



South Carolina
Department of Transportation

Research and Materials Laboratory

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.



Stockpiles of Recycled Materials
(from M. Dickerson, Ltd.)



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.

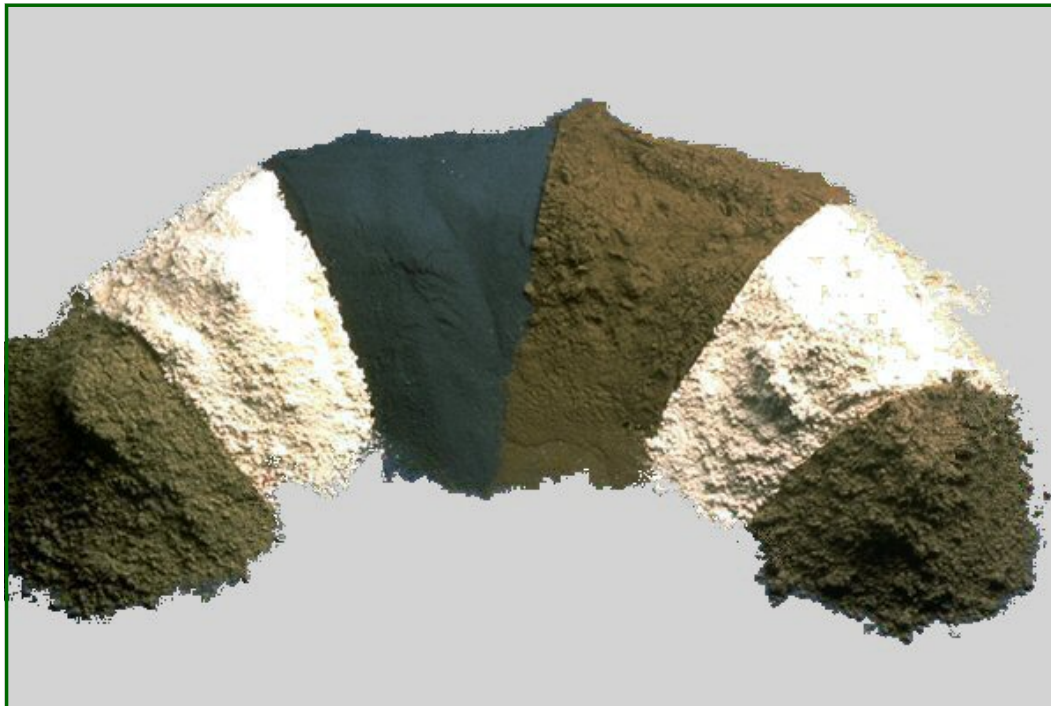
For additional background information, the Federal Highway Administration (FHWA) publication *User Guidelines for Waste and Byproduct Materials in Pavement Construction* includes guidelines for each of the above materials at its Turner-Fairbank Highway Research Center web site, www.tfhrc.gov/hnr20/recycle/waste/begin.htm.

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 U.S. Environmental Protection Agency reported that during 2001, the U.S. electrical utility industry generated about 71.2 million tons of coal fly ash; about 25.1 million tons of fly ash were used, which is more than two times the average annual amount used between 1985 and 1995. 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 and grouting mixes.

**Supplementary Cementitious Materials.**

From left to right, fly ash (Class C), metakaolin (calcined clay), silica fume, fly ash (Class F), slag, and calcined shale.

(from Portland Cement Association)

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.



from Portland Cement Association



from Allied Recycled Aggregates

Examples of Recycled Crushed Concrete for Use as Aggregates

The Construction Materials Recycling Association (CMRA) estimates that more than 100 million tons of concrete is recycled annually

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 landfill. 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.



Asphalt Shingles Ready for Recycling
 (from www.shinglerecycling.org)



Spreading an Asphalt Mix Made with Recycled Asphalt Shingles
 (from www.shinglerecycling.org)

Approximately 11 million tons of asphalt shingles are disposed in landfills every year. (www.shinglerecycling.org).

But shingles will become a major problem as some areas are limiting or banning them from landfills. (www.cdrecycling.org)

 **Recycled Asphalt Pavement (RAP)**

RAP is the nation’s most widely recycled product. The Federal Highway Administration reports that 80.3 million of the 100.1 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 59 percent for steel packaging (mostly cans), 57 percent for yard trimmings, 49 percent for aluminum cans, and 45 percent for paper and paperboard that EPA reported for 2001.

The EPA says that of the 229 million tons of solid waste generated in 2001, the latest year for which figures are available, the nation recycled 68 million tons of paper and paperboard, yard trimmings, glass, metal, plastic and other materials. Including composting, this is a recycling rate of 29.7 percent.

Thus, the 80.3 million tons of recycled asphalt pavement is nearly 20 percent higher than the total 68 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 Reynolds, Smith, and Hill CS, Inc.)

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 Stockpile
(from University of Waterloo)

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 concrete 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 INVESTIGATION**

As described last year in Volume 13 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. Recent inspections of the facility reveal that all materials are performing well. Performance results will be reported in future volumes of this report.



 **NEW INITIATIVE**

The SCDOT has teamed with the Asphalt Rubber Technology Service (ARTS) at Clemson University to place a test section with two pavement layers using mixes made with rubber-modified asphalt. Additional test sections are being planned. 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 instead of conventional materials.

A Stress Absorbing Membrane Interlayer (SAMI) using a Performance Grade (PG) 64-22 binder with 20 percent ground tire rubber, by weight of the binder, was placed on two miles of SC Route 261 in Williamsburg County. A total of 30,507 square yards of SAMI, utilizing 36,600 pounds of crumb rubber (equivalent of 3,660 scrap tires), were placed.

A 9.5mm HMA Surface Course with a PG 64-22 binder and 10 percent tire rubber, by weight of the binder, was also placed on four miles 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.

The test section, as well as any others that are placed, will be monitored through the Research and Materials Laboratory's In-House Investigation Program as Study No. 03-3, "Evaluation of Asphalt Rubber Technology Service (ARTS) Rubber-Modified Asphalt Mixtures." The performance of the rubber-modified asphalt will 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.

