South Carolina
Department of Transportation

Office of Materials and Research

Utilization of Waste Materials in Highway Construction and Maintenance

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This report was prepared for the Governor and General Assembly of the State of South Carolina by the South Carolina Department of Transportation in response to the "South Carolina Solid Waste Policy and Management Act of 1991."

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INTRODUCTION

In a continuing effort to meet the requirements set forth by the "Intermodal Surface Transportation Efficiency Act" (ISTEA) of 1991 and the "South Carolina Solid Waste Management Act," also of 1991, the South Carolina Department of Transportation (SCDOT) investigates, evaluates, and utilizes waste materials in highway construction. Both Acts encourage highway engineers to search for safe and economical methods to use solid waste products and recycled materials in building and maintaining highway structures. By incorporating recycled material into highway applications, SCDOT helps reduce the problem of solid waste disposal in South Carolina. This annual report has been prepared for the Governor and the General Assembly to document the Department's continuing research efforts to find applications for recycled products in the highway construction and materials industry.

Stockpile of Recycled Asphalt Pavement
(Charleston, SC)

APPROVED WASTE MATERIALS

Several waste materials have been approved for routine use in highway construction. These materials include:

- Fly ash in flowable fill and portland cement concrete (PCC).
- Ground granulated blast furnace slag (GGBF slag) in PCC.
- Recycled PCC.
- Chrome and steel slag in hot mix asphalt concrete (HMAC) for low volume routes.
- Asphalt shingles in HMAC.
- Reclaimed asphalt pavement (RAP) in HMAC.
- Recycled glass aggregates in embankments, aggregate underdrains, and HMAC for low volume routes.

For additional background information, the Federal Highway Administration (FHWA) publication *User Guidelines for Waste and Byproduct Materials in Pavement Construction* includes guidelines for each of the above materials at its Turner-Fairbank Highway Research Center web site, www.tfhrc.gov/hnr20/recycle/waste/begin.htm.

Specifically for the first two bullet items, the United States Environmental Protection Agency (EPA) recommends that procuring agencies revise their guide specifications to require that contract specifications for individual construction projects or products allow for the use of coal fly ash or GGBF slag, unless the use of these materials is technically inappropriate for a particular construction application (www.epa.gov/cpg/products/cemspecs.htm).

The National Slag Association lists South Carolina as one of 29 states with specifications that allow the use of slag materials in their highway construction materials (www.nationalslagassoc.org/State_Specs.html).

Fly Ash

The American Coal Ash Association reported that during 2004 the U.S. electrical utility industry generated about 70.8 million tons of coal fly ash, and that about 28.1 million tons of fly ash were used. The majority of coal fly ash products were used in construction-related applications, including cement production and concrete products, structural fills or embankments, soil stabilization, stabilization of waste materials, flowable fill, grouting mixes, mineral filler in asphalt concrete mixes, and mining applications.

Fly Ash.
(from Fly Ash Resource Center)

In South Carolina, fly ash is approved as a replacement material for certain cements in PCC and in flowable fill. When fly ash is used to replace a portion of the cement, the replacement ratio shall not be less than 1.2 to 1 by weight and fly ash shall not replace more than 20 percent of the cement originally called for in the mix. Fly ash is also a very important ingredient in the Department's Class 6500 high performance concrete mix. This mix design has characteristics of being extremely impermeable due in part to the specified use of fly ash. Typically, use of fly ash as a replacement material is left to the discretion of the contractor except in the Class 6500 concrete.

Ground Granulated Blast Furnace Slag

Ground granulated blast furnace slag (GGBFS) is the granular material formed when molten iron blast furnace slag is rapidly chilled (quenched) by immersion in water. It is a granular product with very limited crystal formation, is highly cementitious in nature and, when ground to cement fineness, hydrates like portland cement.

In South Carolina, ground granulated blast furnace slag has also been approved as a replacement for certain cements in PCC mixes. The allowable replacement ratio for cement is 1 to 1, by weight, and up to 50 percent of the original cement can be replaced with ground granulated blast furnace slag.

Ground Granulated Blast Furnace Slag
(from SsanYong Cement)

Recycled PCC

Section 305 of the SCDOT's "Standard Specifications for Highway Construction, Edition of 2000" states that the contractor, at his or her option, may use Macadam Base, Marine Limestone Base, or Recycled Portland Cement Concrete Base when the contract specifies a graded aggregate base course. Experience has shown that the recycled concrete base provides an equivalent structural number to traditional base courses using virgin material. The recycled concrete aggregate must consist of sound, durable particles of crushed concrete, excluding block or pipe. When the contractor selects Recycled Portland Cement Concrete Base Course, the source is inspected, sampled, and tested before being approved by the Department.

Uncrushed PCC Prior to Processing for Aggregates

Recycled PCC Aggregate

Printed on Recycled Paper

Chrome and Steel Slag

In South Carolina, chrome and steel slag have been used successfully in HMAC on low volume routes where a lack of quality crushed stone aggregates makes the use of slag economically feasible. There is no longer a source of chrome slag in South Carolina, but there are sources of steel slag in the state. In April 1994, the SCDOT contracted with the National Center for Asphalt Technology (NCAT) at Auburn University to investigate the feasibility of using both chrome and steel slag in HMAC for high volume roads.

Through laboratory testing, NCAT compared asphalt concrete mixes with the SC slag to mixes using only crushed stone. NCAT concluded in their report that both chrome and steel slag aggregates can provide satisfactory HMAC mixtures if the expansive nature of steel slag is adequately treated and if the stripping potential of the mixture is evaluated and addressed. The final report for the study, titled "Study to Improve Asphalt Mixes (Volume 2—A Study of Crushed Slag Aggregate in Hot Mix Asphalt)" was included in the waste utilization report Volume 6, dated November 1996. Chrome and steel slag have been approved for use as both fine and coarse aggregates in certain types of HMAC roadway courses. Crushed chrome and steel slag must meet the Department's quality and gradation requirements when used as an aggregate.

Steel Slag
(from Edw. C. Levy Co.)

Asphalt Shingles in HMAC

As reported in Volume 11 of this report, as part of a research project an HMAC surface course mix containing 8 percent waste shingles by weight of aggregate was placed in Pickens County. The waste shingles used on the project were obtained from the Pickens County land-fill. Production of the mix at the asphalt plant and placement on the roadway were monitored, and relatively few problems were encountered.

Based on the findings of that study, the SCDOT now permits the use of shingles in Asphalt Aggregate Base Types 1 and 2, Binder Types 1 and 2, and Surface Types 1, 3, and 4.

During 2005, an asphalt contractor in the upstate used shingles on several SCDOT projects.

Recycled Asphalt Shingles Stockpile

Ground Asphalt Shingles Stockpile

(from Ashmore Brothers, Greenville, SC)

Recycled Asphalt Pavement (RAP)

RAP is the nation's most widely recycled product. The Federal Highway Administration reports that about 80 million of the approximately 100 million tons of asphalt pavement that is removed each year during resurfacing and widening projects is reused as part of new roads, roadbeds, shoulders and embankments. That's a recycling rate of 80 percent. This is much higher than the rates of almost 61 percent for steel packaging (mostly cans), 56 percent for yard trimmings, 44 percent for aluminum cans, and 48 percent for paper and paperboard that EPA reported for 2003.

The EPA says that of the 236 million tons of solid waste generated in 2003, the latest year for which figures are available, the nation recycled 72 million tons of paper and paperboard, yard trimmings, glass, metal, plastic and other materials. Including composting, this is a recycling rate of 30 percent.

Thus, the 80 million tons of recycled asphalt pavement is over 11 percent higher than the total 72 million tons of post-consumer recycling. And, it is more than double the post–consumer recycling amount for paper, glass, plastic and aluminum combined.

Milling Asphalt Pavement for Recycling *(from SCDOT)*

Teeth on a Milling Machine *(from SCDOT)*

Printed on Recycled Paper

In South Carolina, RAP has been identified as a viable alternative for new, or virgin, materials used in HMAC mixtures. The use of RAP is approved, through a supplemental specification, in uniform HMAC mixtures for the following cases:

- On certain low and medium volume roads.
- In intermediate courses.
- In asphalt aggregate base courses.

The RAP must be tested and approved by the Department before being used. The mix design for the HMAC course with RAP is then modified to account for the amount and quality of the materials found in the RAP. Depending upon the type of HMAC mix, the amount of RAP allowable can range between 10-30 percent of the total mixture.

Recycled Asphalt Pavement Stockpiles
(Charleston, SC)

The decision to use RAP in an HMAC mix is that of the contractor. The SCDOT does not maintain specific records regarding the total percentage of HMAC that contains RAP in the mix. However, a recent research project collected data from 40 different mix designs for HMAC surface course mixes. Of these, 16 of the mix designs contained RAP.

Recycled Glass Aggregates

Recycled glass aggregates are another waste material that has been approved for use by the Department in:

- Embankments.
- Aggregate underdrains.
- HMAC.

Close-Up of Glass Aggregate
(from hawaiiasphalt.com)

Crushed Glass as a Portion of the Aggregate for a Base Course
(from www.paynesvillearea.com)

The Department has prepared specifications for the use of recycled glass in these applications. A supplemental specification for use in embankments and underdrains was approved in April 1998. The specification allows glass to be mixed with fill material up to 25 percent by weight. The specification also allows recycled glass aggregate as a replacement for stone in underdrain. The HMAC specification limits the use of glass to 15 percent by weight of total aggregate in Asphalt Aggregate Base Types 1 and 2, and in Binder Types 1 and 2.

CONTINUING INVESTIGATIONS

Waste Materials

As discussed in previous volumes of this report, improvements to the rest area adjacent to the southbound lanes of I-95 in Colleton County included the use of several waste materials or products that included the use of waste materials in their production. Examples are loose mulch produced from shredded tires, walkways made from waste tire chips with a binder to hold them together, recycled concrete used as graded aggregate base, fly ash as a replacement for a portion of the cement in the concrete pavement, and cement from a local plant that utilizes waste oils, solvents, and other flammable wastes in their kilns.

The waste materials used on this project are being monitored through the Office of Materials and Research's In-House Investigation Program as Study No. 01-3, "Long Term Evaluation of Waste Tires in Landscaping Applications." Recent inspections of the facility reveal that all materials are performing well. Performance results will be reported in future volumes of this report.

Shredded Tires Used as Loose Mulch and Sidewalk at the Colleton County I-95 Rest Area

Asphalt Rubber

As described last year in Volume 14 of this report, the SCDOT has teamed with the Asphalt Rubber Technology Service (ARTS) at Clemson University to place test sections using mixes made with rubber-modified asphalt. The primary purpose of ARTS is to promote the use of scrap tire rubber in civil engineering applications by providing grants that will pay the difference in price for utilizing recycled rubber or rubber-modified materials verses conventional materials. Sections placed to date are summarized below.

Williamsburg County

As reported last year in Volume 14 of this report, a portion of SC Route 261 in Williamsburg County was paved using two different rubber-modified asphalt applications. The first was a rubber-modified Stress Absorbing Membrane Interlayer (SAMI) placed on a two-mile section. In total, 30,507 square yards of SAMI containing 3,660 scrap tires was used. The second was the standard ARTS rubber-modified asphalt pavement surface course, which was placed on a four-mile section of the same road. A total of 6,174 tons of Surface Course, utilizing 70,400 pounds of crumb rubber (equivalent of 7,040 scrap tires), were placed.

Newberry County

In the fall of 2004, a portion of US Highway 76 in the Little Mountain area of Newberry County from Highway 773 to the Lexington County line was paved using conventional HMAC surface course placed over a rubber-modified SAMI. In total, 63,174 square yards of SAMI containing approximately 7,580 scrap tires were used.

Charleston County

Also, in the fall of 2004, a rubber-modified SAMI was placed on portions of US Highway 17 and US Highway 52 (Rivers Avenue) in Charleston County. The section on US Highway 17 in Awenda consisted of 52,800 square yards of SAMI, using 6,335 scrap tires, placed over a milled asphalt pavement surface. The section on US Highway 52 in North Charleston, also known as Rivers Avenue, consisted of 131,944 square yards of SAMI, using 15,830 scrap tires, placed over two types of surfaces (concrete pavement and milled asphalt pavement).

These test sections are being monitored through the Office of Materials and Research's In-House Investigation Program as Study No. 03-3, "Evaluation

of Asphalt Rubber Technology Service (ARTS) Rubber-Modified Asphalt Mixtures." Recent inspections of each section reveal that all are performing well. The performance of the rubber-modified asphalt will continue to be reported in future volumes of this report. Additional test sections are scheduled to be placed in the upcoming year. The placement and monitoring of these sections will also be reported in future volumes of this report.

CLOSING REMARKS

The South Carolina Department of Transportation is continuously trying to find safe, economically feasible, and environmentally sound applications for waste and recycled materials that can be used in the highway industry without compromising the engineering integrity of the State's roadways. In addition to the Department's research initiatives, the New Products Committee is placing special emphasis on products composed of recycled materials.