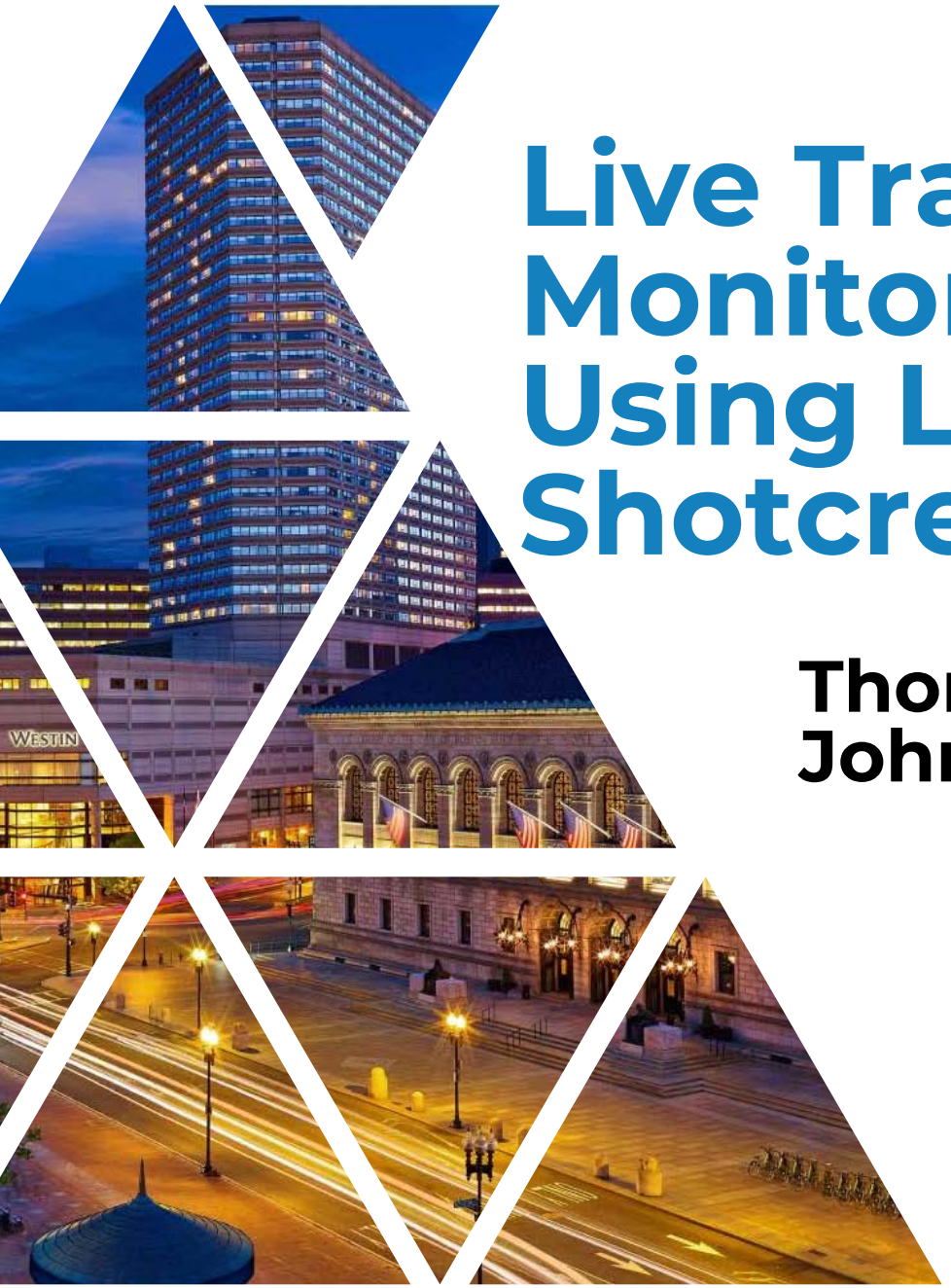

Live Traffic Repairs at Monitor-Merrimac Using Low Dust Shotcrete

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Restore | Repurpose | Renew

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Presentation Objectives

- Explore shotcrete materials and low-dust shotcrete technology
- Highlight the shotcrete process, and how it is vital to the successful repair of many tunnel and infrastructure projects
- Discuss the challenges associated with live roadway repairs
- Promote importance of collaboration between manufacturers and contractors for specialty repair technologies

Packaged Shotcrete Manufacturing Basics

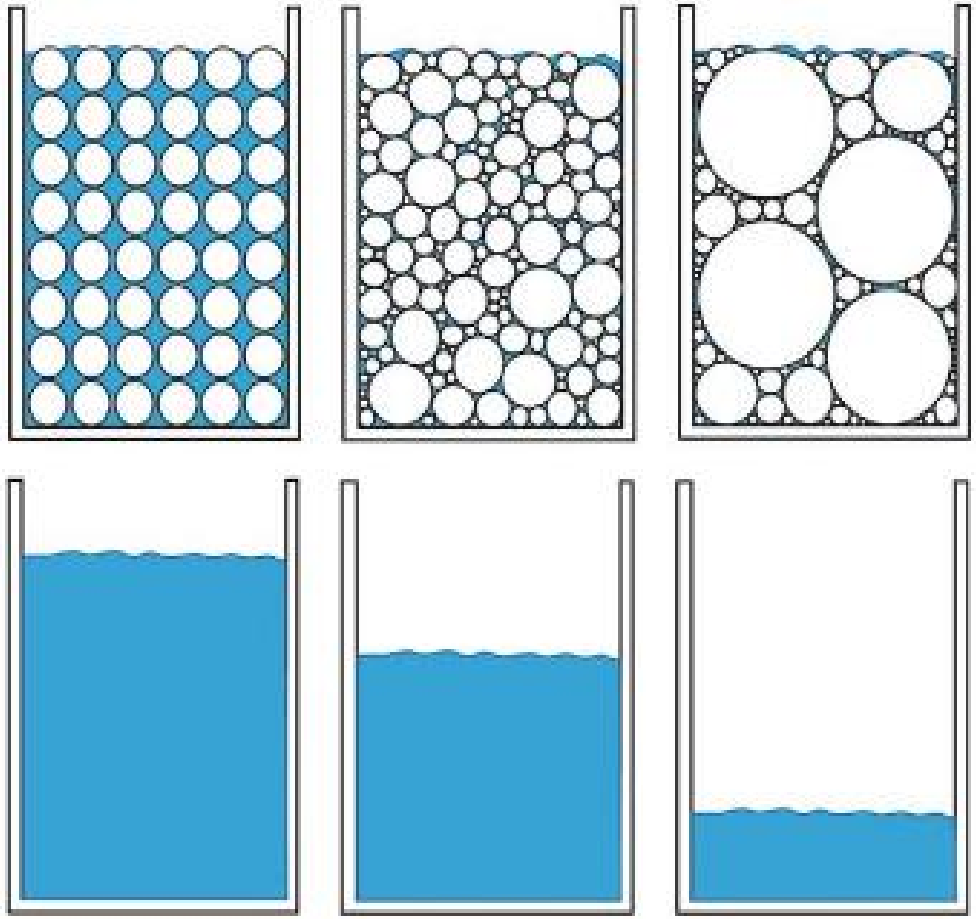
- Materials used in the shotcrete process are simple, yet versatile
- ACI 506 outlines mix ratios, key materials, and optimal aggregate gradations
- Fast-setting, fiber-reinforced, polymer-modified, and specific colors are all examples of commonly requested and utilized materials
- Single component, pre-packaged materials can greatly simplify construction planning, and allow for specific material properties

Shotcrete & Dust

- Shotcrete as a means for applying structural concrete can be a game-changer on any project: greatly reduced setup, installation time and equipment needs are commonly advertised advantages compared to form & pour
- In choosing wet vs dry process shotcrete, many contractors / installers have a preference.
- Historically, dry process shotcrete tends to be known to cause more dust, pushing many safety regulations and owners to favor the wet process

What in the Material Causes Dust

- When significant dust occurs with a Shotcrete product, it means not only is there an ***exposure to dust***, but also ***material is going to waste***
- As ACI 506 details, product formulation, and more specifically aggregate selection, plays a vital role in shotcrete rebound
- The gradations specified in ACI 506 are specifically designed to allow for proper compaction, and account for rebound of larger particles



Aggregate Gradation Impact on Water Demand and Hydration

What in the Process Causes Dust

- Dust occurs in two main points in the Shotcrete process: at the material hopper (mostly dry mix) and at the point of application
- Depending on several job-specific factors, the dust exposure can be higher in either location
- Most notably, shotcrete being applied indoors or underground could be subject to prolonged or increased dust exposure

The Search for a Safer Dry-Process Shotcrete

- OSHA regulates permissible exposure limits (PELs) for airborne particulates. Total respirable dust, which includes silica, is closely observed and influences required PPE

Process / Standard	Average Observed Exposure
OSHA PEL – Respirable Dust Exposure	5 mg/m^3
Dry Mix Shotcrete Dust Exposure*[1]	26.5 mg/m^3
Wet Mix Shotcrete Dust Exposure*[2]	15.8 mg/m^3

* Based on data reported in referenced articles

- Packaged shotcrete material manufacturers have long been researching low dust shotcrete, to provide a ***safer***, ***more efficient*** product
- Historically, these products were met with significant drawbacks (lower compressive strength, inconsistent set times, etc)

Dust Reducing, Rebound Compensating Technology

- Manufacturers have begun use of admixtures that reduce dust and rebound *without sacrificing other major material qualities*
- When combined with aggregate that is graded according to ACI 506, these admixtures can function as a dust and rebound suppressant
- Dust exposure and NIOSH 0600 & 7500 testing have shown a 95% reduction in dust compared to traditional dry mix shotcrete products

Field Efficacy Case Study

- Dust exposure of each member of a dry-process shotcrete crew was measured over a several hour period
- Resulting measurements of the maximum dust exposure measured 2.45 mg/m^3 across the two experiments, a figured lower than the OSHA PEL, and a significant improvement over historical dust concentration data

Position	Test 1 Dust Exposure) (mg/m^3)	Test 2 Dust Exposure) (mg/m^3)
Mixer	**2.90**	0.95
Nozzleman	0.98	**2.00**
Finisher 1	0.31	0.18
Finisher 2	0.26	0.20
Helper	0.25	N/A

Process / Standard	Average Observed Exposure
OSHA PEL – Respirable Dust Exposure	5 mg/m^3
Dry Mix Shotcrete Dust Exposure*[1]	26.5 mg/m^3
Wet Mix Shotcrete Dust Exposure*[2]	15.8 mg/m^3
Average Max Dust Exposure in tests using USCP dust reduction technology	**2.45 mg/m^3**

* Based on data reported in referenced articles

Applicability of Shotcrete Technology

Shotcrete as a process enables:

- Vertical and overhead application without forms
- Rapid repair capabilities
- Minimized equipment for large placement capabilities

A low dust shotcrete can allow for:

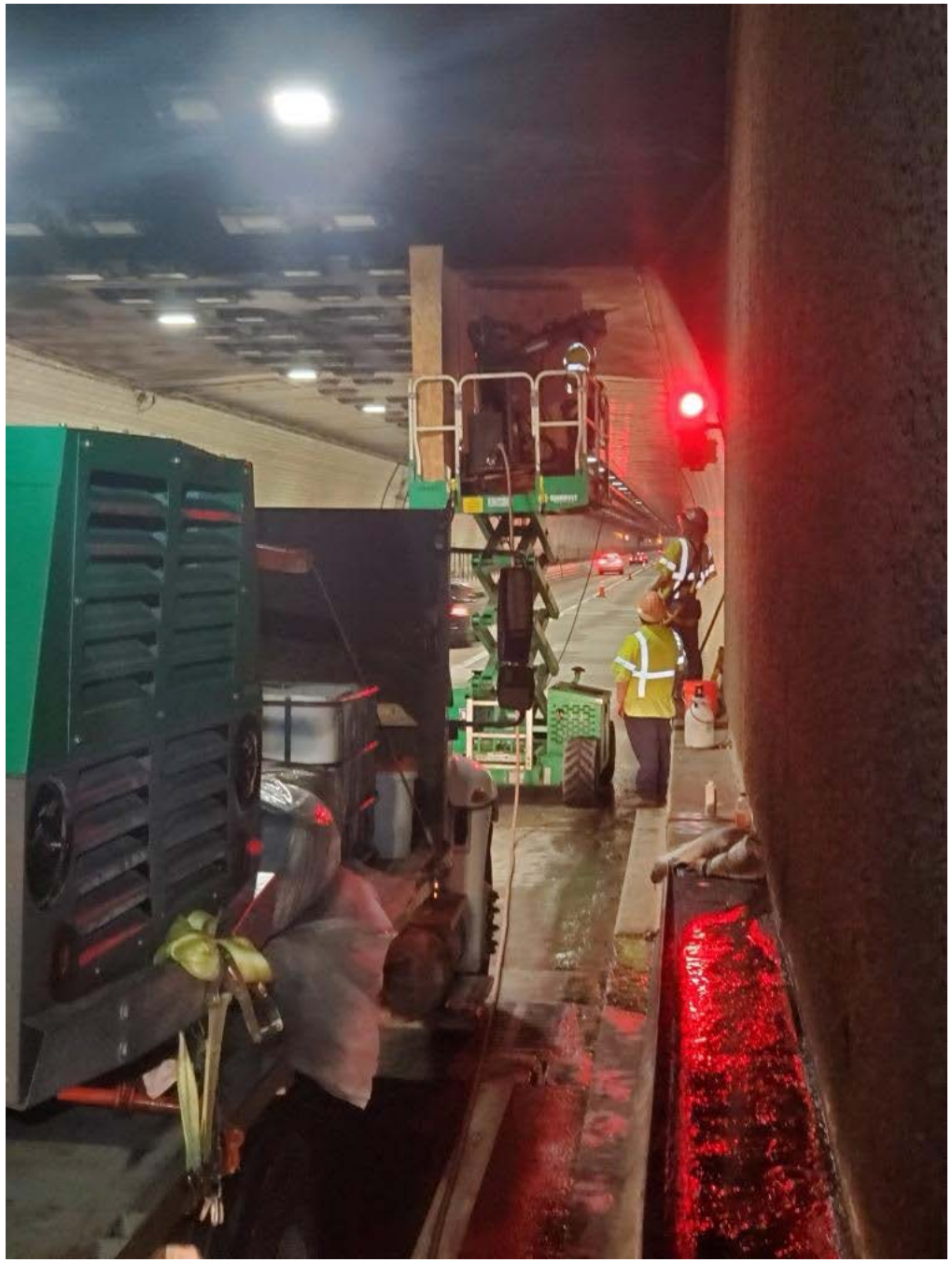
- Flexibility in active environments
- More efficient application of material
- Use of shotcrete without urban disturbance

Monitor Merrimac Bridge Tunnel Structure

- Completed in 1992 connecting Suffolk VA to Newport News VA (I-664)
- 4,800 ft long (1,500 m)
- Double tube, four lanes, artificial islands
- Operated by the Virginia Department of Transportation

Why Emergency Repairs?

- Delaminated concrete above roadway at portals discovered in all portals during inspection July 2022
- Emergency priority given to night lane closures to remove threat to traffic
- PAM pneumatic arm with chipping hammer mounted on a scissor lift boxed in with plywood allowed concrete removal next to traffic



Why Repair w/ Shotcrete vs Conventionally?

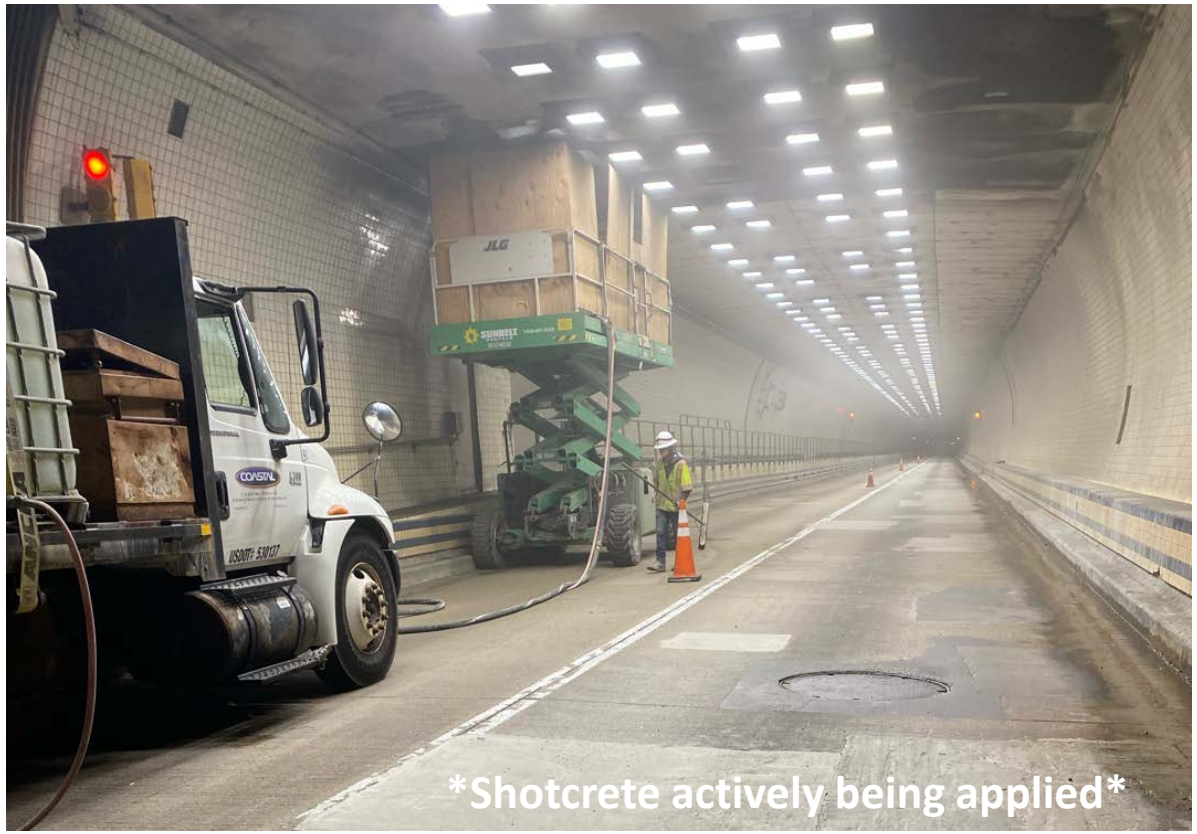
- Excellent track record with VDOT completing similar work using shotcrete in the fresh air duct of a neighboring tunnel
- Shotcrete with novel dustless material suggested and tested
- Fast production, no formwork, **did not require tunnel closure**
- Testing determined no added accelerator was needed

Field Execution: Preparation

- All Loose and Delaminated Concrete Removed
- Embedded Corroded Utilities Replaced
- Deteriorated Steel Replaced with Mechanical Splices
- Abrasive Blasted
- Cleaned with water using Shotcrete Nozzle

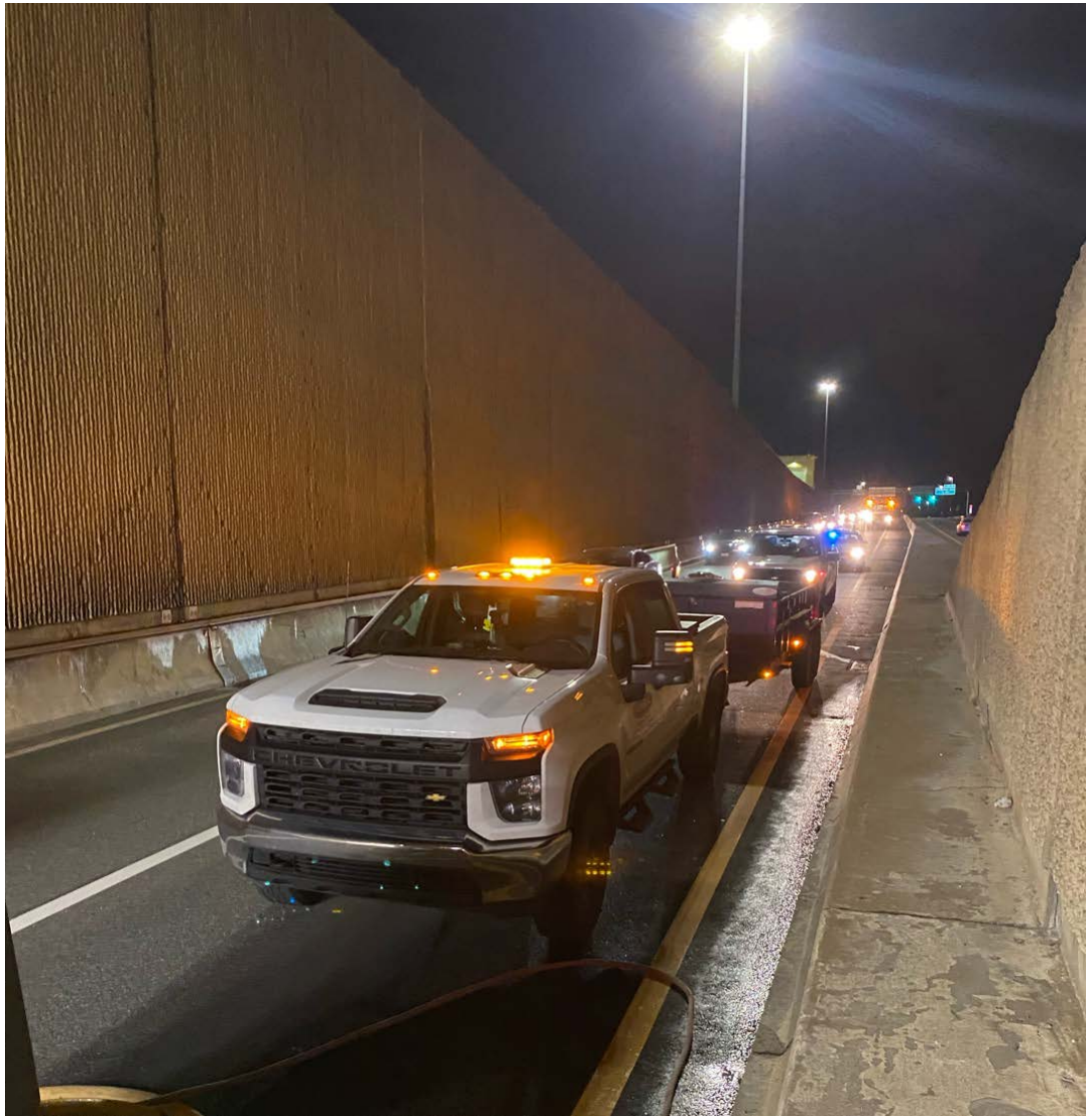
Field Execution: Concrete Placement

- Placed using Dry Mix Shotcrete Method
- Rotary style Piccola Gun
- Finished with trowels, brooms
- Wax based curing compound applied

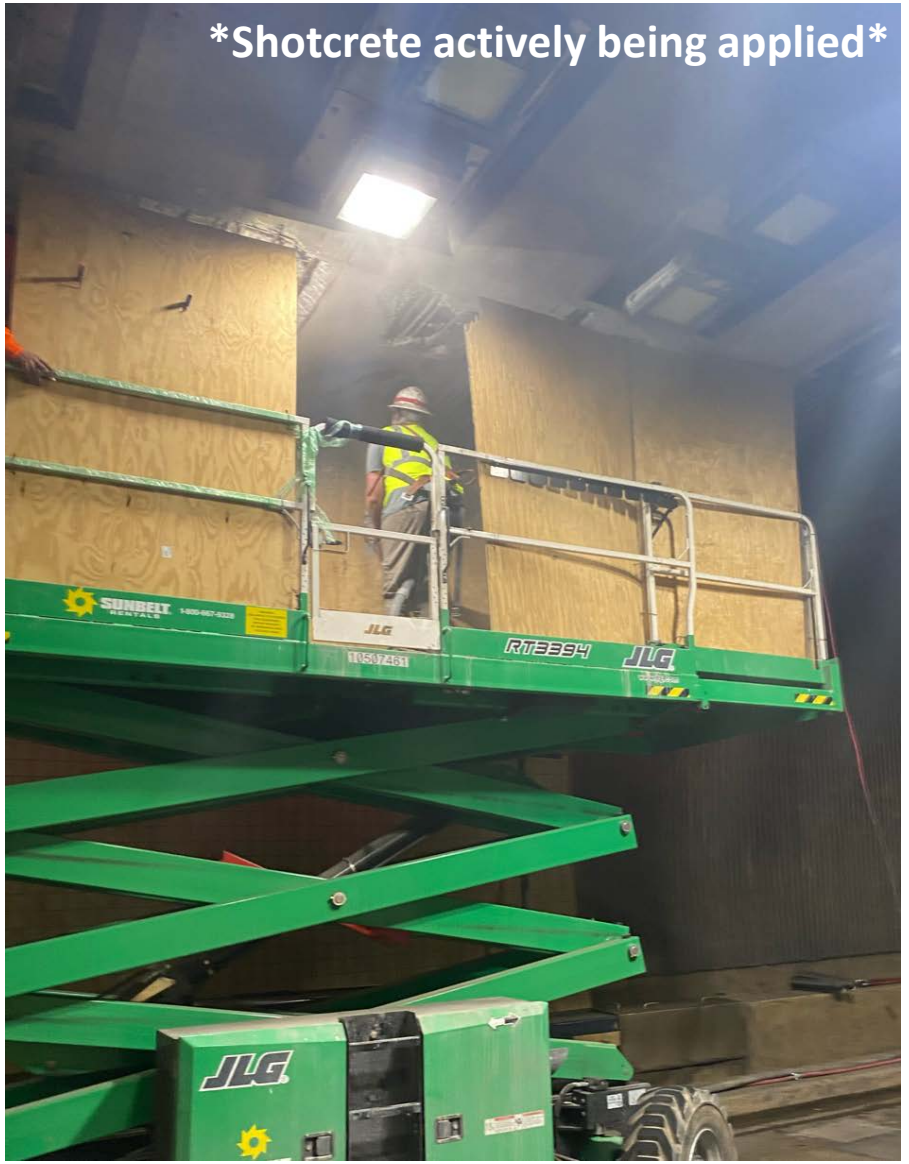


Planning Considerations: Traffic

- Night work, Effective Hours 10 PM to 3 PM
- 20 Min Stoppages after Midnight
- Shot during stoppage, finish and move with live traffic
- After emergency demolition was completed, lowered priority resulted in limited availability of closures, complex coordination with other projects
- *Sudden tunnel evacuation ability required*



Project Material Benefits: Reduced Dust

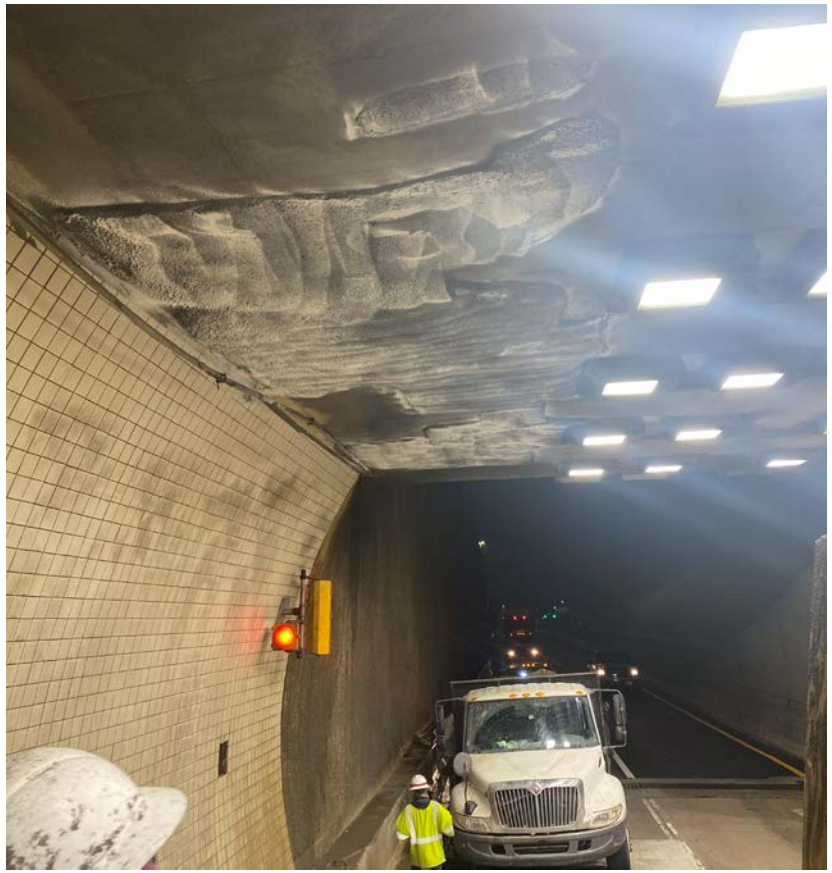


- Roadway visibility never impacted
- Limited cleanup on adjacent surfaces and roadway

Additional Project Material Benefits

Increased Build Out Rate

- Allowed placement during stoppage time.
- Increased productivity



Reduced Rebound

- Limited cleanup
- Kept live roadway and traffic clean

Enhanced Visibility

- Enabled increased confidence of reinforcement encapsulation
- More placement control and less finishing required

Low Dust Shotcrete Advantages

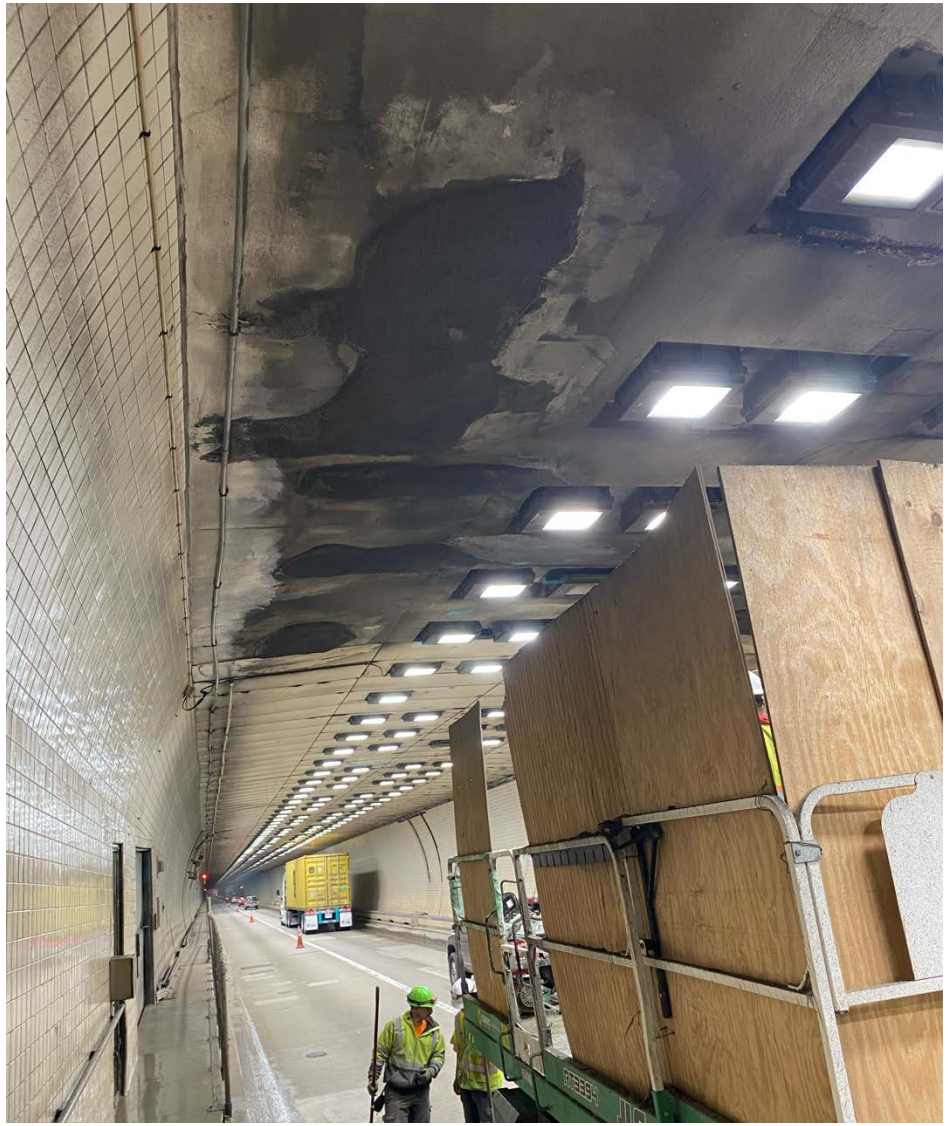
Compact Footprint / Waste

- Enabled quick mobilization/demobilization in allowed hours
- Ability to quickly evacuate roadway if needed
- Limited clean-up required, done by gun operator while in finishing and moving stages

Rapid Overhead Application

- Shotcrete process eliminated the need for forms
- Trowel-applied products would have taken significantly longer to apply

Project Recap & Review



- Quick effective repair with very limited impact to regional traffic
- High Quality and High Efficiency
- Effective implementation of a material technology

- Special thanks to VDOT Partners
  - Patriki Das P.E, Construction Manager
  - John Sparks, Senior Inspector
  - Shannon Terns P.E., District Special Structures Engineer
  - David Gibbings P.E., Jacobs Solutions

Thank You!

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