REEVALUATE RESEARCH RENEW

RECYCLING PHILOSOPHY IN NORTH CAROLINA

AZAM AZIMI, FRANKIE DRAPER, AND MARIE CASEY

North Carolina is among the fastest-growing states in the nation, with some of the top technology centers in the country. The state's Research Triangle area (Raleigh, Durham, and Chapel Hill) has been continually rated one of the most desirable places in the nation to live and work. Other metropolitan areas on the Piedmont Interstate 85 corridor, such as Charlotte and the Triad area (Greensboro, High Point, and Winston-Salem) continue to attract commerce, industry, and new residents. This influx has added to the already enormous amount of waste produced in the state. The responsibility for disposal and recycling falls to the state and local governments. As waste proliferates in the state, disposal sites are dwindling.

The North Carolina Department of Transportation has a long history of using recycled and solid-waste materials. Since the early 1980s NCDOT has routinely milled and recycled its asphalt pavements, used pavement lane markings made with recycled glass beads, and incorporated reinforcing bars made from recycled steel into transportation structures. The department has allowed the replacement of up to 20 percent of cement with fly ash in most classes of concrete, used concrete bridge slabs from bridge removals as artificial fishing reefs, and taken the initiative to integrate other waste and recycled products into highway construction. The ratification of the North Carolina Solid Waste Management Act of 1989, in addition to widespread public interest in preserving a clean environment, prompted NCDOT to take further action to address recycling and solid-waste management.

The act requires all North Carolina state agencies to develop solid-waste management programs, meet certain waste-reduction goals, and promote the successful development of markets for recycled items. The department of transportation has gone beyond the minimum requirements of state law through its research, pilot projects for trial use of products, national literature review, outreach to private manufacturing industries, review of specifications for deterrents, and efforts in other areas to enhance acceptance and use of solid wastes and recycled products in state transportation activities. The department developed policies to institutionalize a recycling philosophy in both internal operations and its contracting and purchasing processes.

NCDOT established the Recycled Products and Solid Waste Utilization Task Force as a central point of contact for various agencies, municipalities, and industries with specific proposals to use recycled or solid-waste materials in highway construction or maintenance operations. The task force establishes goals for the use of recycled and solid waste materials and identifies products for further study and analysis in market development. The task force also acts as the department's contact for individuals and industries interested in developing a market for recycled and solid waste products.

INCENTIVES AND RESULTS

A recycled products and solid waste materials provision is currently included in all NCDOT projects that are let to contract. This provision provides a monetary reward to contractors who successfully propose a method to incorporate waste materials in projects, including plastic; recycled plastic; glass; paper; cardboard; shingles; tires; fly ash; bottom ash; silica; and debris from clearing and grubbing of construction sites, demolition of structures, and pavement removal.

NCDOT's first targeted recycling project was awarded in February 1991 and construction was completed in July 1994. This effort was unique in the range of products and ideas tested in a single

Tire Chips

A New Road-Building Geomaterial


HUMPHREY

Placing tire chips with dump truck and bulldozer.

Tire chips have unique properties that make them particularly useful for road construction: low compacted density, low lateral earth pressure, low thermal conductivity, and high permeability. This material has already been put to use in more than a dozen U.S. highway projects. Each cubic meter of tire-chip fill contains 100 scrap tires (75 tires per cubic yard). A typical highway project uses many tires; a recently constructed tire-chip fill in Maine, which was 120 meters (400 feet) long, used 200,000 tires. Highway construction has the potential to make a significant contribution to disposal of the 2 billion to 3 billion scrap tires that are stored or discarded throughout the United States.

The in-place density of tire chips is less than 50 percent of that for a typical gravel fill. This makes tire chips an ideal lightweight fill to stabilize embankments against landslides. Tire chips can be placed with conventional earthmoving equipment. In 1989 the Oregon Department of Transportation used a tire-chip fill that was 4.3 meters (14 feet) thick to lighten the load at the top of an embankment vulnerable to landslide. In Maine tire chips are being used to construct a bridge-approach fill that is also 4.3 meters thick to correct stability problems caused by a weak clay foundation.

What about the effect of a compressible tire-chip layer on pavement life? For two projects in Maine, it was found that placing 1.8 meters (6 feet) of soil cover over 0.61 meters (2 feet) of maximum-size tire chips yielded tensile strains at the bottom of the test pavement that were the same as for a control section with no tire chips. Even for soil covers as shallow as 0.76 meters (2.5 feet), the tensile strains at the bottom of the pavement were only 40 percent greater than those in the control section.

The low unit weight and high permeability of tire chips makes them an attractive retaining-wall backfill. A test wall constructed at the University of Maine showed that the lateral earth pressure at the base of tire-chip fill 4.3 meters.(14 feet) thick with a 36-kPa (750-psf) surcharge was less than 50 percent of that for a typical gravel fill. Lower pressures would allow thinner, lower-cost walls to be constructed. These low earth pressures could result in significant cost savings for retaining walls and bridge abutments.

Tire chips are also a good thermal insulator to limit frost penetration beneath roads. Their thermal resistance is approximately eight times higher than that of gravel. A test project constructed on a gravel-surfaced road in Maine showed that 0.3 meters (1 foot) of tire chips reduced the depth of frost penetration by 40 percent.

Finally, tire chips are inexpensive compared with natural fill materials. Tire chips can typically be purchased for between $2 and $13 per cubic meter ($1.50 to $10 per cubic yard). Their affordability, combined with their proven uses, is sure to increase their rate of use in highway construction.

—Dana N. Humphrey
University of Maine

project, including chipped tires for embankment fill materials, ground tires for hot-mix asphalt, and whole truck tires to construct a retaining wall. The clearing and grubbing debris from the project construction site was used for erosion control, and leaf mold was applied as plant mulch. Recycled plastic fence posts were integrated into control-of-access fencing, and recycled plastic posts served as roadway delineators. Recycled plastic traffic control barricades and refurbished traffic signal heads were also used.

Additional recycled and solid-waste materials were incorporated into a second recycling project awarded in December 1992 and completed in 1994. In addition to materials incorporated in the first project, crushed glass served as drainage aggregate, and plastic pipe made with recycled polyethylene resins was used for the first time. These pilot projects will be periodically monitored and evaluated.

A total of 15 construction projects containing recycled and solid-waste products have been

Azam M. Azimi is value management engineer, Frankie Draper is special services engineer, and Marie Casey is resource conservation engineer, North Carolina Department of Transportation.

awarded to date by NCDOT, and more than 3 million tires have been reused. The incorporation of chipped tires into embankment fill appears to be the most cost-effective way for NCDOT to divert used tires from landfills.

Where Rubber Meets Road

The Intermodal Surface Transportation Efficiency Act of 1991 required state highway departments to use crumb-rubber modifiers in asphalt. NCDOT has awarded six projects that incorporate this material, recycling approximately 120,000 scrap tires at a cost of $420,000 more than conventional asphalt pavement.

ISTEA does not address the cost-effectiveness of crumb-rubber modifiers. Environmental, health, and safety concerns also exist in relation to the use of crumb-rubber modifiers in hot-mix asphalt production. According to a study conducted for NCDOT, although the use of crumb-rubber-modified asphalt does not seem to significantly increase total pollutant emission rates, hazardous air pollutant emissions do seem to significantly increase. Inadequate data exist on the national level to develop a quantitative characterization of absolute or relative human health or environmental risks associated with production, application, recycling, or disposal of crumb-rubber-modified asphalt.

NCDOT joined 47 other state departments of transportation, through the American Association of State Highway and Transportation Officials, to adopt a resolution requesting the repeal or substantial modification of the ISTEA requirement. The U.S. Congress repealed the provision when it passed the National Highway System Act in November 1995.

The department has incorporated scrap rubber into some of its applications. The use of 2,500 whole scrap tires in the construction of a retaining wall saved $170,000 over conventional construction methods. The department's New Products Evaluation Committee has approved the use of several types of noise walls containing waste tires. However, no specific applications of those walls are currently planned.

Another unique application was the incorporation of 47,000 chipped tires as lightweight fill material to raise the roadway grade over an existing culvert. This application, which allowed the existing culvert to be retained, resulted in a savings of $7,400.

The current goal of the department is to reuse approximately 1 million tires in its highway construction projects annually, nearly 15 percent of the total tires discarded in North Carolina each year. This current goal may need to be reevaluated if the number of industries that recycle and reuse waste tires increases.

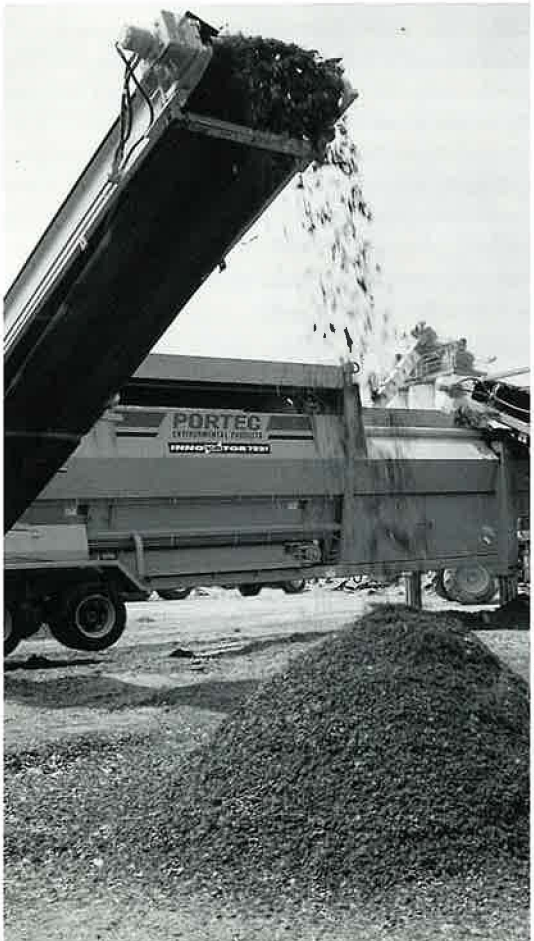
In 1995 North Carolina DOT incorporated post-industrial shingles (*below*) ground to penny-sized particles (*opposite page*) into asphalt pavement.

NORTH CAROLINA DOT

Strength in Solid Waste

The North Carolina Department of Transportation is committed to evaluating at least one additional solid waste product each year. In 1995 a project with fly ash in embankment fill was constructed. No construction problems were encountered. Fly ash and bottom ash are produced in large quantities in North Carolina. However, the sources of these ashes are not necessarily near the projects that require the material. The department allows substitution of fly ash for up to 20 percent by weight of portland cement in all classes of concrete. The fly-ash particles, which are 10 to 15 times finer than portland cement, fill the pores in the concrete, improving its quality and increasing its durability against freezing, thawing, and chemical attacks. Fly ash also improves the workability of fresh concrete and the long-term strength of hardened concrete. In addition, it mitigates potential alkali-silica reactivity. Fly ash is under consideration for use in flowable fill for back fill and similar applications. NCDOT also allows fly ash to be used for soil and road-base stabilization.

Condensed silica fume or microsilica, a by-product of the silicon and ferrosilicon alloys, is also beneficial to the quality of concrete. Silica fume is more than 100 times finer than cement particles and fills most of the pores in the concrete matrix, further increasing its durability and mitigating alkali-silica reactivity. Silica fume also contributes to optimum development of compressive strength in concrete. NCDOT is considering silica fume for use in high-early-strength and high-performance concrete. Specifications are being developed to allow processed silica to be placed in the cores of embankments.



NORTH CAROLINA DOT

Specifications have been developed for experimental use of silica fume in bridge deck overlay, which will help in the evaluation of the state-of-technology effectiveness of thin bonded overlay as part of the Applied Research and Technology Program established under ISTEA. Two bridge decks were overlaid with silica fume in 1995. The initial costs for silica-fume overlay are comparable to latex-modified concrete, with equal or better long-term performance expectations.

Several thousand metric tons of post-industrial shingles are produced annually in North Carolina. The amount of postconsumer shingles is much higher. Because additional refining procedures are needed to combat the possible contamination of postconsumer shingles, the current cost of use is prohibitive.

In fiscal year 1995 the use of post-industrial shingles, consisting of shingle fragments and tabs, was allowed in asphalt pavement. The shingles were ground to a uniform consistency of approximately penny-sized particles and added to the drum-mix plant as if they were recycled asphalt pavement. No problems were reported during grinding, mixing, or placement of the pavement. Experience on this project demonstrated that the cost of using shingles in asphalt is comparable to the cost of using recycled asphalt.

Putting Pavement Back To Work

North Carolina uses reclaimed asphalt pavement, allowing up to 60 percent in hot-mix asphalt design. About 25 percent of asphalt produced in the state contains reclaimed asphalt pavement. The state also allows the rubblization of existing concrete pavement for reuse as base material for new pavement. NCDOT has examined the feasibility of using recycled concrete in place of aggregate base course by including it in a temporary detour project. The performance of the recycled concrete as aggregate base course was monitored over one year. When it was found satisfactory, a permanent section of roadway was constructed with recycled concrete as the base. Future applications of recycled concrete will be considered whenever feasible.

NORTH CAROLINA DOT

At North Carolina DOT, base material for new pavement *(above)* can be made from recycled concrete pavement *(opposite page)*.

The possibility of crushing discarded concrete pavements to generate recycled coarse and fine aggregates for pavement construction is being considered. This application requires the mix to have sufficient workability and air entrainment. A rupture modulus of at least 3.8 MPa (550 psi) at the age of 14 days is also required, which research at North Carolina State University shows that the specifications requirement of 3.8 MPa (550 psi) at 14 days can be achieved by using up to 80 percent recycled coarse aggregate and 75 percent recycled fine aggregate.

Glass and Plastic for Safety and Durability

Glass beads manufactured with 100 percent recycled glass are currently used in pavement markings. Nearly 3,175,000 kilograms (7,000,000 pounds) of glass beads are used each year in pavement markings for retroreflectivity throughout North Carolina.

NCDOT has developed specifications to allow use of recycled plastic offset blocks instead of pressure-treated wood or steel blocks. Offset blocks are used to prevent the wheel of a vehicle from hitting a guardrail post and help keep the rail upright. The recycled blocks passed the Federal Highway Administration crash test for both wood and steel post systems. Unlike wood offset blocks, the recycled plastic blocks do not shatter when vehicles hit the guardrail, and frequently can be reused.

Recycled plastic sign posts have been included in one project and are being evaluated. It takes more time to install these posts because additional hardware is needed to attach the signs to them. The initial field evaluation has also shown that high temperatures cause the posts to warp, and wind from passing truck traffic make them sway. The state department of transportation is working with the manufacturer to strengthen the posts and will also consider using them in low-speed areas with minimal truck traffic.

The Ferry Division is testing composite plastic piling, 17 meters (18.6 yards) long and made from recycled materials, in a new ferry ramp. This experimental project will help department personnel evaluate whether the additional cost of this piling will offset the cost for the maintenance of traditional timber piling, which is susceptible to marine-borer worm damage.

Green Policies

The use of yard waste, sewage sludge, and municipal solid waste is allowed for state highway landscaping applications. An advanced alkaline-stabilized sludge has been developed to allow contractors the option of including municipal waste materials in state projects. Either this sludge or lime-stabilized sludge material can be used instead of conventional material to adjust the acidity level of soil before planting.

NCDOT has established a program for in-house solid-waste management. For example,

NORTH CAROLINA DOT

most worn tires from department vehicles are recapped or sold to commercial business for recapping, for manufacturing tire-derived fuel, or for making crumb rubber for use in hot-mix asphalt. Scrap metal, miscellaneous tire casings and used batteries are sold to recycling companies. Volatile fluids to clean equipment, aluminum beverage containers, cardboard, prime paper, and plastic pesticide containers are recycled statewide.

The state's rest-area recycling program, initiated in 1991, includes facilities at all 59 rest areas statewide. Glass, newspapers, plastic soda containers, and aluminum cans are collected from these sites for recycling. The cost-effectiveness of installing picnic tables, benches, trash receptacles, collection bins, and parking bumpers made from recycled materials in some of these rest areas is being considered.

Research on Recycling and Solid Waste Products

Four of NCDOT's current contract-research projects address the application of recycled products. One project addresses the use of crumb rubber blended with asphalt in the context of Strategic Highway Research Program SUPERPAVE design criteria, to investigate the applicability of SUPERPAVE performance grading to crumb-rubber-modified asphalt binder.

Research is under way on alkali-silica reactivity, in which applications of different proportions of Type F fly ash are being studied for their mitigation of alkali-silica reactivity in concrete for new construction. Another project is focused on milled asphalt concrete for cold in-place recycled pavement. The research will investigate the feasibility and methodology of using all milled material without stockpiling.

A laboratory study on the use of ground scrap tires in portland cement concrete (rubcrete) is currently in progress. Loose steel and fibers are removed from scrap tires and the rubber is finely ground and substituted in the mix for up to 30 percent of fine aggregate by volume. Early test results showed some reduction in the compressive strength of rubcrete but investigation continues into ways to mitigate the strength loss. The NCDOT Research and Development Unit publishes the Recycling and Solid Waste information bulletin every four months to provide the staff with the latest information on the use of recycled and solid-waste materials.

Making Reuse a Priority

The idea of using recycled products in the highway industry is relatively new. There is not much competition among vendors yet. Some products, such as crumb rubber, require special processing. Shredded tires or reuse of cleared trees and vegetation for erosion control require chipping and shredding. Long-term performance and durability, environmental impacts, and availability of continuous supplies of products are concerns that need ongoing evaluation.

continued on page 62

Reevaluate, Research, Renew
continued from page 21

The North Carolina Department of Transportation will monitor the performance and evaluate the potential for transportation applications of various solid wastes and recycled products. Research will continue into the best methods to incorporate these products in highway construction and maintenance. Engineering considerations, marketing potentials, availability of products, and cost considerations are integral to the department's efforts to implement state and federal legislative initiatives. Additional projects requiring the use of various solid wastes and recycled products will be identified, designed, and let to contract. Scrap tires, roofing shingles from the manufacturing waste stream, plastics, vegetative debris, shingles, fly ash, and demolition debris will remain the focus of research, testing, and use by North Carolina.

Dredged Material
continued from page 45

SUMMARY

Dredged material has many common uses, and new uses continue to be identified. In general, coarse-grained materials lend themselves to industrial and commercial development and beach nourishment. Fine-grained materials are more suitable for recreational, natural resource, or agricultural uses. Legal, regulatory, and economic constraints are more likely than technical feasibility to limit these uses. When beneficial uses are considered in project strategy, they should be incorporated into the early stages of project planning.

ACKNOWLEDGEMENT

Permission was granted by the Chief of Engineers, U.S. Army Corps of Engineers, to publish this information.

Numerous reports, workshop proceedings, and manuals on the topic of reclaiming dredge material are available from the Waterways Experiment Station U.S. Army Corps of Engineers. The American Society of Civil Engineers has accumulated and published additional information. The Permanent International Association of Navigation Congresses has recently published a practical guide on the topic that is accessible to a wide audience.

For additional information, contact the following individuals at WES: Thomas R. Patin (telephone 601-634-3444; e-mail patint@ex1.wes.army.mil); Mary C. Landin (telephone 601-634-2942, e-mail landinm@ex1.wes.army.mil); and Charles R. Lee (telephone 601-634-3585; e-mail leec@ex1.wes.army.mil).

Profiles
Smith *continued from page 53*

Florida and has actively promoted engineering education, placing particular emphasis on the need for professionalism. He has served on or chaired educational committees for the American Society of Civil Engineers, the Florida Engineering Society, and the Accreditation Board for Engineering and Technology. He has written many research papers for FDOT that have been published in numerous professional journals.

At the national level Smith has represented FDOT through his membership on three AASHTO committees: the Subcommittee on Materials, the Standing Committee on Research, and the Research Advisory Committee. He has served as president of both the local branch and state section of ASCE. He has been named Engineer of the Year by both the local and state sections of ASCE, and he received the same honor from the North Central Chapter of the Florida Engineering Society. His other awards include the 1990 Annual Award from the Geotechnical and Materials Engineer Council of the Florida Institute of Consulting Engineers, and the Distinguished Service Award from the University of Florida in 1992.

Smith is currently leading a national initiative to respond to recent changes in the Federal Aid Policy Guide that relate to materials acceptance and certification on federal-aid projects. He hopes to achieve consensus among AASHTO's relevant committees on a course of action to expand the scope of laboratory certification programs, to provide a smooth transition to the implementation of new federal guidelines for construction materials.