WASTE MATERIALS IN HIGHWAY CONSTRUCTION

LESSONS FROM NEW YORK STATE

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New York State's urban areas are among the most densely populated in the country. Restrictions on land use in some areas of the state have contributed to a shortage of landfill space and granular material sources for highway construction. Such shortages could be alleviated by reclaiming and recycling waste materials. The construction and rehabilitation of highways demand large volumes of construction materials, leading the New York State Department of Transportation to explore the use of waste materials in highway construction.

A series of state and federal legislation has influenced NYSDOT's use of waste materials. In 1976 the Resource Conservation and Recovery Act established the federal policy on recycling and reclaiming waste. This legislation was the precursor to New York's Solid Waste Management Act of 1988, which set forth the state's policy of recycling and reclaiming before landfilling and required state agencies to promote recycling and find uses for waste materials. In 1987 an amendment to the New York State Highway Law mandated that the department of transportation conduct a pilot project to promote the use of fly ash as a fill material. In 1991 Governor Mario Cuomo signed Executive Order 142, which specified the steps that NYSDOT would take to comply with the Solid Waste Management Act. In 1991 the U.S. Congress also enacted the Intermodal Surface Transportation Efficiency Act. Section 1038 of ISTEA required states to use rubber from old tires in hot-mix asphalt. However, in fall 1995 Congress placed a moratorium on this requirement.

New York State's experience with reclaiming and recycling waste materials in highway construction has been varied. The department of transportation's policy on recycling includes use of waste materials of good quality and uniformity that perform satisfactorily and are cost-effective. Waste materials that conform to this policy are usually listed as options in the *NYSDOT Standard Specifications*. The policy allows designers and contractors to find the least expensive way to build a highway of good quality while reusing materials as warranted by the department.

SUCCESS WITH RECYCLED PAVEMENT

Recycled Portland Cement Concrete Aggregate

One successful application of waste products for highway construction is the use of recycled portland cement concrete as aggregate in subbase course and fill. This material was first allowed as a substitute item by the state in 1982 and has become the standard for material used as subbase in the New York metropolitan area, where nearly 100 percent of the material currently placed as subbase for state highways consists of recycled portland cement concrete aggregate (RPCCA). All of the portland cement concrete removed during highway rehabilitation projects in the area is used as feedstock for RPCCA.

Crushed portland cement concrete from highway reconstruction projects or construction demolition sites is trucked to an aggregate supplier equipped with crushers, and processed into RPCCA. The *NYSDOT Standard Specifications* require the material to be essentially free of foreign matter such as glass, wood, and asphalt, and to meet strict testing requirements for aggregate used in the mix. After processing, the recycled material is nearly indistinguishable from granular material obtained from naturally occurring sources.

The department rejected RPCCA as an aggregate in asphalt cement concrete because even a small amount of foreign material is deleterious in asphalt. In states where RPCCA was used as aggregate in portland cement concrete and asphalt cement concrete, it was found to absorb more moisture than naturally occurring materials. The amount of moisture absorbed is unpredictable, making the design of mix proportions difficult.

The primary reason that the department approved the use of RPCCA as a subbase is that its use has cost benefits. By 1982 shortages in landfill space and sources for granular materials caused localities near New York City to begin using the recycled pavement. Aggregate producers formed an association to intercede with the state department of transportation, and contractors and engineers lobbied for a state specification for the use of RPCCA. In 1986 NYSDOT recommended RPCCA as a granular material on the basis of its performance history. By 1987 contractors and producers from other areas in the state had begun to inquire about the material, and it was applied in a project outside of the New York City area for the first time. It became a standard optional subbase item in 1989 and was permanently entered into the *NYSDOT Standard Specifications*. Table 1 shows the growth of the use of RPCCA in the New York metropolitan area with quantity in cubic meters.

More than one-half of all RPCCA used as subbase on state highway projects has been supplied since 1991. In 1994 and 1995 contractors in Region 5 began to use the material for subbase applications. Inquiries continue from NYSDOT regional offices about specifications and standards for the use of this material.

The growth in such use indicates that it is an economical resource in its own right. Contractors pay producers to accept portland cement concrete debris, and later purchase RPCCA from producers at a lower cost than that for other granular materials. Based on 1993 prices the cost to contractors for RPCCA is $4 per cubic meter ($5 per cubic yard) less than the cost of granular materials. Contractors who would have to store or dispose of debris from rehabilitation projects realize additional savings.

According to almost all criteria, RPCCA outperforms naturally occurring granular material because it is lighter and carries loads just as well. No problems related to the subbase course have been observed on any highways constructed from this material in New York State, some of which are now more than 10 years old.

Environmental Concerns Despite initial concern that RPCCA could contain concentrations of alum salts, heavy metals, or other contaminants that could leach into groundwater, no alum salts have been detected in the recycled material, and only trace elements of heavy metals and other contaminants have been found. Other characteristics of the material are cause for concern, however. The pH of RPCCA is usually above 11, a level that is corrosive to aluminum and to the zinc galvanizing on pipes. Care must be used in the placement of the aggregate in some structural fill applications. Conversely, high pH aids in the prevention of corrosion in ferrous materials, making RPCCA an excellent item for fill around such structures as reinforced earth walls and spread footings.

A calcium-based solution has also been found by other states to leach from RPCCA, encrusting porous media and pipes, which prevents proper subsurface drainage (see sidebar on page 26). This can lead to the early distress and failure of the supported pavements. NYSDOT has not had problems with plugged drains caused by this cementitious leachate.

In 1988 New York State passed the Solid Waste Management Act, regulating the use of RPCCA. This law could have considered the placement of this material to be construed as creating a landfill, subjecting its use to a permitting process with

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TABLE 1
Growth of Recycled Portland Cement Concrete Aggregate and Suppliers in New York Metropolitan Area

Year	Producers	Quantity	Year	Producers	Quantity
1982	1	9328	1989	9	77 280
1983	2	3440	1990	11	127 493
1984	2	9633	1991	12	127 337
1985	2	14 355	1992	10	110 669
1986	2	24 745	1993	12	108 299
1987	4	19 573	1994	12	125 253
1988	6	66 979	1995	12	138 153

Note: Total RPCCA used in New York metropolitan area from 1982 through 1995 is 1 034 688 cubic meters. Conversion factor: 1 cubic meter = 1.3 cubic yards.

a lengthy checklist for control procedures. However, because this material had been successfully used since 1982, the New York State Department of Environmental Conservation considers recycled portland cement concrete aggregate to be essentially free from contaminants. Producers only need to obtain a license and can then file for a beneficial use exemption from the permitting process.

The economic benefits of RPCCA, as well as its excellent performance, have turned a waste disposal problem into a resource of significant value. The use of RPCCA has replaced the placement of naturally occurring granular materials in densely populated areas. NYSDOT's process for approving the use of this recycled material began with initial investigation, moved on to specifications and standards, and allowed time for experience and material history to accumulate. Common-sense environmental regulations aided the process.

Reclaimed Asphalt Pavement

NYSDOT makes economical use of reclaimed asphalt pavement, the asphalt-cement concrete removed by milling machines during pavement rehabilitation. These millings, with the consistency and appearance of a stabilized granular material, usually are of sufficient quality and meet performance requirements so well that the *NYSDOT Standard Specifications* allow hot-mix asphalt concrete to contain up to 70 percent recycled asphalt pavement in a closed system and 50 percent in an open system. Generally only 25 to 30 percent of a mix, as compared with the 50 to 70 percent allowed by the specification, would be recycled because of moisture content considerations.

No problems have been reported with pavement constructed with reclaimed asphalt in New York State. It is used for a top course on rural roads, curbing, shoulder backup, parking lots, and miscellaneous stabilized fill items. In 1994 NYSDOT used approximately 45 400 metric tons (49,940 tons) of reclaimed asphalt pavement, and New York City used approximately 38 100 metric tons (41,910 tons).

In addition to its usefulness as aggregate in base and binder courses, reclaimed asphalt pavement can be treated with emulsion and applied as a base course for shoulders. Shoulder base is also cold-mix recycled by milling it from the site and treating it with a stabilization agent either on site or at a plant. No contractor has elected to use this option because of the material's value elsewhere. Reclaimed asphalt pavement is less expensive than naturally occurring aggregate and reduces disposal costs.

Mixed Results with Other Materials

Fly Ash

Coal-burning electric generation facilities can produce an enormous amount of fly ash and many places are looking for a way other than landfilling to dispose of this material. The coal-fired plants in New York State produce about 877 700 metric tons (965,470 tons) of fly ash each year. However, the quality of this fly ash varies.

The Materials Bureau of NYSDOT has had a specification for the use of fly ash in portland cement concrete mix for more than 20 years. The specification allows up to 15 percent of the cement portion of the mix to be fly ash. Approximately 36 290 metric tons (39,919 tons) of fly ash—the output of one medium-sized power plant—is added to the portland cement concrete placed on New York State highways each year. No problems related to this application of fly ash have been reported in the state.

Fly ash, with a long history of use as fill in highway construction in other states, is an accepted fill material with standards and specifications supported by the Federal Highway Administration. After 15 years of effort, fly-ash fill has yet to be used on a New York State highway project, although stockpiling fly ash and bottom ash has become a costly factor in electric power generation. New environmental regulations, budget restraints, and politics have prevented New York State from taking advantage of this resource.

Cullet

ISTEA and the Governor's Executive Order required the use of rubber in hot-mix asphalt. Waste glass (cullet) may be substituted for rubber on a state highway project to avoid federal penalties for nonuse. However, because of the moratorium on this requirement, NYSDOT's rubber and glass consumption has declined to almost nothing during the last two years.

Cullet is a standard optional item for aggregate in hot-mix asphalt concrete used in base and binder courses. The department has experienced a stripping problem with this material that can be rectified through the use of a binding agent, which adds cost. There is also a concern that glass in a top course could result in liability in cases of claims of additional injury to motorists and bicyclists from the glass. Therefore, NYSDOT does not allow glass cullet in wearing or surface courses.

The *NYSDOT Standard Specifications* allow a maximum of 5 percent of the mix to be waste glass, the same amount specified by the Executive

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Process for reusing crushed portland cement concrete from highway reconstruction projects or construction demolition sites *(from top)*: transport to aggregate supplier equipped with crushers; processing; and placement as subbase for pavement.

Effect of Recycled Subbase Aggregates on Pipe Underdrains

For decades the Ohio Department of Transportation has used by-product aggregates such as iron and steel slag, slacker aggregate, and steam-boiler slag for highway subbase courses. These aggregates are cost-competitive with natural aggregates in areas near their production sources. The department recently used recycled concrete pavement as subbase on two projects and in-place rubblized concrete pavement as subbase on several others. The use of these by-product aggregates does pose some risk. Steel slags, slacker aggregate, recycled concrete, and rubblized concrete pavement have been identified as sources of tufa precipitate, which builds up in pipe underdrains and storm sewer systems on highway projects. Tufa is a porous calcium carbonate deposit that forms as water drains through aggregate containing free lime.

The problem of precipitate formulation was first identified in 1977 during field data collection for a research project performed by Kent State University on erosion and sloughing of highway slopes in northeastern Ohio. The tufa build-up at underdrain outlets, sewer outlets, and on slopes was attributed to pavement water leaching through carbonate base course. However, the specific type of aggregate involved was not determined. Further research undertaken in 1980 by the university identified slag and slacker aggregate as the aggregates involved and detailed the chemical reaction of the precipitate formation. Differentiation among the different types of slag still was not made.

Ohio DOT personnel, in evaluating the usefulness of flushing and repairing existing underdrains, established the seriousness of the precipitate problem. Underdrain systems had been rendered nearly useless by deposits that plugged pipes and by the cementing of the sand or slag backfill in underdrain trenches. The department therefore prohibited the use of slag and slacker aggregate for subbase material and specified exclusive use of natural pea gravel (American Association of State Highway and Transportation Officials No. 8 aggregate) for backfill for underdrain trenches.

Research conducted in the mid-1980s by ODOT determined that steel slags and slacker aggregate were sources of tufa because of their high free-lime (CaO) content. Iron slags (air-cooled blast-furnace slag and granulated slag) were not potential sources of tufa because they lack free lime. Basic oxygen slag had a much greater potential for precipitate formation than open-hearth slag, which has less initial free lime and in most cases has been stockpiled for decades. As a result, iron slags were again permitted as subbase aggregate and underdrain backfill. Basic oxygen slag was still prohibited, and limited use of open-hearth slag was allowed on the basis of past performance of open-hearth from specific stockpile sites.

Observation of the projects in which recycled concrete and rubblized concrete pavements had been used as subbase material indicated that these aggregates also have some potential for causing precipitate formation. Based on these observations, the Ohio DOT does not permit the use of recycled concrete as subbase and has limited the use of rubblized in-place concrete pavement as subbase.

Researchers at Toledo University recently developed testing procedures to quantify free-lime content of steel slag and recycled concrete aggregates. Using these tests and previous site performance, ODOT hopes to identify specific sources of these aggregates for which indications of precipitate potential are minimal. Aggregates from those sources may then be used as subbase material. Further research has been proposed to identify measures of economically reducing this precipitate potential. It is hoped that the results of this work will lead to a solution that allows broader use of these waste aggregates without compromising drainage systems.

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Order. No glass was used on state projects in 1995. Only 19 385 metric tons (21,324 tons) were used in 1994. Without mandates and legislation, glass cullet would likely not have been included in the *Standard Specifications*.

Mandating the specific use of a material can increase the cost of a project. During 1994 many upstate suppliers began to stockpile waste glass in anticipation of an announcement by the Corning Glass Company that it had perfected a process to use this material as feedstock for fiberglass insulation manufacture. This stockpiling of cullet drove up its price. If cullet had been specified as the material for aggregate on a NYSDOT project, cost would have increased substantially.

Rubber Tires

The 8.5 million light-duty vehicles (cars, pick-up trucks, vans, and recreational vehicles) registered in New York State generate approximately 11.3 million used tires each year. Many of the state's landfills no longer accept tires. The effects of long-term stockpiling and landfilling of tires are not known, but leaching of pollutants is a concern. Tire fires are difficult to extinguish and release harmful and noxious substances into the air. In addition, tire stockpiles are ideal breeding grounds for mosquitoes.

There are three proposed applications for tires in highway construction: asphalt cement, crack-filler modifier, and lightweight fill. Cryogenation allows the rubber to be removed and crushed from discarded tires for use in the first two applications, and the steel to be extracted. Clean tires are needed for feedstock, so mining tires from landfills is cost-prohibitive.

New York's experience with use of crumb rubber as asphalt cement and crack-filler modifier indicates that it does not enhance the performance of these applications. The *Standard Specifications* allow a maximum of 5 percent of asphalt cement to be crumb rubber. In 1994, 547 metric tons (602 tons) of rubber equal to 100,517 tires were used in state highway projects, of which approximately 13 metric tons (14.3 tons) were used as crack filler.

The NYSDOT Geotechnical Bureau has developed a specification for the use of chipped rubber tires as lightweight fill either alone or mixed with granular material. However, the department prefers to use other materials as lightweight fill. Environmental uncertainties associated with rubber tires indicate that they must be located above the groundwater table when used in highway construction.

Observations

The New York State Department of Transportation has recycled and reclaimed waste materials for a variety of reasons, primarily in response to state and federal legislation and executive policy requiring the specific use of certain waste materials in highway construction. Private industry also has proposed the use of some materials that have proven economical and effective.

Recycled portland cement concrete aggregate and recycled asphalt pavement have demonstrated engineering properties necessary for a construction material, as well as economic feasibility. Cullet and rubber tires are examples of materials that have had limited success in New York State, but have been successfully used elsewhere. With landfill space at a premium and pressure to recycle increasing, New York must continue to take a hard look at using recycled materials in highway construction. Many difficult questions remain. How may NYSDOT make better use of materials—such as rubber and fly ash—that still elude state recycling efforts? Should highways constructed of recycled materials be treated as landfills under solid-waste management laws, with all the effort and expense that entails? NYSDOT will continue to search for answers to these difficult questions while balancing environmental concerns with the need to protect the motoring public on highways that have been built to exacting standards and with high-quality engineering.