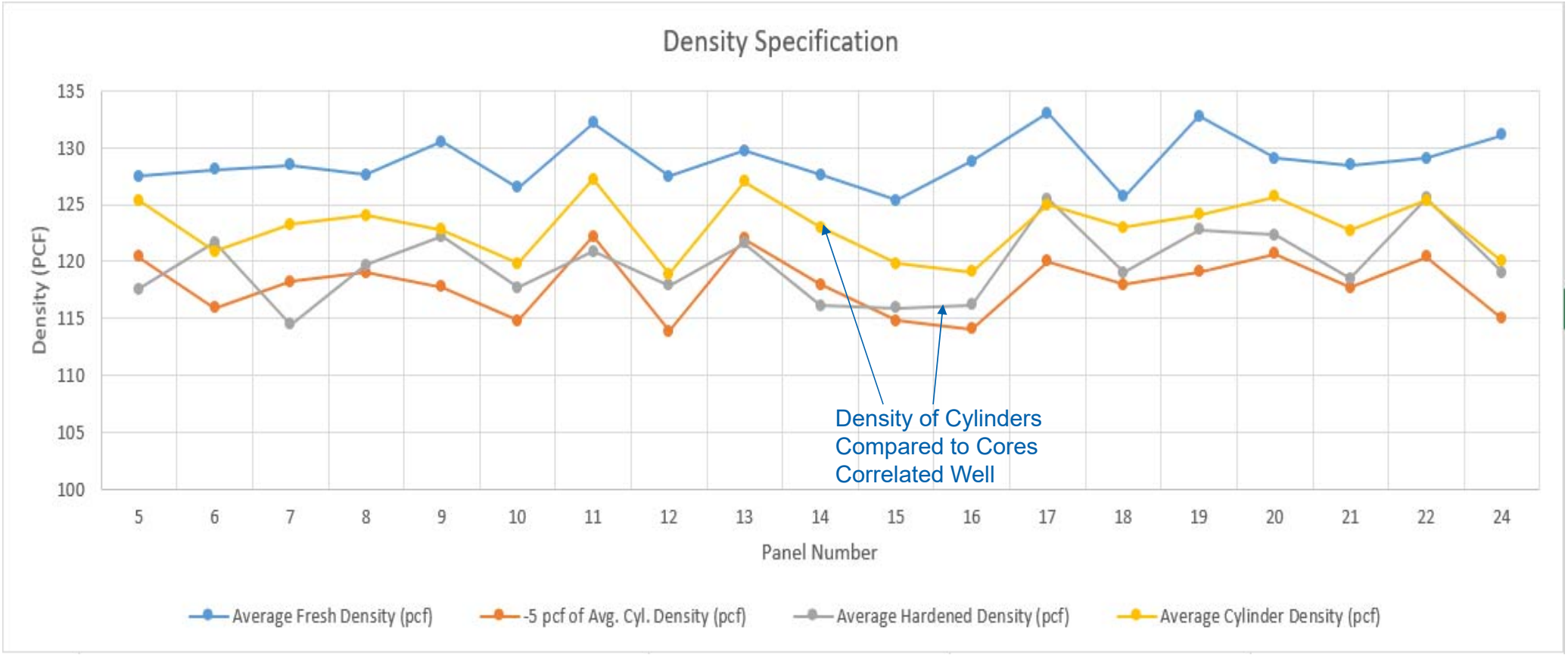
Test Slab No. 3 Results

- **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

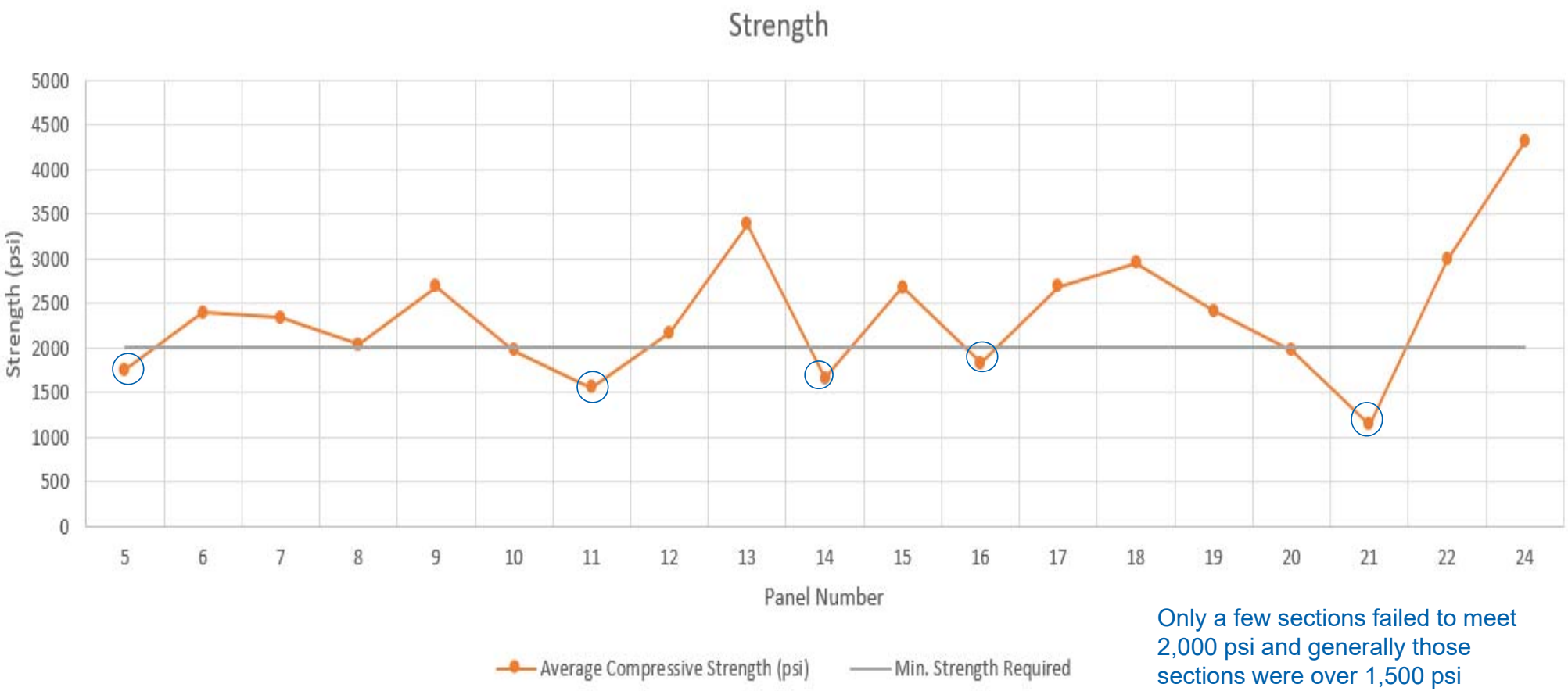
Test Slab No. 3 Results

- 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

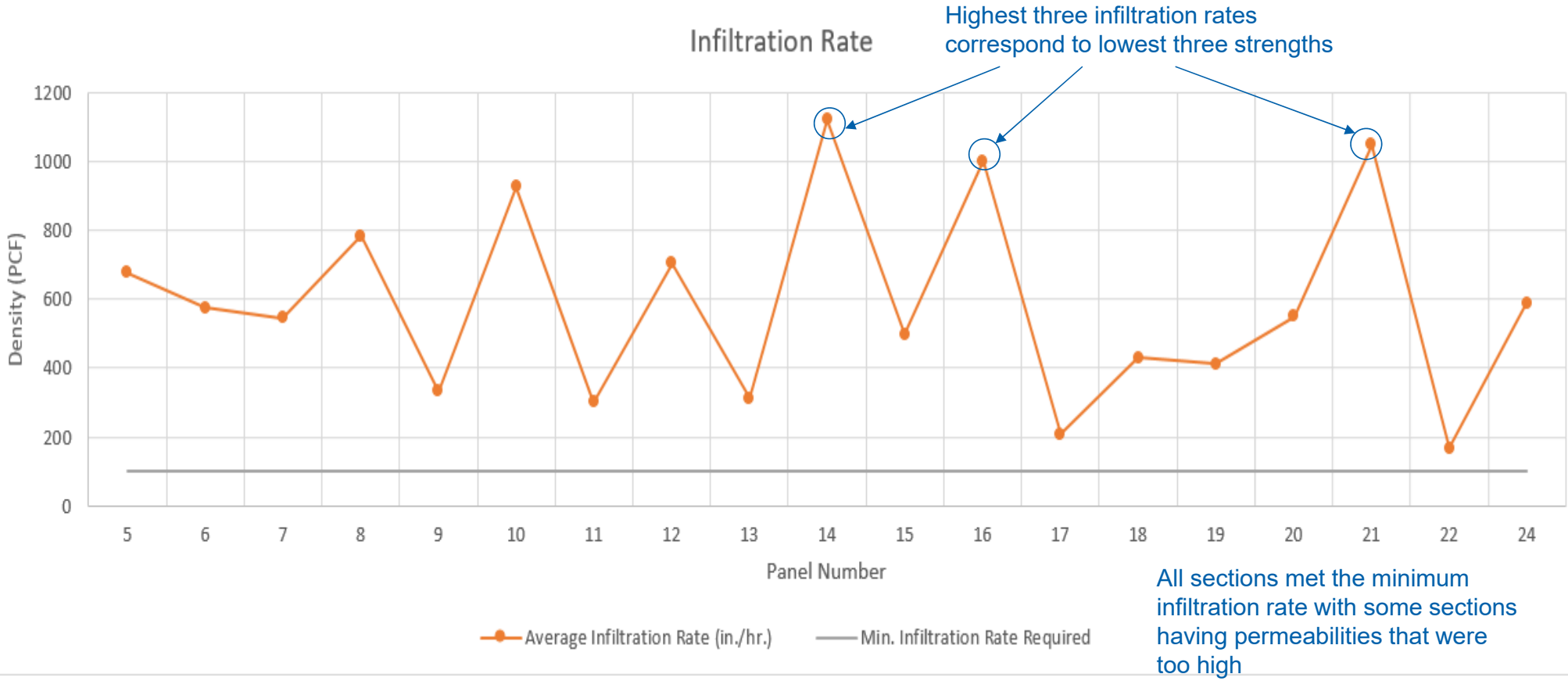


Overall Results - Strength



Only a few sections failed to meet 2,000 psi and generally those sections were over 1,500 psi

Overall Results – Infiltration Rate



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

The Goal

Strength, Durability and Permeability

QUESTIONS?