RECYCLING A BYWAY

A significant portion of a scenic byway through a pristine national forest was completely reconstructed and upgraded using a method that recycled 100 percent of the existing roadway, shoulders, and subgrade soils—saving time and money and reducing impacts on the environment.

By Peter J. Kempf and
Jason A. Snyder, P.E., M.ASCE

Pennsylvania State Road 321, which carries the Longhouse National Scenic Byway through Allegheny National Forest, is used not just by outdoor enthusiasts but also by the forestry and gas and oil industries.

NORTHWESTERN Pennsylvania is the home of the commonwealth's "Wilds" region, which boasts expansive white pine and hemlock forests, pristine rivers and lakes, and a wide variety of wildlife, including elk, beavers, bobcats, bears, otters, turkeys, and white-tailed deer. The Wilds is also home to many of Pennsylvania's cultural and historical resources, including the Pennsylvania Grand Canyon (Pine Creek Gorge), the Kinzua Dam and Allegheny Reservoir, Cherry Springs State Park, and even Punxsutawney Phil, the famous groundhog believed to have the ability to predict the lengths of winters. Among the region's landmarks is the Kinzua Viaduct, the longest and tallest railroad bridge in the world at the time of its construction. (Read "Lessons from the Kinzua," by Thomas G. Leech, P.E., S.E., A.M.ASCE, Jonathan D. McHugh, P.E., A.M.ASCE, and George Dicarlantonio, P.E., *Civil Engineering,* November 2005, pages 56–61.)

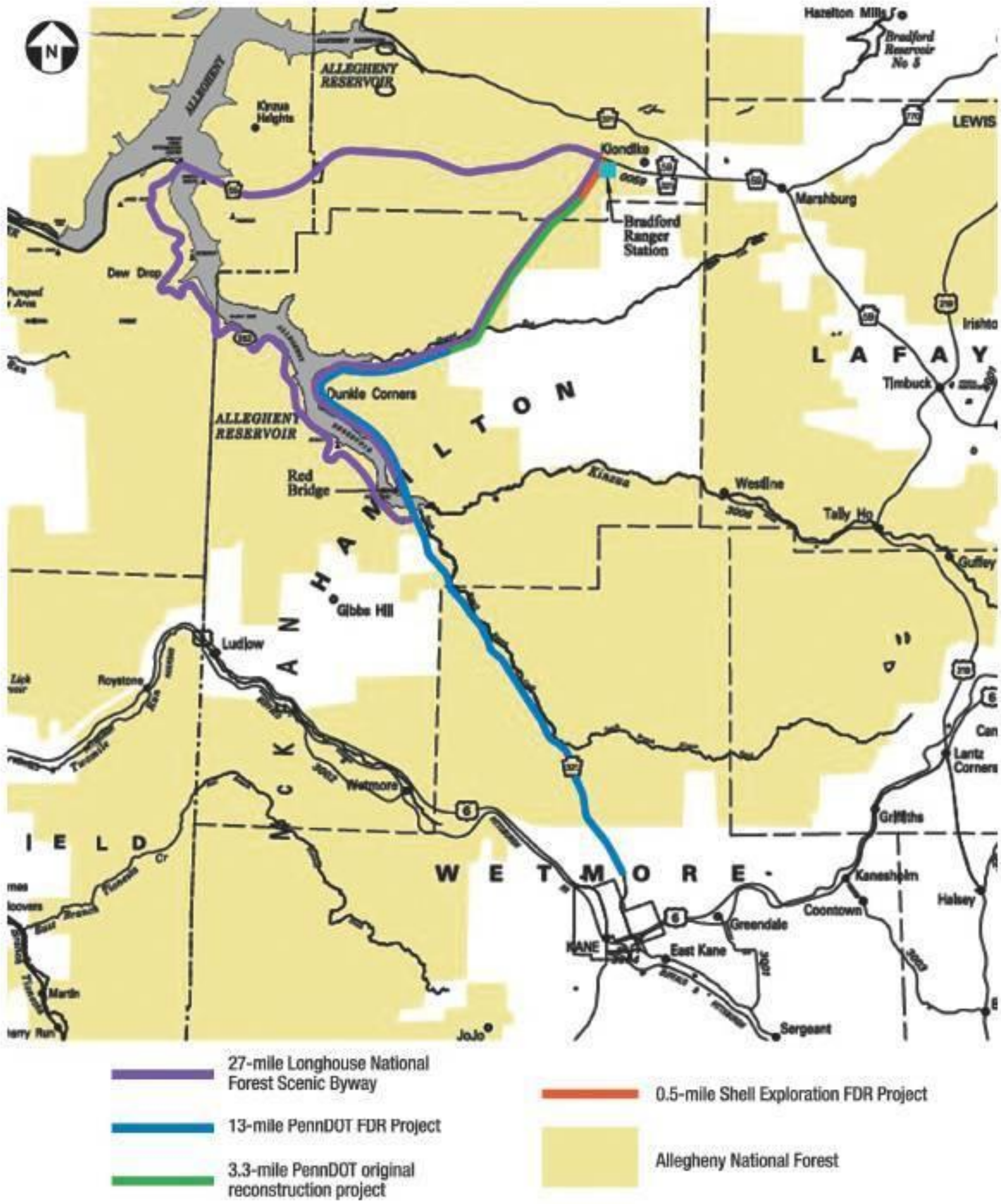
Three state scenic byways are located in the region: the 100 mi Bucktail Trail follows the Old Sinnemahoning Trail; the 27 mi High Plateau passes through Sproul State Forest; and the Kinzua provides access to one of the engineering marvels of the 19th century. On the federal level, the 27 mi Longhouse National Scenic Byway takes travelers deep into the forests of McKean County.

That so many of the roadways through this rural area of the country are paved can be attributed to the former Pennsylvania governor Gifford Pinchot. Pinchot was the first chief of the U.S. Forest Service (1905–10) and the 28th governor (1923–27 and 1931–35) of Pennsylvania. (At that time Pennsylvania governors were prohibited from serving consecutive terms.) In addition to his renown for forestry management, he was responsible for the development and paving of more than 20,000 mi of Depression-era roads in Pennsylvania, his goal being to "get the farmers out of the mud." Most of the so-called Pinchot roads were cost-effectively constructed and were intended to carry traffic from farm to market. The majority of these roads are still in use, but they were never intended to carry modern traffic volumes and loads. Damage to Pennsylvania's roads is often exacerbated by weather. The area for the most part is underlain by glacial till, which is susceptible to severe frost-induced heave. Nearly daily freeze/thaw events throughout the late winter and early spring can result in complete roadway failure and loss of portions of the transportation network.

Pennsylvania State Route 321 (SR 321) is a roughly 19 mi segment of roadway that for the most part traverses the Longhouse National Scenic Byway. The byway provides access for many activities within Allegheny National Forest, including hiking, fishing, and hunting, as well as forestry and gas and oil exploration. But the paved section of SR 321 has not been able to withstand continued heavy truck traffic. Records maintained in the roadway management system of the Pennsylvania Department of Transportation (PennDOT) indicate that the last significant paving project on SR 321 was completed in stages between 1966 and 1969 and that maintenance seal coats were applied on the basis of a 10-year cycle beginning in the 1980s.

The byway, which was never designed for heavy truck traffic, had been deteriorating for years, *right,* and was eventually limited to use by vehicles weighing less than 10 tons. Under an innovative program that enabled workers to crush and reuse the roadway material on-site, the roadway was reconstructed and improved at a cost savings of more than $600,000.

To preserve the integrity of SR 321, signs restricting vehicular weight of 10 tons were posted on July 1, 2010. Such heavy haulers as timber harvesters and oil and gas companies that wished to use the route were required by Pennsylvania’s posting and bonding regulations to “bond” the roadway, that is, to take responsibility for any damage that might occur if they operated heavier vehicles on the roadway and to address any damage that their hauling activities might cause. Even so, significant hauling activities exposed the roadway to severe traffic loads throughout 2013 and 2014, resulting in significant base failure and severe pavement degradation. Approximately $1 million in roadway milling and filling repairs, as well as upgrades, were made by the timber harvesting and oil and gas exploration industries along the corridor in accordance with their maintenance bonds. The road, however, continued to degrade around the repairs, resulting in significant challenges for PennDOT as it tried to maintain the roadway in a safe and passable condition.



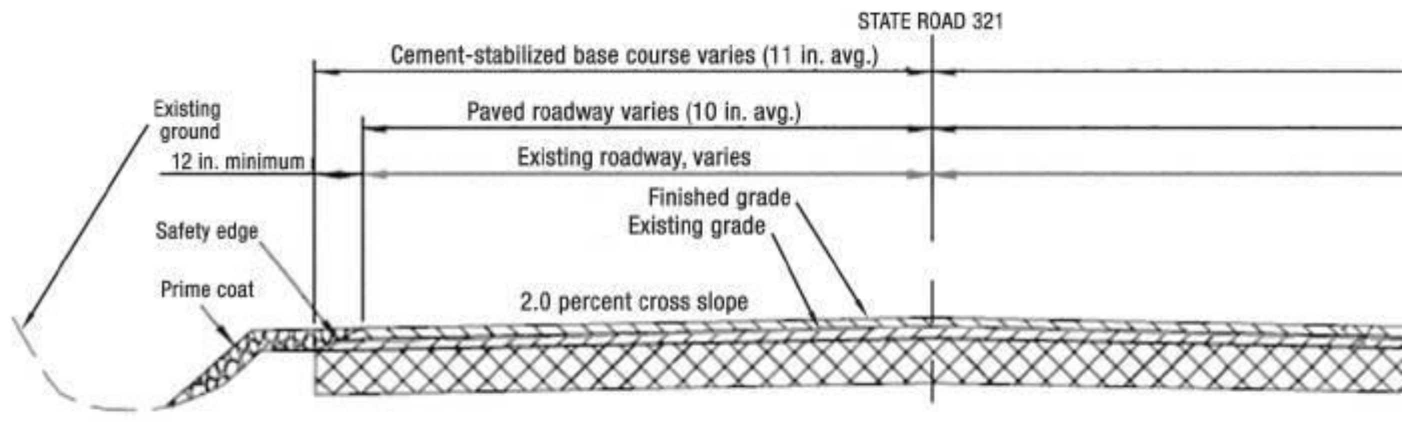
PROJECT LOCATION

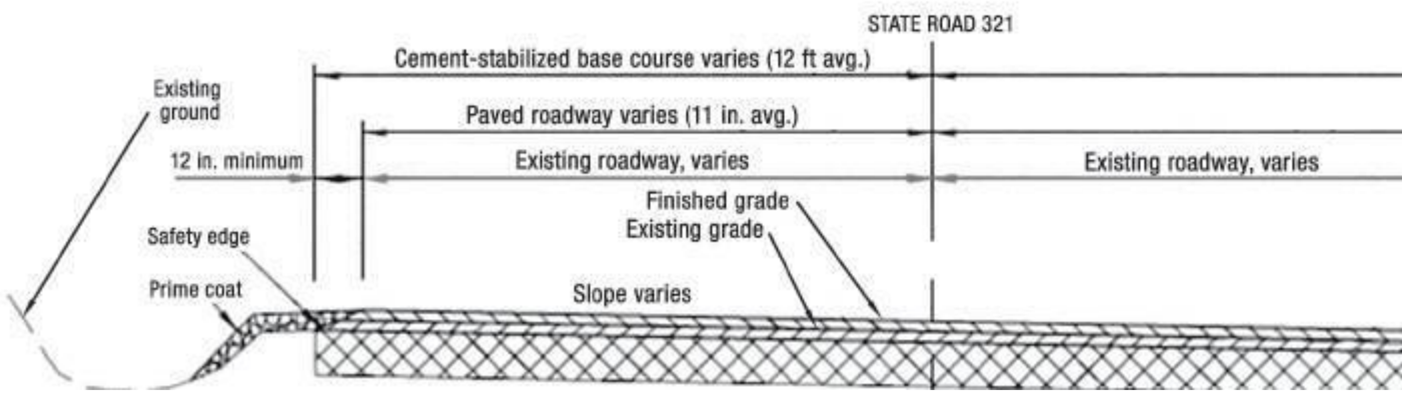
As a result, three independent projects for the corridor were coordinated through PennDOT's District 2-0, which is based in Clearfield, Pennsylvania. The district and the commonwealth, with the concurrence of the U.S. Forest Service, initially proposed a repair to portions of the roadway that would include conventional widening, base repair, milling, and placement of variable-depth binder and bituminous overlay over a length of approximately 3.3 mi. Meanwhile, one of the oil and gas companies—Shell Western Exploration and Production, Inc. (SWEPI LP), based in Houston—as part of its obligation to maintain the roadway in a safe and passable condition, determined that it would be more cost effective to reconstruct a 0.5 mi portion of SR 321 at its intersection with SR 59, adjacent to the Bradford Ranger Station, than to continually carry out repairs. Shell submitted highway reconstruction plans and full-depth reclamation (FDR) pavement design reports to PennDOT for review. The project was quickly reviewed and approved by PennDOT and completed in late July 2013.

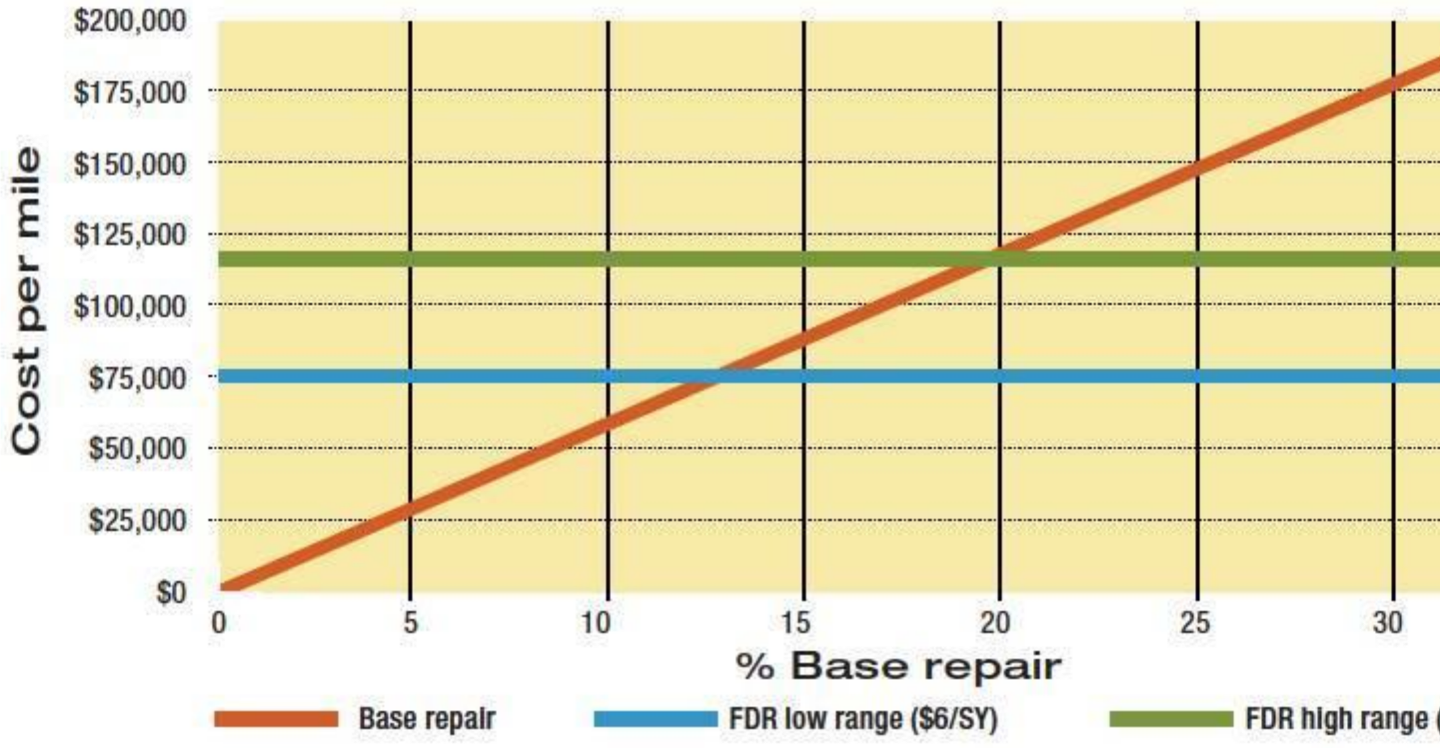
Fortunately, while the initial project was under design, Act 89, also known as the Pennsylvania Transportation Bill, was signed into law in 2013 by Governor Tom Corbett, authorizing $2.3 billion per year in badly needed transportation funding. The bill allowed PennDOT to fund upgrades to the remaining 13 mi portion of roadway with the intention of utilizing an FDR approach to accommodate the tight design and construction scheduling window. This would be the third project coordinated by PennDOT. The department fast-tracked this project and coordinated the contract letting dates to encourage bidders to bid aggressively on both the 3.3 mi section and the 13 mi section.

A scoping and environmental review meeting kicked off the fast-tracked (13 mi) portion of the SR 321 project on February 12, 2014. If it was to meet the May 8, 2014, contract award date, the design team had less than two months to address community needs and environmental concerns and develop an inclusive bid package. The department’s goal was to issue a notice to proceed to the contractor on June 8, 2014, with a substantial completion date for the project scheduled at the end of the 2014 construction season. In view of the historical pavement data, the underlying glaciated soils, and the extent of the damage to SR 321, as well as the need for an environmentally responsible design, conventional repair methods were determined to be too time consuming and costly. Structural overlays would not address the base failure issue; in fact, they would hide the problem while creating grade problems and making it necessary to reset the guardrail, regrade ditches, and resolve other drainage concerns. Given the success of several FDR contracts in the area, the department design team decided on an FDR approach. The figure below illustrates the cost of FDR versus that for conventional base repair determined on the basis of data collected between 2010 and 2014 on more than 500 mi of FDR roadway designed by the team on this project, which came from the Harrisburg, Pennsylvania, office of URS Corporation (now a part of Los Angeles–based AECOM). The red line represents the cost per mile for conventional base repairs calculated on the basis of the percentage of failure of the pavements, while the green line and the blue line represent the historical low and high ranges of FDR costs per mile. In view of the fact that the SR 321 project exhibited more than 20 percent base failure throughout the length of the roadway, it was deemed more cost effective to use FDR for the entire project while stabilizing 100 percent of the roadway subgrade, not just the 20 percent that would be repaired during the conventional base repair process. Pavement design was contracted through an openend design contract with URS in conjunction with Geo-Technology Associates, Inc., of York, Pennsylvania; PennDOT's District 2-0 prepared the bid package in-house.

THE SLAB CREATES A SNOWSHOE EFFECT, DISTRIBUTING THE VEHICULAR LOADS OVER THE LOW-QUALITY GLACIAL TILL SUBGRADE.







ROADWAY REHABILITATION COST COMPARISON CHART

Soil sampling, laboratory testing, and analyses were completed within a very tight design window in May 2014 using a combination of PennDOT maintenance forces and staff members from URS and Geo-Technology Associates. Nine test pits were excavated along the original 13 mi corridor. The majority of the subgrade soils were silty sand and gravel changing halfway through the project to the predominantly clayey sand and gravel that are representative of the typical glacial tills found in the area. Laboratory testing was conducted to determine the particle size, liquid and plastic limit, and California bearing ratio of the samples, and use was also made of the Proctor compaction test. The URS design team cataloged the pavement and subgrade soil thicknesses and types, comparing the information with the historical roadway data in PennDOT's roadway management system.

Given the remoteness of the site and the extent of the damage to SR 321, FDR was determined to be the most economical solution, as well as the fastest, for it would eliminate the excessive costs associated with undercutting the roadway, disposing of the materials, and hauling virgin material long distances. Moreover, the roadway could be reopened to local traffic each day, minimizing inconvenience to the traveling public. With the FDR design pending, the department decided to put the project out for bids on the basis of a variable cement application rate of 3 to 8 percent, the bid quantity of cement computed for the maximum rate. The design would be provided to the contractor prior to the start of work.

Cement was transported to the project in bulk tanks and transferred pneumatically to smaller spreaders, which worked section by section.

Soil analyses for the project were conducted while the project was out for bids. Numerous admixtures can be added to a roadway during the pulverization and mixing process, including emulsions, fly ash, calcium chloride, lime, and cement. On the basis of the soil type, the asphalt and aggregate thicknesses, and environmental considerations, portland cement was chosen to increase the strength of the proposed pavement section. The addition of portland cement creates a low-grade concrete material and enables the section that underwent FDR to act as a slab. The slab creates a snowshoe effect, distributing the vehicular loads over the low-quality glacial till subgrade.

The FDR mix designs were prepared and analyzed for the addition of 3, 5, and 7 percent portland cement to the roadway, the goal being to create a pavement layer that would have an average compressive strength of 300 psi. The pavement section was designed in accordance with PennDOT's *Pavement Policy Manual: Publication 242* by using Dar-WIN, a pavement design and analysis system developed by the American Association of State Highway and Transportation Officials.

On the basis of close collaboration by URS, Geo-Technology Associates, and PennDOT, the design team recommended a 12 in. FDR chemical stabilization using 4.5 percent type I/II portland cement by dry weight (or approximately 48 lb/sq yd) with a 3 in. bituminous binder and 1 1/ 2 in. bituminous wearing course.

Both the initial 3.3 mi project and the fast-tracked 13 mi project were let on May 8, 2014, and IA Construction through its affiliate Base Construction Technologies, Inc., of Grove City, Ohio, was the successful low bidder for both projects. Once PennDOT's crews arrived at the site, they determined that additional deterioration had occurred from the continued use of the roadway by the industrial sectors and that the base repair and widening methods designed for the initial project would therefore not be sufficient.

The entire roadway and the subgrade material, to a depth of 12 in., were pulverized and mixed to create a homogeneous material.

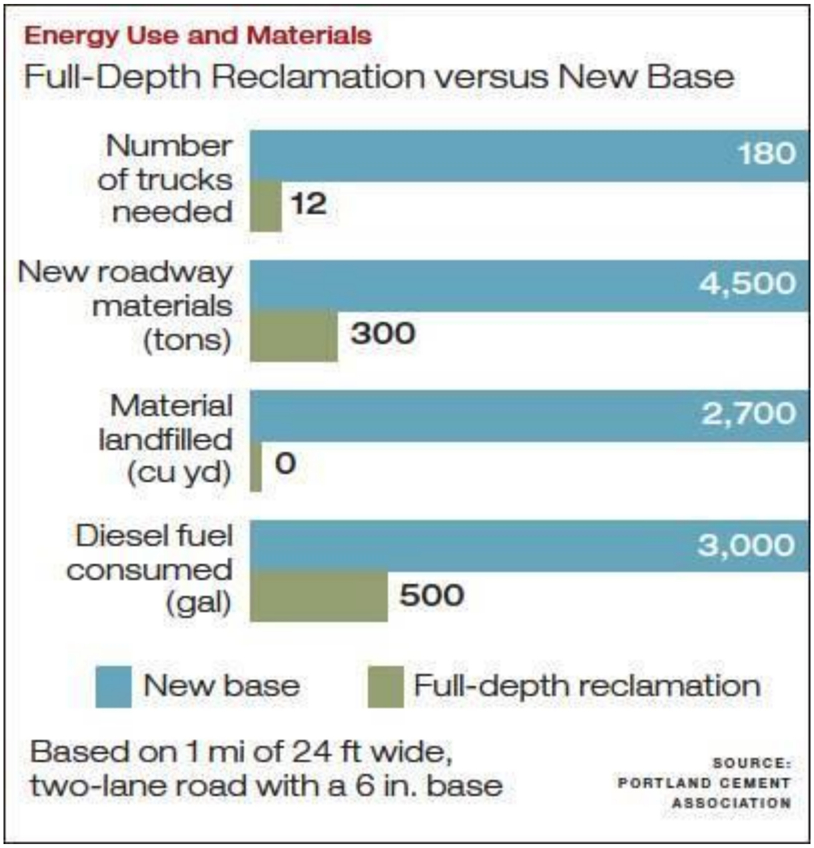
Since the same contractor had been chosen for both projects, the department was successful in negotiating modification to the contract to change the rehabilitation method to include FDR in lieu of the bituminous base repair and widening. The U.S. Forest Service concurred with this change in the scope of work. As a result of this modification and other contract savings, overall savings on the project exceeded $600,000. The total project cost to reconstruct the combined 16.3 mi section of SR 321 was $9,818,888, or approximately $600,000 per mile.

The original pavement design report was submitted to the department on June 1, 2014. An expedited review procedure enabled the design team to address the department’s comments and issue the final pavement design report on June 11, 2014, only three days after the contractor’s notice to proceed.

Two separate reclaiming operations were used on the project to ensure consistency and maximize efficiency. The first, which used machinery from Wirtgen America, based in Antioch, Tennessee, focused on pulverization, grinding the entire roadway and subgrade and mixing it to a homogeneous mixture to a depth of 12 in. The vast majority (95 percent) of all material produced by the reclaiming operations was required to meet a 2 in. nominal aggregate size.

GREAT CARE WAS TAKEN TO ENSURE THAT ENVIRONMENTAL REGULATIONS WERE MET IN HANDLING THE CEMENT. ALL CEMENT WAS MIXED, SHAPED, AND COMPACTED UPON PLACEMENT TO AVOID FUGITIVE DUST EMISSIONS.

In addition to pulverization, this team was responsible for making minor vertical grade adjustments and reconstructing both the crown and the superelevation of the roadway. It was also responsible for roadway compaction, following the former alignment of SR 321. Following this operation was a team equipped with a motorized grader, a padfoot compactor, and a smooth drum compactor. PennDOT provided extensive survey control to ensure that the roadway was reconstructed in its original position within the commonwealth's right-of-way.



Since pulverization activities are typically more efficient than stabilization activities, the pulverization team made good progress along the corridor. To further increase efficiency while reducing erosion potential, a 4 mi restriction was placed on the length of roadway that could be pulverized in advance of stabilization.

The second operation used a Wirtgen reclaiming machine to execute chemical stabilization. Portland cement applied to the surface in front of the reclaimer was immediately mixed and hydrated by the machine. Again, a motorized grader, a padfoot compactor, and a smooth drum compactor followed to ensure that the proper density was achieved.

The optimum moisture content and target in-place density were determined at the start of each workday. Both moisture content and density were then monitored throughout the day. Although this project contained relatively consistent subsoils, the FDR technician recalculated the maximum target density if the mixture changed during the day. The maximum dry density of the subgrade soils varied from 110.7 to 120.3 pcf, while the target density for this project was 98 percent with optimum moisture at no more than 3 percent.

Great care was taken to ensure that environmental regulations were met in handling the cement. All cement was mixed, shaped, and compacted upon placement to avoid fugitive dust emissions. The contractor was responsible for making sure that all equipment was fully functioning on a daily basis. Worn, damaged, and missing skirts and filters were replaced immediately or the equipment was removed from service.

Cement was transported to the project in bulk tanks and transferred pneumatically to smaller spreaders. Air pressure was regulated during the transfer process to minimize the chance of fugitive dust, and the transfers were managed by the inspector on-site. Transfers were prohibited in the immediate vicinity of water bodies, dwellings, and livestock. Cement was not applied during periods of high wind.

Once the dry cement was placed, the contractor could use the reclaimer and the spreader only within the lift. Care was taken to avoid pushing cement onto the shoulders and into the ditches and cross-pipes during the process; the equipment was operated in a manner and at speeds determined to reduce dust emissions.

Great care was taken at all bridge approaches and structures to guarantee a smooth transition both into and out of each structure. The FDR base continued into each structure so that the full paving section could be constructed without the need to either install a thinner paving section or create a “bump” at the structure. Temporary aggregate wedges were installed as a transition between the FDR and the structure prior to paving. Additional measures for controlling erosion also were implemented, including filter socks and rock filters, at all structures and water courses.

Upon completion of the FDR, a bituminous prime coat was applied to the roadway to retain moisture and aid in curing. Five days were allowed for the FDR to cure and gain sufficient strength prior to paving activities or use by trucks and other heavy vehicles. However, the contractor was able to allow passenger vehicles and light trucks to use the roadway almost immediately, one of the many benefits of FDR.

In view of the remoteness of the project, segregation of the asphalt in transit was a concern. A Roadtec material transfer vehicle was used to remix the asphalt so as to eliminate segregation and improve ride quality. The Roadtec vehicle then delivered the material to a Caterpillar asphalt paver. A Caterpillar vibratory roller was used on the first pass, a Caterpillar pneumatic roller was used on the second pass, and a BOMAG finish roller was used on the third pass. Together, these passes ensured the proper compaction. Because of severe lake-effect weather, the asphalt mix, which was designed in accordance with the American Association of State Highway and Transportation Officials' Superpave method, contained a PG 58-28 binder to counteract shrinkage cracking. (Such binders are capable of withstanding a seven-day high temperature of 58ºC and a one-day low temperature of –28ºC.) The contractor achieved nearly a 100 percent acceptance of its material placement.

In accordance with the contract documents and PennDOT specifications, cores and loose box samples were taken by the paving technician throughout the project to assess material quality and compaction. To determine the optimal rolling patterns for achieving a specified compaction density for a particular asphalt mix, the commonwealth allows a technician to prepare a control strip and graph the number of roller passes versus densities of the strip obtained with the aid of nuclear equipment (capable of measuring, for example, the attenuation of gamma radiation). This was accomplished in the field for this project. Asphalt material quality assurance and quality control were provided daily by the asphalt plant and the associated PennDOT staff members. The entire project, including tracking reports, quantities, change orders, and payments, was administered through PennDOT's Electronic Contract Management System.

The safety of those within work zones and of the motoring public is a primary concern on all PennDOT projects. Unfortunately, since 1970, 85 highway workers have been killed while on duty in the commonwealth. The SR 321 project used both intermittent and full-road closures with detours to improve safety and productivity. Full personal protective equipment, including appropriate clothing, hard hats, and gear to protect hearing and vision, are standard on all PennDOT projects. As an added safety measure, the SR 321 project was limited to daylight operations.

PennDOT is also committed to good community relations, and even with the fast-tracked approach, this project was no exception. The department coordinates all work within and adjacent to the confines of Allegheny National Forest with the engineer of the forest, Daniel Salm, and his staff.

In addition to working with forestry personnel, there was careful coordination with the nearby Red Bridge Campground and with surrounding businesses to ensure access for campers during the construction activities, including those with recreational vehicles and trailers. PennDOT provided electronic updates through the campground's electronic reservation system and website, and detour phasing was implemented to provide access to the campground from either the southern or the northern approach at all times.

CREDIT CATEGORY	APPLICABLE POINTS	EARNED POINTS	INNOVATION POINTS	TOTAL POINTS PURSUED	% OF APPLICABLE POINTS
Quality of life	155	25	1	26	17
Leadership	106	37	0	37	35
Resource allocation	89	72	3	75	84
Natural world	126	24	1	25	20
Climate and risk	116	9	1	10	9
Total project points	592	167	6	173	29

SCORES ENTERED FOR ENVISION ASSESSMENT

The team took great care to protect the pristine surroundings of Allegheny National Forest. While cost savings and speed were strong arguments in favor of FDR for this reconstruction project, the final factor was its minimal effect on the environment.

In assessing an FDR project in relation to a total reconstruction project, the design team considered the Portland Cement Association's cost comparison data (see the chart on page 79). That association's data were found to be conservative compared with the findings from this project. The project recycled 100 percent of the existing roadway, shoulders, and subgrade soils over a length of 16.3 mi, and its remote location gave FDR an overwhelming environmental benefit. On the basis of the design engineer's calculations, approximately 145,000 tons of material were recycled in place. In addition to approximately 4,600 tons of portland cement, roughly 55,000 tons of Superpave hot-mix asphalt was used.

The team was able to recycle the entire roadway in place, eliminating the need to remove, transport, and recycle the existing paved roadway. If they had been necessary, such steps would have involved approximately 45,000 tons of recycled asphalt pavement. The approach taken also made it unnecessary to remove and transport to landfills roughly 140,000 tons of unsuitable subgrade soils and to import approximately 140,000 tons of virgin aggregate to create a suitable road base.

Considering the material volumes outlined above, approximately 15,000 to 16,000 truck trips were eliminated, saving well over 150,000 gal of diesel fuel and, given the project's remote location, significantly reducing carbon dioxide emissions.

The process is also considered to be a particularly effective management practice because it immediately stabilizes the roadway surface, thereby eliminating the potential for erosion and sedimentation in nearby areas.

The design team completed the Institute for Sustainable Infrastructure's Envision checklist; however, the substantial registration fee ($1,000) and verification fee ($17,000) made Envision certification impractical for this publicly funded project. The team nevertheless feels that it demonstrated its commitment to environmental stewardship. The table above presents the results of the Envision assessment, which would have made the project eligible for bronze or perhaps even silver certification.

The project was completed on time (November 3, 2014) and under budget. The second FDR project to be completed by PennDOT's District 2-0, it is the largest PennDOT FDR undertaking known to have been completed in Pennsylvania. The project was honored in 2015 in the awards program in recycling organized by *Roads & Bridges* and the Asphalt Recycling and Reclaiming Association. The successful completion of the SR 321 project has led to the inclusion of FDR in the design of a large project on SR 44 and SR 144 scheduled for this year in Pennsylvania's Potter County. That endeavor will include approximately 30 mi of FDR roadway stabilized with portland cement, giving PennDOT's District 2-0 more than 60 mi of FDR roadway. **CE**

Peter J. Kempf is the posted and bonded roads coordinator for the Pennsylvania Department of Transportation's District 2-0, and Jason A. Snyder, P.E., M.ASCE, is a principal engineer and the Appalachian basin surface transportation manager for AECOM and works in the firm's Harrisburg, Pennsylvania, office.

Kempf

Snyder

PROJECT CREDITS Managing agency: Pennsylvania Department of Transportation District 2-0, Clearfield, Pennsylvania **Primary consultant:** URS Corporation (now AECOM), Harrisburg, Pennsylvania **Primary contractor:** IA Construction through its affiliate Base Construction Technologies, Inc., Grove City, Ohio (Nathan Kellett, project manager)