South Carolina
Department of Transportation

Research and Materials Laboratory

Utilization of Waste Materials in Highway Construction and Maintenance

Volume 12, November 2002

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.

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 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.

Fly Ash

The U.S. Environmental Protection Agency reported that during 1999, the U.S. electrical utility industry generated about 62.7 million tons of coal fly ash; about 20.8 million tons of fly ash was used, which is nearly two times the average annual amount used between 1985 and 1995. The majority of coal fly ash was used in construction–related applications, including cement production and concrete products, structural fills or embankments, stabilization of waste materials, flowable fill and grouting mixes, and mineral filler in asphalt paving.

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 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, 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.

Chrome and Steel Slag

In South Carolina, chrome slag has been used successfully for many years in HMAC on low volume routes where a lack of quality crushed stone aggregates makes the use of chrome slag economically feasible. South Carolina has two sources of slag, one for steel slag in Georgetown and one for chrome slag in Charleston. 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.

Asphalt Shingles in HMAC

As reported last year in Volume 11 of this report, as part of a research project an HMAC surface course mix containing 8% 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 and 2.

Recycled Asphalt Pavement (RAP)

A Federal Highway Administration Report shows that 80 percent of the asphalt pavement removed each year during widening and resurfacing projects is reused as part of new roads, roadbeds, shoulders, and embankments. According to Mike Acott, president of the National Asphalt Pavement Association, "… every year, approximately 73 million tons of reclaimed asphalt pavement (RAP) is reused, or nearly twice as much as the combined total of 40 million tons of recycled paper, glass, aluminum, and plastics." As shown in Figure 1, RAP ranks as the top recycled product in the United States.

How much is recycled?

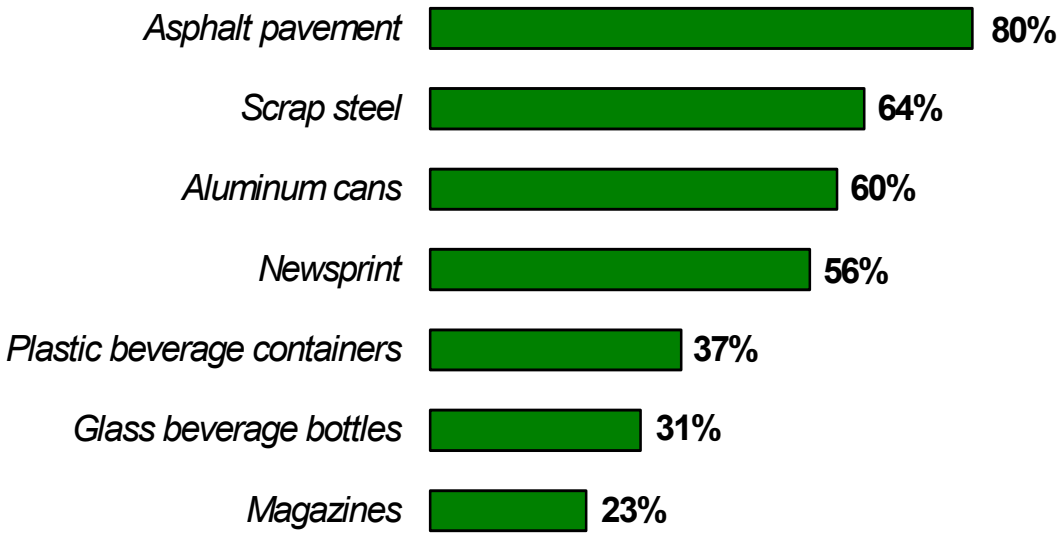

Figure 1. Recycling Percentages for the U.S.
(Source: National Asphalt Pavement Association)

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 allowable amount of RAP can range between 15 – 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.

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.

CONTINUING INITIATIVE

As indicated last year in Volume 11 of this report, work was pending on a project utilizing waste materials in construction of a rest area. Improvements to the rest areas on I–95 in Colleton County are currently being made under S.C File No. 15.627. The Department has made an effort to use waste materials, or products that utilize waste materials in their production, on the facility adjacent to the southbound lanes.

This rest area will contain some landscaping products made from waste tires. This includes loose mulch for use in selected areas around the facility and mats to be used as vegetation barriers around trees. The loose mulch is to be ½–inch chips produced by shredding tires with a colorant added to resemble conventional wood mulch. An example of this type of material is shown in Figure 2. Mats are made from rubber chips mixed in a dark brown binder and molded into rings for use around trees for ease of mowing.

Figure 2. Photograph of Mulch Made from Recycled Tires

There will be other less noticeable uses of waste materials in this rest area. Plans are to remove the existing concrete pavement, crush and grade the material, and then use it as graded aggregate base under a portion of the new pavement. Also, the cement to be used in the concrete is from Holcim Cement in Holly Hill, South Carolina. This plant utilizes waste oils, solvents, and other flammable wastes in their kilns to produce the cement. Furthermore, the concrete mix will contain fly ash, derived from the burning of coal, as a replacement for a portion of the cement.

In addition, specifications for the project allow the contractor to use recycled asphalt pavement (RAP) and shingles in certain HMAC mixtures. Specifications for use of the materials are included in Appendix A.

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

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.

APPENDIX A

Supplemental Specifications: Recycled Hot Mix Asphalt Mixtures Allowed at the Rest Area on I–95

SUPPLEMENTAL SPECIFICATIONS

January 15, 1998

RECYCLED HOT MIX ASPHALT MIXTURES

DESCRIPTION

The work specified by this section consists of the production, delivery and placement of a recycled hot mix asphalt mixture. The work shall include crushing and screening, if necessary; the mixing of reclaimed asphalt pavement and new aggregate and additional asphalt binder in either a batch plant or drum mix plant; and placing and compacting the recycled hot mix asphalt mixture in accordance with lines, grades, typical sections and applicable sections of the plans and specifications. All applicable Special Provisions, Supplemental Specifications and Sections of the Standard Specifications, except as noted herein will apply.

MATERIALS

Recycled Asphalt Pavement (RAP) – The RAP will be milled material from Department projects. Stockpiles of RAP material shall be separated by project and a sign satisfactory to the Engineer shall be erected and maintained by the Contractor on each stockpile to identify the source(s).

The Contractor shall maintain at the plant site a record system for all RAP stockpiles. These records shall contain, but not be limited to, the following:

A. Stockpile identification
B. Sketch of all stockpile areas at the plant site
C. RAP Source (project, state route, road or street name)
D. Dates milled and approximate number of tons in the stockpile
E. All extraction test results

The RAP stockpile records shall be available to the Engineer at the plant site. The Department reserves the right to reject, by visual inspection, any stockpiles that are not kept clean and free of foreign materials.

Extraction tests shall be performed at the rate of one per 1,000 tons (900 tonnes) of RAP with a *minimum* of 3 per stockpile.

The RAP shall be processed in such a manner that all particles will pass a 2 in. (50.0 mm) screen prior to entering the plant and shall be free of foreign matter or other contamination and shall be uniformly graded. RAP particles retained on the 2 in. (50.0 mm) screen may be recrushed in such a manner that will not result in further degradation of the aggregates.

New Aggregate – Additional aggregate material required in the recycled hot mix asphalt mixtures shall meet the applicable requirements of Section 401.03 of the Standard Specifications, applicable Supplemental Specifications and applicable Special Provisions.

Bituminous Materials – Additional asphalt binder that is required in the production of the recycled asphalt concrete mixtures shall be a PG64–22 meeting the requirements of AASHTO MP2. Binders meeting the requirements for PG67–22 or higher grade will not be permitted.

Softening agents, asphalt modifiers/rejuvenators, or recycling agents will not be allowed.

If during construction it is determined by the Engineer that the grade of asphalt binder so selected is not performing satisfactorily, the Department reserves the right to change, without a change in the Contract Unit Price, the grade of asphalt binder being used in the mixture.

Liquid Anti-Strip Additive – When liquid anti–strip additives are specified, the anti–strip additive shall be blended into the new asphalt binder at a rate of 0.7%. The liquid anti–strip additive shall be blended with the new asphalt binder in accordance with Section 401.02 of the Standard Specifications.

Hydrated Lime – When hydrated lime is specified as the anti–strip additive, the hydrated lime shall be added at a rate of 1.0% by dry weight of virgin aggregate. The hydrated lime will be introduced and mixed with the damp virgin aggregate in accordance with procedures described in the Supplemental Specification titled "Hot Mix Asphalt Concrete Base, Binder and Surface Courses."

Composition of Recycled Mixture – The recycled hot mix asphalt mixture shall meet all applicable requirements contained in the Standard Specifications, Supplemental Specifications and Special Provisions, except as indicated herein. Samples of RAP and additives proposed for use in the recycled hot mix asphalt mixture shall be submitted to the Research and Materials Laboratory in Columbia, SC, at least 30 days prior to the beginning of the work. A minimum of 50 pounds (23 kg) of representative milled material shall be submitted by the Contractor along with the RAP stockpile records and asphalt mix design approval request (Lab Form 269).

At least 10 cores should be submitted by the Contractor if milled material from a project is not available. Cores shall be 6 to 8 inches (150 to 200 mm) in diameter, sliced at the proposed milling depth and should be representative of the material to be milled. In addition, the Contractor shall perform a minimum of six extraction tests on cored roadway samples prior to submitting an asphalt mix design approval request. The Contractor's extraction test results and cores representing the material to be milled shall be submitted with the asphalt mix design request.

During mix design verification, approval of the grade of asphalt binder will be based on the absolute viscosity of the asphalt binder recovered from the recycled mix. The recovered absolute viscosity at 140°F (60°C) shall be in the range of 2,000 to 8,000 poises (200 to 800 Pa-s) following the AASHTO T170 and T202 procedures.

The range of RAP in recycled hot mix asphalt mixtures is as follows:

TYPE MIX	% RAP*
Asphalt Aggregate Base Types 1& 2	10 – 30
Binder Types 1 & 2 and Surface Types 3 & 4	10 – 25
Surface Type 1	10 – 20

* RAP is limited to 15% maximum when introduced in the hot elevator

Reclaimed asphalt pavement will not be allowed in Superpave or Surface Types 1A, 1B and 1C.

Random project inspections will be made by the Central and District Laboratory Asphalt Inspectors so that samples of recycled hot mix asphalt mixtures can be obtained for checking the recovered absolute viscosity of the asphalt binder. The absolute viscosity at 140°F (60°C) of the asphalt binder recovered from the field samples shall be in the range of 3,000 to 14,000 poises (300 to 1,400 Pa–s).

All asphalt mixtures shall conform to the job mix formulas approved by the Research and Materials Engineer within the tolerance range specified.

EOUIPMENT

General – The recycled hot mix asphalt mixtures shall be produced in a batch plant or drum mix plant which meets all applicable requirements of the Standard Specifications, Supplemental Specifications and Special Provisions and which has been modified in a manner satisfactory to the Engineer in order to accomplish the hot recycling process. The plant shall be capable of producing uniform mixtures at the temperatures specified.

The plant shall be capable of meeting all applicable local, State and Federal pollution requirements. The Contractor shall be familiar with all regulations and shall be aware that plant emissions resulting from the recycling process may be monitored.

Batch Plants – RAP may be introduced into the plant at the hot elevator (Maximum of 15% RAP) or in the weigh hopper.

When RAP is introduced into the weigh hopper, RAP shall be accurately weighed and proportioned using an automatic proportioning system. The RAP weight tolerance shall be ± 1.5% of the total batch weight. The RAP weight for each batch shall be printed on the weight ticket along with the other batched materials.

When RAP is introduced in the hot elevator, the maximum amount of RAP shall be 15%. The RAP cold feed rate and virgin aggregate cold feed rate shall be weighed, controlled and monitored continuously. The weighing system shall have an accuracy of 0.5%. Means shall be provided for conveniently diverting RAP and virgin aggregates into trucks or other containers for checking accuracy of cold feed delivery systems. The plant shall be calibrated by the Contractor before starting production.

Provisions shall be made electronically for introducing the determined moisture content of the cold feed materials (RAP and virgin aggregates) in the belt weighing system and automatically correcting wet material weights to dry material weights. Moisture content of the RAP and virgin aggregates shall be determined by the Contractor twice a day during production or when the Engineer deems necessary. **The plant inspector will record the Contractor's moisture test results on the daily plant report.**

Hot elevator RAP introduction systems shall be equipped so that the dry RAP and dry virgin aggregate rates in tons (tonnes) per hour will be printed on a cold feed ticket at a time interval prescribed by the Engineer. The cold feed tickets shall be submitted to the Engineer at the end of each day's production.

Drum Mixing Plants – the RAP cold feed rate and virgin aggregate cold feed rate shall be weighed, controlled, interlocked and monitored continuously. The weighing system shall have an accuracy of 0.5%. Means shall be provided for conveniently diverting RAP and virgin aggregates into trucks or other containers for checking accuracy of cold feed delivery systems. The plant shall be calibrated by the Contractor before starting production.

Provisions shall be made for electronically introducing the determined moisture content of the cold feed materials (RAP and virgin aggregates) in the belt weighing systems and automatically correcting wet material weights to dry material weights. Moisture content of the RAP and virgin aggregates shall be determined by the Contractor twice a day during production or when the

Engineer deems necessary. **The plant inspector will record the Contractor's moisture test results on the daily plant report.**

The RAP shall be introduced in the plant at a location far enough down-stream from the burner to be away from the flame and extremely hot gases.

The drum mixing plant shall be equipped with a printer to print the following plant information: (1) dry virgin aggregate rate in tons (tonnes) per hour, (2) dry RAP rate in tons (tonnes) per hour, (3) asphalt binder in tons (tonnes) per hour, (4) total virgin aggregates, RAP and asphalt binder in tons (tonnes) per hour. The above mentioned plant information shall be printed on a ticket at a time interval prescribed by the Engineer. Plant information tickets shall be submitted to the Engineer at the end of each day's production.

CONSTRUCTION

The production, spreading, compaction, etc., of the recycled hot mix asphalt mixture shall conform with applicable requirements of the Standard Specifications, Supplemental Specifications and Special Provisions.

METHOD OF MEASUREMENT

The quantity of asphalt binder in the recycled hot mix asphalt mixture to be paid for shall be the number of tons (tonnes) in the completed and accepted work. (This will include the asphalt binder in the Reclaimed Asphalt Pavement material.) The amount of asphalt binder shall be determined by SC–T–64 or SC–T–75.

Recycled hot mix asphalt mixture shall be measured for payment in accordance with Subsection 401.29 of the Standard Specifications.

SUPPLEMENTAL SPECIFICATIONS

January 1, 2001

UTILIZATION OF SHINGLES IN ASPHAL T MIXTURES

DESCRIPTION

The work specified by this section consists of the materials, job mix design, mixing procedures, delivery and placement of an asphalt mix containing shingles. All applicable special provisions and sections of the Standard Specifications except as noted herein will apply. Shingles will be permitted in Asphalt Aggregate Base Types 1 and 2, Binder Types 1 and 2 and Surface Types 1, 3 and 4.

MATERIALS

Shingles: The asphalt mixture shall be a uniform and reacted mixture of compatible paving grade binder quality fine and coarse aggregates, antistrip additive, and shredded shingles.

Amount of Shingles in the Mixture: The amount of the shingles used in each mix shall be in accordance of the job mix formula requirements for that mix. The Contractor shall utilize 3 – 8% shingles by the total weight of the aggregate.

Shredded Shingles: The shredded shingles shall be produced primarily from the processing of shingles at a processing facility or during delivery to a landfill. The shingles shall be produced by ambient temperature grinding processes only. The use of shingles of multiple types from multiple sources is acceptable provided that the overall blend of shingles meets the gradation requirements. The manufacturer of the roofing shingles shall remove all debris such as nails, wood, metal, dirt, large stones, etc. and render the materials to a size of less than ½". The materials delivered shall be 99.7% (by weight) free of any debris.

GRADATION

The gradation of the shingles when tested in accordance with AASHTO T 27 shall meet the following requirements:

Sieve Size	% Passing
½"	100
#4	67 – 82
#100	0 – 7
#200	0 – 3

The length of the individual particles shall not exceed ½" (12.7 mm) .The shingles shall be sufficiently dry so as to be free flowing and to prevent foaming when blended with hot binder. The shingles must be free of chemicals, oils, or any other hazardous materials (e.g. asbestos). The shredded shingles shall be accepted by certification from the shingle supplier.

TEST PROCEDURES

Mix Design: Marshall method of mix design described in SC–T–81 can be used for design of HMA mixtures containing shingles. After heating the aggregates to the proper temperatures and one hour before the addition of the binder, add the proper amount of the shingles (e.g., 8% of total weight of the aggregate or 0.080 × total weight of aggregate) and mix thoroughly and place

the mix back in the oven. After one hour, add the required amount of the binder and mix. The temperature of the mixture shall be checked to insure it has reached the compaction temperature before applying the compactive effort using the Marshall hammer.

Extraction: The extraction process shall be in accordance with requirements described in the Standard Specifications. The testing procedures described in SC–T–75, "Determination of Asphalt Binder Content for Asphalt Paving Mixtures by the Ignition Oven" shall be followed to obtain the binder content of the mixture. However, shingles contain approximately 31% (by total weight of shingle) binder, so there shall be a correction factor of 2.0 used to obtain the correct virgin binder content. Therefore, the binder content obtained from the ignition oven shall be adjusted by 2.0% (i.e., Adjusted binder content = the binder content obtained from the ignition oven – 2.0).

EQUIPMENT

Shingle Blending Equipment: The required amount of shingles shall be added to the hot mix asphalt mixture either manually or mechanically. The system, if mechanical, shall be fully integrated with controls for mineral aggregate, binder, and antistrip additive. The system and methods of adding the shingles to the mix shall be discussed and determined in the pre-construction meeting. The system (manual or mechanical) shall be approved by the Engineer.

Storage Area: A storage area shall be provided for storing the shredded shingles and shall be kept free and clear of all debris such as dirt, wood, paper, stones, etc.

Silo Storage: If the mixture is discharged from the mixer into a hot mix surge or storage silo, the bin shall be operated so that segregation of the mixture will be minimized. Storage time is not to exceed 4 hours.