



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."



TABLE OF CONTENTS



INTRODUCTION	1
APPROVED WASTE MATERIALS	2
Fly Ash	2
Ground Granulated Blast Furnace Slag	3
Recycled PCC	4
Chrome and Steel Slag	4
Asphalt Shingles in HMA	5
Recycled Asphalt Pavement (RAP)	6
Recycled Glass Aggregates	8
RECENTLY COMPLETED INITIATIVE	8
CLOSING REMARKS	12

 **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.

The EPA says Americans recycle only 28 percent of the materials in the municipal solid waste stream.

Asphalt Rubber Technology Service





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 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 under-drains, and HMAC for low volume routes.

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, and mineral filler in asphalt paving.

More than 35% of the annual production of coal fly ash is used beneficially. The remainder is landfilled.

It is estimated that using 1 ton of fly ash in concrete will avoid about 1 ton of carbon dioxide emitted from cement production.

U.S. EPA



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.

GGBFS is a 100% recycled material, using significantly less energy at reduced levels of CO₂ emissions during production as compared to portland cement.

Cement Americas

 **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.



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.

Old concrete that has reached the end of its service life can be recycled and reused as aggregate for new concrete mixtures.

Concrete yields 45% to 80% usable coarse aggregate and can be crushed and reused in new concrete or as a base material.

Cement Americas

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.

Approximately 11 million tons of asphalt shingles are disposed in landfills every year.

HMAC is the largest current market for recycled asphalt shingles (RAS).

shinglerecycling.org

 **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.

 **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. In terms of tonnage, only scrap metal comes close at 70 million tons, which represents a recycling rate of 64 percent for steel.

The EPA says that of the 217 million tons of solid waste generated in 1997, the latest year for which figures are available, we recycled 60.7 million tons of paper and paperboard, yard trimmings, glass, metal, plastic and other materials.

Thus, the 80.3 million tons of recycled asphalt pavement is approximately one-third higher than the total 60.7 million tons of post-consumer recycling. And, it is double the volume of paper, glass, plastic and aluminum combined.




How asphalt pavement recycling stacks up by weight:

- 1.1 × steel*
- 2.3 × paper & paperboard*
- 12 × other metals*
- 13 × newsprint*
- 24 × concrete pavements*
- 27 × glass bottles*
- 73 × plastic*
- 89 × aluminum cans*

Asphalt Pavement Alliance



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.

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.

Percentage recycled:




- 80%: Asphalt pavement*
- 64%: Scrap steel*
- 60%: Aluminum cans*
- 56%: Newsprint*
- 37% Plastic beverage containers*
- 31% Glass beverage bottles*
- 23%: Magazines*

National Asphalt Pavement Association



 **Recycled Glass Aggregates**

Another waste material that has been approved for use by the Department is recycled glass aggregates in:

-  Embankments.
-  Aggregate underdrains.
-  HMAC.

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.

 **RECENTLY COMPLETED INITIATIVE**

Improvements to the rest areas on I-95 in Colleton County were recently completed under S.C File No. 15.627. The Department made an effort to use waste materials, or products that utilize waste materials in their production, on the facility adjacent to the southbound lanes.

If recycled glass is available, and it does not exceed the cost of aggregate, the Hawaii DOT requires the inclusion of "construction-grade cullet" (crushed recycled glass) into HMA base course on the order of 10 to 15% by weight of aggregate.

Hawaii Asphalt Paving Industry



This rest area contains landscaping products made from waste tires. Loose mulch produced from shredded tires was placed around shrubbery and trees at the front and back of the building. Figures 1 and 2 show the waste tire mulch at the rest area.



Figure 1. Mulch Made from Shredded Tires



Figure 2. Close-up of Mulch Made from Shredded Tires

218 million tires are recycled each year: 33M are processed into ground rubber, 15M are exported, 8M are made into new products, 115M are used for fuel, 40M are used for civil engineering projects, 7M are categorized as "other."

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Also, two walkways made from waste tire chips with a binder to hold them together were placed at the facility leading from the parking lot to covered picnic tables. Figures 3 and 4 show the waste tire walkways.



Figure 3. Walkway Made from Waste Tire Chips



Figure 4. Close-up of Walkway Made from Waste Tire Chips

Some uses for scrap tires:

- Rubberized asphalt
- Embankments
- Mulch
- Erosion control
- Drainage layers
- Fill materials
- Turf grass
- Playground surfaces
- Retaining walls
- Molded goods

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There were other uses of waste materials at this rest area. Concrete removed from projects in South Carolina was recycled, crushed, sized, and used as graded aggregate base (GAB) under portions of the pavement. Also, the cement used in the concrete came from Holcim Cement in Holly Hill, South Carolina. This plant utilizes waste oils, solvents, and other flammable wastes in their kilns used to produce the cement. Furthermore, the concrete mix contained fly ash, derived from the burning of coal, as a replacement for a portion of the cement.

The performance of the waste materials used on this project will be monitored and documented in future reports.

Landfills in the USA:

1984: 10,500
 1989: 7,300
 1990: 6,300
 2000: 2,150

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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.

40% of kids ages 6–16 want their parents to do two things:

–Stop smoking.

–Start recycling.

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