

2022 Honorable Mention

# Taking Tuscarora into another Century

By Kristina Smith

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Fig. 1: Pennsylvania Turnpike's Tuscarora Tunnels

Pennsylvania Turnpike's Tuscarora Tunnels are undergoing a \$110m rehabilitation, aimed to deliver the 'wow' factor to its users. Kristina Smith reports.

**T**he Tuscarora Mountain Tunnels in Pennsylvania have a fascinating history. The older of the two tunnels, built between 1938 and 1940, was designed to carry a railroad that never came into service. Industrialists of the day, William Henry Vanderbilt and Andrew Carnegie, were backers of the scheme which was halted when they struck a deal with rival railroad owners.

From 1940, the 5326 ft (1.6 km) tunnel and later its twin, which was built from 1962 to 1968, have carried a different mode of transport: motor vehicles. They are part of the Pennsylvania Turnpike, a 360-mile (580 km) toll road that runs east to west between state borders, passing through the Appalachian Mountains. When it opened, the toll road

was remarkable because of its seven single tube tunnels; three of these were later bypassed to deal with bottle necks while the remaining four were twinned.

Now the operators of the Turnpike are looking to the future with a \$110M rehabilitation of the Tuscarora Tunnels which aims to extend their lives for another century. The older tunnel will receive the most attention with the construction of an additional internal waterproofing layer and shotcrete skin to fight the ingress of groundwater, which has earned the tunnel the loving nickname of 'Lake Tuscarora.'

"Groundwater is a tunnel owner's worst nightmare," says Jim Stump, bridge engineer manager at the Pennsylvania Turnpike Commission. "You can try to control the water, but it always finds the weakest point."

The younger tunnel will have more modest waterproofing repairs with both tunnels receiving new electrical systems,

lighting, and ventilation; new signage and CCTV; and upgrades to the tunnel entrances and portal building.

For contractor Mosites Construction, which has worked on most of the Turnpike's seven sets of tunnels over the years, this waterproofing method is new. Specialist contractor Schneider-Moran will install the PVC membrane, but Mosites' own crews will be performing the shotcreting.

"Due to the quantity of shotcrete on the project and the weekly productions that must be maintained due to traffic requirements, the installation of the shotcrete lining and accompanying waterproofing activities will be one of the biggest challenges on the project," says Mosites' director of heavy operations Derrick Jeannerette. "We will make sure our crews are appropriately prepared prior to production shooting."

There have been several attempts over the years to stem the flow of water from the mountain, which is made up of sandstone and quartzite, into the tunnels. The most recent major intervention was in 2005 using grout injections. "That worked well for a while, but after 15 years, the water was back," says Stump.

"The ingress of water not only causes the tunnel's fabric to deteriorate, it also leads to the build-up of ice in the winter. Maintenance crews would have to stop traffic or divert it to the other tunnel in order to knock the ice off the walls a couple of times each day," says Stump, "and knock down the icicles using paddles."

Gall Zeidler – subconsultant to the main consultant Gannet Flemming – proposed several different solutions to tackle the incoming water. "We presented the Turnpike with a bunch of options that ranged from a Pontiac used car all the way through to a Rolls Royce: a really robust design with a 100-year design life," says senior tunnel engineer Thomas Martin of Gall Zeidler.

The Commission decided on the Rolls Royce. "We have not done anything to these tunnels for a long time," says Stump. "We are looking for the 'wow' factor, so that people who use the Turnpike really know we have done something to these tunnels."

## WATERPROOFING SOLUTIONS

It isn't just age that causes the eastbound tunnel to leak more than the westbound one. Over the 30 years between the construction of the two tunnels, concrete technology has advanced; the younger tunnel was constructed from air-entrained concrete, whereas the older one wasn't.

"Air-entrained concrete contains little bubbles which means that when the water infiltrates the concrete and then freezes, there is space for it to expand into," explains Thomas Leckrone, project manager for Gannett Fleming.

"As a consequence of the action of freeze-thaw in the older, eastbound tunnel, the tunnel's extensively cracked ceiling has been totally removed. The ceiling in the westbound tunnel will remain in place. It is still sound and will prevent water from dripping onto traffic if more leakages appear in the arch above it in the future," says Martin.



*Fig. 2: Drainage installation - The new 'umbrella' waterproofing in the eastbound tunnel will be directed into the existing system beneath the tunnel.*

The eastbound tunnel, with its 18 in. (450 mm) thick concrete walls and construction joints every 30 ft (9 m), has been leaking significantly through its arch area and its walls. The tunnel did have a copper water stop, but this has worn out over the years.

"There were the options of patching and curtain grouting, but that just means that the water could pop up in another area," says Martin. Unlike an urban tunnel, where rainwater is directed from impervious surfaces such as concrete and asphalt into drainage networks, in a rural area all the rainwater just permeates down to the tunnel, points out Stump.

"Rather than trying to fight the water, we are creating an umbrella system here," explains Martin. "Water will run down the back of the PVC membrane into the existing drainage system." (Fig. 2)

"At the construction joints, the design calls for three drainage relief holes to be drilled with a 1 ft wide (300 mm) J-drain – a dimpled plastic sheeting – placed over the joint to convey water down to the side wall drains at the base of the tunnel walls. The relief holes will also be packed with filter material to prevent large solids flowing into the system," adds Martin.

"Having prepared the existing tunnel walls, Mosites will install a 0.75 in. (20 mm) geotextile fleece. Preparation of the walls involves filling in any holes to create a flatter surface, although – having installed the first few sections – it seems that the geotextile itself does a good job of smoothing things out," says Jeannerette.

The PVC waterproofing layer also incorporates water barriers welded horizontally and longitudinally to create

compartments. Grout tubes installed for each area will protrude through the shotcrete layer so that grout can be pumped into these in the event of a leak in that zone.

Once the membrane is in place, Mosites will install lattice girders at 5 ft (1.5 m) spacings with two layers of welded wire mesh supported by the lattice girders. “We hate anchors!” says Martin, who goes on to explain that, by using stainless steel channels to hang the lighting from the lattice girders, the design has avoided thousands of anchors through the new shotcrete liner of the tunnel. The shotcrete and mesh will be installed in two layers to a total thickness of 8 in. (100 mm).

Mosites expects to spend around three years in the eastbound tunnel and just a year in the westbound one. Waterproofing work in the westbound tunnel will comprise patching work in the arch area, drilling relief holes at the construction joints, and directing the water to the drainage system in the tunnel through PVC pipes located at the construction joints.

“It’s definitely a less involved version of what we are doing in the eastbound, but the idea is similar,” says Martin. “The difference here is that we are not having the same level of infiltration, so we are only addressing the primary infiltration spots.”

The design team has walked the plenum of the westbound tunnel several times to assess the water infiltration levels, most latterly in late 2019. “We noted that there was not extreme infiltration at the joints, but there was some infiltration at the shoulders,” says Martin. One of the surprise observations was that some areas of spalling were also leaking; these will be treated in a similar way to the cracks.

Crack repairs are mapped out for the arch of the tunnel and the upper and lower surfaces of the ceiling slab. Gannett Fleming has prescribed three different forms of repair using grout injection, resin, or polyurethane grout if there is water in the cracks.

## WORK WELL UNDERWAY

The Pennsylvania Turnpike Commission awarded the rehabilitation contract to Mosites in July 2019. Mosites was the lowest bidder with a cost just shy of \$110M and only \$4M below the next lowest bid.

Work started on site in August 2019 with Mosites preparing the westbound tunnel to take bi-directional traffic. The operation included additional lighting at entrance areas, directional arrow signs above the roadway, and directional arrows in the pavements themselves.

The rehabilitation contract allows Mosites to work only during weekdays in the eastbound tunnel. From Friday morning to Sunday evening, both tunnels must be open to traffic. Urban tunnels tend to have daily rush hours, but the Turnpike’s tunnels have peaks at weekend and during holiday periods due to their rural locations.

“People don’t want to sit there for an hour in traffic and then pay money to get off the toll road,” says Stump. “That means that there are tighter restrictions than for a normal



*Fig. 3a: Work underway in Eastbound - Mosites has removed the ceiling and the barriers at either side of the tunnel. Each weekend, the tunnel must be reopened to traffic.*



*Fig. 3b: Ceiling removed in Eastbound - The concrete in the older, eastbound tunnel was not air-entrained so the cracking of the ceiling was far more extensive; here we see the tunnel with its ceiling removed.*

DOT (Department of Transportation) job. That has extended the contract because we can only work here at certain times.”

Mosites must also be ready to move swiftly out of the eastbound tunnel if there is an incident in the westbound one. “To enable fast mobilisation and de-mobilisation, the contractor keeps as many materials as possible on trailers,” explains Jeannerette, “with temporary barriers always to hand inside the tunnel.”

Work started in the eastbound tunnel in February 2020 with the removal of the cracked ceiling. Mosites then moved on to demolishing the barriers that run along either side of the tunnel, followed by additions to the drainage at the base of each wall. (Fig. 3a and Fig. 3b)

Currently, Mosites is working on the left side of the tunnel installing drainage angles and porous concrete, and working with Schneider-Moran to install the PVC waterproofing to a level just above the height of the new barriers, with the construction of the barrier following on behind.



*Fig. 4: Demolition 1 - The barriers at the side of the eastbound tunnel were removed so that the new waterproofing system could be installed.*



*Fig. 5: PVC membrane installation - Specialist contractor Schneider-Moran is installing the first sections of waterproofing in the eastbound tunnel on the lower sections of tunnel wall.*

Mosites proposed some changes to the phasing of the barrier reconstruction. Rather than pouring short sections of each side, they suggested demolishing both sides during the same phase and using temporary precast barriers for the entire tunnel length on both sides, shifting the traffic lanes over by a couple of feet to give more working room. They also proposed slipforming for the barriers rather than consecutive pours, striking, and resetting the formwork.

“We think this particular project lends itself to slipform well,” says Jeannerette. “We discussed this with the owner and their designer, and they were receptive to the idea.”

The crack and spalling repair will be a precise business. “The Turnpike and their consultants have done a good job in mapping out where these repairs are. The tunnels are broken down into construction joints every 30 ft or 50 ft (15 m) (depending on the tunnel), which are all numbered so you can get a feel for where you are, how many repairs there are, and what kind of repair,” says Jeannerette. “It does require a lot of coordination between us and the inspection crews so that everybody is on the same page.” (Fig. 4)

“Having a crew that is made up of over 70% of Mosites’ own people makes a huge difference here,” says Jeannerette. All the repairs are unit price items which means that the foremen must record carefully what they have done each week. “They all understand how important it is to keep good records because we get paid for every foot they put in,” he says. “They are diligent.”

“An experienced and loyal workforce will also be vital for achieving the right quality and productivity for the shotcrete application,” says Jeannerette. “I have full confidence that the people we have will learn quickly and make a good job of it.” Mosites has employed a craft nozzleman with direct experience in the wet-mix process, since Mosites’ team usually works with the dry process, as well as a shotcrete consultant who can advise on any issues or concerns.

“The contract calls for every nozzleman to have a certain amount of experience and for each to produce mock panels which are 40 ft by 10 ft (12 m by 3 m), which is important to ensure quality,” says Dominic Reda, a partner at Gall Zeidler. “With the mock-up panels, we can physically observe them, cut the panels so that we can see how the concrete has been applied, and test the material,” says Reda. “And during construction, we will have very experienced inspectors, as part of the owner’s representatives, to physically observe that they are doing everything we have agreed.”

The shotcreting operation is complicated by the fact that it must follow right behind the PVC waterproofing application. Though it is self-extinguishing, the PVC would off-gas certain chemicals in a fire, so covering it up as quickly as possible protects road users as well as limiting the risk of damage to the membrane.

Mosites did apply for a change in the shotcreting process, to replace the mesh reinforcement with fibres, in order to speed up the whole process by cutting out the mesh fixing step – and save the owner money – but the Turnpike and its designers decided not to go with this option due to concerns about the finished surface which will be coated with a sprayed epoxy.

“The waterproofing and shotcreting process must be like a well-oiled machine,” says Jeannerette. Schneider-Moran will be working two shifts – day and night – to install the geotextile and membrane, with Mosites’ teams spraying concrete on one shift and fixing lattice and mesh on the other, as well as removing the temporary lighting from the next section before the waterproofing work can begin.

“Achieving the required production may take time,” says Jeannerette. “Welding on the water barriers, for instance, is a time-consuming process, so any ideas which lead to savings there would be welcome.”

“It’s a very involved process. It will have to be just like clockwork every week for a year straight,” says Jeannerette. “That will be the biggest challenge.” (Fig. 5)

## MULTI-DISCIPLINARY

For the owner and its designer, this tunnel rehabilitation project involves a jigsaw of stakeholders and regulations. “There are so many different disciplines involved, so many moving parts, so many different departments,” says Stump. “There are restrictions with traffic, on the available working hours, and a lot of things in each phase that have to be buttoned up before you can open traffic up.”

“Though Mosites has multiple subcontractor interfaces to handle, long relationships and related experience will help counter any issues here,” says Jeannerette. “For instance, the electrical contractor, which has a big role to play on this project, has worked with Mosites many times before.

“They are from the Pittsburgh area, so we have worked with them a bunch,” he says. “We have a good level of comfort with these guys.”

The mechanical contractor, which will be installing Saccardo nozzles for ventilation to replace the existing slot ones, is new to Mosites, but the scope of works isn’t.

And at the heart of all this is Mosites’ supervisor, Mike Rhoads. “We have a very experienced superintendent who has a good, open line of communication with all the subcontractors,” says Jeannerette.

The location of the project, however, has proved somewhat challenging. Since it is in the middle of the countryside, there’s no popping to the local hardware shop to top up supplies. “If a lorry is heading out to site, you’d better check and double check that everything it’s supposed to have on it is there,” says Jeannerette.

The COVID 19 pandemic has put the project a little behind schedule. “Unlike some other states, Pennsylvania shut down all its construction sites which meant that Mosites was off the job for five-to-six weeks, all of which was used to plan a safe return,” says Jeannerette. “On the flip side, some of the summer restrictions on working periods have been relaxed a little.”

There are now protocols in place for working at a safe distance, where possible, and wearing extra PPE where it is not; hand washing stations on site; and increased cleaning regimes for offices and communal areas. Thankfully, no one working on the project has tested positive for the virus.

“Materials deliveries have been affected by outbreaks further afield. Some items coming from California were delayed by around six weeks, and waterproofing materials from Germany also arrived late. However, Mosites had allowed enough lead time to be able to absorb those delays,” says Jeannerette. Pandemic allowing, the rehabilitation of both tunnels should be complete by late summer 2023.

## MORE TO COME

Although Mosites’ workload is largely rehabilitation projects — whether roads, bridges, or tunnels — the ‘umbrella’ waterproofing design for the eastbound Tuscarora Tunnel is a first for the contractor. That is also true for main designer Gannett Fleming. “When we were reviewing the proposals for design, we wanted to put together a good team,” says Stump, who will have spent 10 years working on the design and delivery of the rehab by the time it’s done. “We wanted Gannett Fleming due to their experience with our tunnels and Gall Zeidler on the team because they had the waterproofing experience and had done it before.”

With many tunnels in the US reaching the ends of their serviceable lives, and groundwater almost always one of the issues to be tackled, this most certainly won’t be the last time such a system is employed. Gannett Fleming and Gall Zeidler, both separately and together, are working on the design of several tunnel rehabilitation projects in other states.

## 2022 HONORABLE MENTION

### *Project Name*

**Pennsylvania Turnpike Commission –  
Tuscarora Tunnel Rehabilitation**

### *Location*

**Burnt Cabins, PA**

### *Shotcrete Contractor*

**Mosites Construction Company**

### *Architect/Engineer*

**Gannett Fleming Inc.**

### *Material Supplier*

**New Enterprise Stone & Lime Company Inc.**

### *Equipment Manufacturer*

**King Shotcrete Equipment Inc.**



*With a career that began on site as a graduate engineer, **Kristina Smith** has been writing about civil engineering and construction for over 20 years. Starting out as a technical writer on Construction News, she progressed to features editor before being poached by Property Week to be assistant editor. After a stint as editor on*

*the monthly magazine, Construction Manager, Kristina began her freelance career in a bid to balance home and work commitments. Tunnelling articles are among her favourites, with every assignment offering the chance to learn something new and to talk to some of the world’s most interesting engineers and experts. Kristina has been writing for Tunnelling Journal for 12 years, covering topics from tunnel linings to deep interventions, and reporting on tunnelling projects around the world.*