Paper from: *Waste Management and the Environment*, D Almorza, CA Brebbia, D Sales & V Popov (Editors).
ISBN 1-85312-907-0

# ARTS: Paving the way for rubber recycling technology in South Carolina

S. N. Amirkhanian
*Civil Engineering Department, Clemson University, USA*

## Abstract

South Carolina's Department of Health and Environmental Control (DHEC) awarded a $6 million, five year grant to the Clemson University for a research-outreach program to establish Asphalt Rubber Technology Service (ARTS) that could literally pave the way toward eliminating the millions of worn-out tires that clog the state's landfills. Each year, approximately 4,000,000 waste tires are generated in South Carolina. Around the country that number is estimated to be around 280,000,000 tires each year. Through the project, many highways and secondary roads will be paved with rubberized asphalt. In addition, the scrap tires will be utilized in embankments, retaining walls, running tracks, new tires, and golf-course cart paths. Recycling discarded tires could have significant impact on the reduction of solid waste in South Carolina and the rest of the nation. The five-year project will enable the ARTS team to work with agencies and communities statewide to identify recycling markets for waste tires and to provide education, training and technical services. Approximately $950,000 of grants will be available each year to help fund projects throughout the state. Grant money comes from the state's Waste Tire Trust Fund. A $2 fee is paid on each new tire sold in South Carolina. Of that fee, 44 cents is placed in the Waste Tire Trust Fund. The ARTS' funding is for the differential cost of conducting a project using crumb rubber versus using just the raw materials (i.e., no crumb rubber). This paper will discuss several issues involved with recycling tires and several projects that have been completed to date. The technical and environmental issues involved with such projects will be discussed. The benefits and disadvantages of such technology will also be addressed.

Paper from: *Waste Management and the Environment*, D Almorza, CA Brebbia, D Sales & V Popov (Editors).
ISBN 1-85312-907-0



# 1 Introduction

The United States spends approximately $13 billion annually on highway construction and repairs. This requires nearly 350 million tons of both natural and manufactured construction materials. Moreover, the Federal Highway Administration (FHWA) estimates that the cost to bring our nation's roads up to minimum engineering standards over the next 20 years will be between $565 and $655 billion [1].

A solid waste generation and disposal problem exists in the United States. Approximately 4.1 billion metric tons (4.5 billion short tons) of non-hazardous solid waste are generated annually. Of this, over 209 million tons of municipal solid waste (MSW) is generated annually, an equivalent of 2.0 kg/person/day. Even after materials are removed from the waste stream for recycling or composting, approximately 1.52 kg/person/day is being disposed of in the USA. This is equivalent to 160 million tons of MSW being discarded annually by combustion or landfilling.

One issue that local and state agencies have to deal with regarding the MSW is the method used to dispose of waste tires. Approximately 280,000,000 scrap tires a year (1 tire/person/year) are generated each year in the United States. For instance, the local municipalities around the state of South Carolina are responsible for disposal of approximately 3.5 million tires each year. A typical passenger car tire weighs approximately 9 kilograms and will provide approximately 60% rubber, 20% steel and 20% fiber and other waste products. There are many uses of crumb rubber including rubberized asphalt, other civil engineering applications (e.g., embankments), as a fuel source, and numerous other uses.

Scrap tire recycling mandates are written into both the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 and the Resource Conservation Recovery Act stating that federal-aid highway funding would be withheld from states if they do not comply with these Acts. Section 1038 of the ISTEA (Use of Recycled Paving Material) addresses the use of scrap tires in asphalt mixtures; however, in 1995, the Senate repealed this Section.

In South Carolina, the legislature passed the SC Solid Waste Policy and Management Act of 1991, which requires the SC DOT to investigate the use of certain waste products (e.g., tires) in various aspects of highway construction. Because of this Act and environmental concerns, the SC DOT has been conducting several research projects since 1991.

This article reports on several issues involved with rubberized asphalt mixtures and actual field projects, which utilized crumb rubber modifiers constructed in the State. In addition, the newly developed Asphalt Rubber Technology Service (ARTS) is described. This program will provide coordination, technology transfer, training workshops, information services, special project administration, research, and a forum for sharing lessons learned.

There are many factors to consider when a state agency uses rubber in its pavements including cost, specifications, type of equipment to be used, expertise of the contractor, potential recyclability of materials, etc. The reported advantages for

Paper from: *Waste Management and the Environment*, D Almorza, CA Brebbia, D Sales & V Popov (Editors).
ISBN 1-85312-907-0



using rubber in asphalt mixtures include: thinner lift, increased pavement life, retarded reflection cracking, decreased traffic noise, reduced maintenance costs, decreased pollution and increased environmental quality.

There are many issues and problems associated with the use of tires in asphalt pavements that must be researched and analyzed. Some of the issues and problems include: potentially high initial costs; lifecycle economics; lack of product specifications; potential lack of scrap tire uniformity; the recyclability of the rubberized pavements; environmental concerns; and potential modifications made to the asphalt plants or equipment.

In 2001, there were approximately 500 scrap tire processing facilities in the United States. In addition, there were 82 facilities using scrap tires as a fuel source including 36 cement kilns, 18 pulp and paper mills, 17 industrial boilers and 11 utility boilers. Most of the states (48) have some form of scrap tire legislation or regulations. There are 33 states that charge a fee for changing tires. Approximately 38 states have a ban for landfilling whole tires and there are 11 states that ban all scrap tires from landfills.

## 2 Asphalt rubber technology service (ARTS)

The South Carolina Department of Health and Environmental Control (DHEC) awarded Clemson University a grant to establish a program to promote the utilization of scrap tires in civil engineering and other applications. The grant was awarded by DHEC's Office of Solid Waste Reduction and Recycling through their Waste Tire Trust Fund. A $2 fee is paid on each new tire sold in South Carolina; 44 cents of that fee is placed in this Trust Fund.

One of the major functions of ARTS is to provide technical assistance for public works agencies in local governments across the state, in the promotion, design, testing, and use of rubberized asphalt and other crumb rubber in civil infrastructure applications. The technical staff of ARTS will design, procure, manage, and evaluate field demonstration projects. In addition, other projects utilizing crumb rubber in civil infrastructure applications will be designed and managed each year. These projects will be performed by independent contractors under the direct supervision of the ARTS staff and they will be monitored for performance.

### 2.1 South Carolina's previous experiences with rubberized asphalt

Before the creation of ARTS, SC DOT had constructed five rubberized projects around the state. The following is a brief summary of three of these projects.

#### 2.1.1 Pelham Road, Greenville county - dry process

In 1992, the SCDOT initiated a study to field test a rubberized asphalt mixture. Tires were collected from dumpsites around the state by Michelin Tire Corporation and were shredded and pulverized down to gradation specifications for addition into the asphalt mix. The dry method was used to produce the rubberized asphalt. The scrap rubber was graded and packaged into 1,000 Kg bags, which were separated

Paper from: *Waste Management and the Environment*, D Almorza, CA Brebbia, D Sales & V Popov (Editors).
ISBN 1-85312-907-0



into coarse-ground and fine-ground rubber. The mixture contained 80% coarse-ground (6.3 mm to 20 mesh) rubber and 20% fine-ground (-20 mesh) rubber to form the composite gradation required.

This road section was monitored for several years to evaluate the performance. Several cores were taken and tested periodically. Friction tests were also performed. Visual inspections indicate that the condition of the road appears to be very good after 10 years of service. It has been noted on each inspection that there are rubber crumbs on the pavement surface. Rubber crumbs are a common occurrence on dry-method rubberized asphalt projects and the amount of rubber lost from the mix is negligible and will decrease with time.

#### 2.1.2 SC-24, Anderson county - wet process

In 1993, another asphalt rubber project using the wet process was started. The crumb rubber was added at the rate of 11.8 Kg per ton, or 18% by total weight of the binder. A product named TBS-20 was added to the binder as part of the 18% of crumb rubber to obtain the desired elasticity. TBS-20 consisted of ground tennis ball scraps obtained from rejected tennis ball production and was used because of the natural latex from which it was made.

In this process, the crumb rubber in 22.7 Kg bags was added to the mixing tanks which were hand fed into the machine. This road test section has been performing satisfactorily to this date. Roadway cores are routinely being tested. The results, in general, indicate that the asphalt rubber mixture is producing higher wet indirect tensile strength and tensile strength ratios than the control mixture. In addition, the results of the friction testing indicate that the rubberized mixture is performing better than the control mixture.

#### 2.1.3 US-76, Marion county - wet process

In October of 1994, approximately 11,000 metric tons of rubberized asphalt was placed in Marion County, South Carolina (4 lanes, each 8 km in length). This project was the SC DOT's largest to test these materials at that time. The mix design was performed using the same methodology as the SC-24 project. All roadway densities were satisfactory and it was relatively trouble-free and proceeded at a rapid pace. The performance of this section of the experimental pavement has been very good.

### 2.2 ARTS projects

In August 2000, ARTS was formed and the first set of projects were paved with rubberized asphalt in the summer of 2001. Six projects have been completed to date and at least five others are in the planning stages. Details of some of completed projects are discussed below. Table 1 shows some mix design information regarding these projects.

Paper from: *Waste Management and the Environment*, D Almorza, CA Brebbia, D Sales & V Popov (Editors).
ISBN 1-85312-907-0



Table 1. Mix design information for rubberized asphalt projects

| Properties | Pickens County School District | Anderson County Phases I-II | Anderson County Phase III |
|---|---|---|---|
| % Optimum Binder | 6.30% | 6.10% | 5.60% |
| % Air Voids | 4.02% | 4.14% | 3.88% |
| % VMA | 18.70% | 18.38% | 16.75% |
| % VFA | 78.50% | 77.45% | 76.84% |
| % Wet ITS† | 77.0 psi | 77.0 psi | 88.7 psi |
| % TSR†† | 85.1% | 85.1% | 88.4% |
| % Cost Increase* | 13% | 19% | 38% |

† ITS: Indirect Tensile Strength
†† TSR: Tensile Strength Retained
* Compared to conventional asphalt mix

### 2.2.1 Pickens county school district

Pickens County School District received a grant for placing approximately 2,600 tons of rubber modified HMA on several driveways, parking areas, and play areas at various elementary schools. A 9.5mm Superpave mix ($N_{des}$ = 75 gyrations) using PG 64-22 binder modified with 10% ground tire rubber (#40 mesh) was used on this project. In general, there were no major problems in the plant production of this mix. Blending of the asphalt rubber was performed at plant site using equipment specifically designed for asphalt rubber blending (Figure 1). Minimal plant modifications were necessary for the use of this equipment.

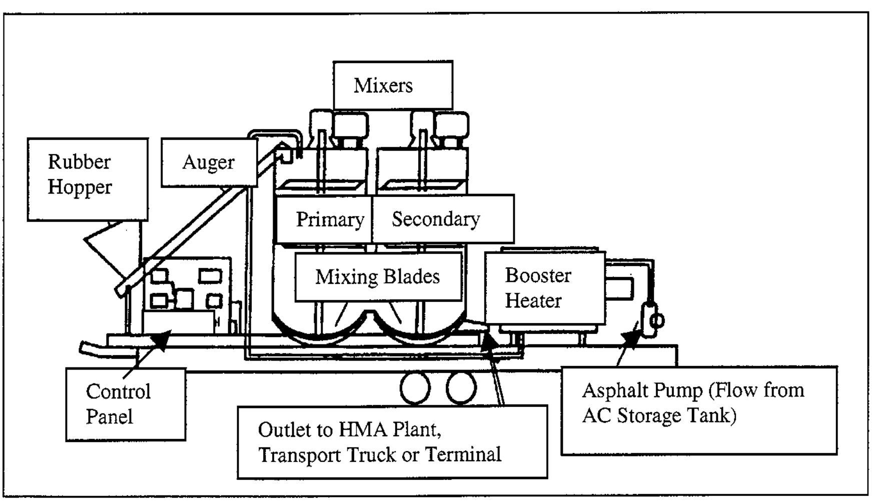


Figure 1: Portable blending unit

Paper from: *Waste Management and the Environment*, D Almorza, CA Brebbia, D Sales & V Popov (Editors).
ISBN 1-85312-907-0



The mixing temperature for this project was set at approximately 166° C to 171° C (330° to 340° F). The production rates for this plant allowed the contractor to produce as much as 600 to 1,500 tons per day. The total amount of rubber modified HMA produced for the project was approximately 2,600 tons and took 7 days.

A few problems were encountered during production of this mix. For instance, the asphalt plant was set to introduce 6.10% binder, initial tests indicated that the actual binder content was somewhat lower. In general, test results showed that the actual binder content was approximately 0.50 to 0.70 points lower than the desired level. This was attributed to the fact that the asphalt rubber had a significantly higher viscosity than the unmodified binder normally used in the plant. The binder pump had not been calibrated for the asphalt rubber and therefore could not perform accurately. To solve this problem, the plant's control computer was set approximately 1.5 points higher than the desired asphalt binder content. Most of the other job mix requirements were generally met.

The HMA mix was hauled to the project site (45 km away) in dump trucks and took 45 minutes to one hour depending on traffic. Once at the site, the mix was placed in a two-inch lift using conventional paving methods and equipment. Compaction was generally attained through the use of two steel wheel rollers. Due to the poor condition of the existing pavement in most locations, target densities were based on optimum compaction obtained in the field instead of lab densities.

There were no major modifications to the paving process using this mixture. Significant amounts of "handwork" were required in several of the parking lots, but no special problems were noted with this process either. In general, paving proceeded as with a normal hot mix asphalt.

### 2.2.2 Anderson County, Michelin Boulevard phases I-II

This project involved placing approximately 10,000 tons of surface course rubber modified mix on several newly constructed roads in Anderson County. A 9.5mm Superpave mix ($N_{des}$ = 100 gyrations) using PG 64-22 binder modified with 10% ground tire rubber (#40 mesh) was designed and used on this project. As other projects, minimal plant modifications were necessary for the use of conventional equipment.

Placement of this mix was very similar to that of standard Superpave mixes. Like many Superpave mixes, a "tender zone" was encountered during the rolling process when the asphalt mat reached temperatures between approximately 93 °C to 121 °C (200° F and 250° F). However, this problem was resolved by altering the rolling pattern to avoid this temperature zone. Compaction was attained through both vibratory and static steel wheel rollers. Pneumatic tire rollers were not utilized due to the tendency of the asphalt to adhere to the tires. In general, most of the mix's job mix requirements were met (e.g., compaction).

Paper from: *Waste Management and the Environment*, D Almorza, CA Brebbia, D Sales & V Popov (Editors).
ISBN 1-85312-907-0



### 2.2.3 Anderson County, Michelin Boulevard phase III

Phase III of the Michelin Boulevard project varied from the other ARTS projects in that rather than blending the asphalt rubber mix at a local asphalt plant, the asphalt rubber was pre-blended at a supplier's terminal in Pensacola, Florida and shipped to the contractor's asphalt plant using tractor trailers equipped with heated tanks. A separate tractor-trailer with a heated and mechanically agitated tank was stationed at the contractor's asphalt plant to be used as a temporary storage tank for the asphalt rubber. This temporary storage tank was connected to the contractor's asphalt binder pump so that the asphalt rubber could be metered into the asphalt plant (Figure 2).

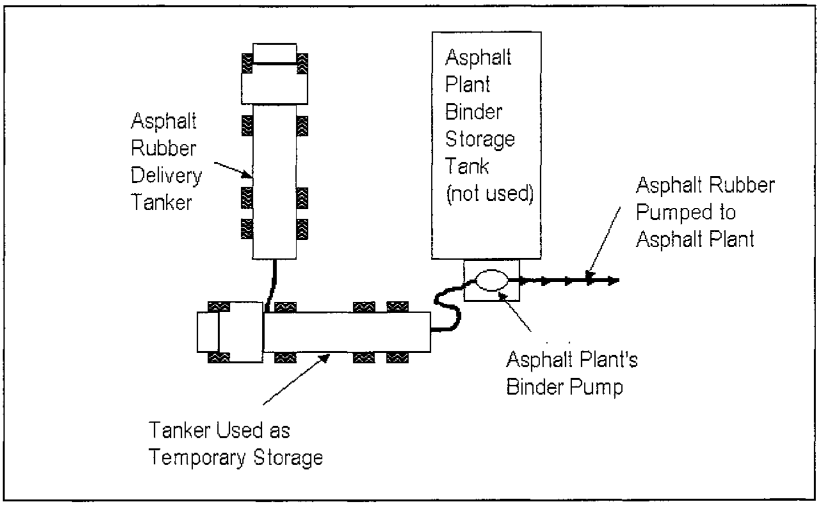


Figure 2: Plant setup for blending of asphalt rubber mix

There were no modifications made to the contractor's asphalt plant. Approximately 4,000 tons of rubber modified HMA on a newly constructed county road was placed. This mix was a 9.5 mm Superpave mixture ($N_{des}$ = 100 gyrations) utilizing PG 64-22 binder modified with 10% ground tire rubber (#40 mesh).

In general, production of the rubber modified HMA proceeded normally. The mixing temperature was set at approximately 330° F to 340° F (166° C to 171° C). The mix was stored in the silos, and loaded into dump trucks for delivery to the project. This project took five days to complete. No substantial problems were encountered during the production of the mix, although a higher level of communication and coordination with the binder supplier was used due to the long haul distance of the asphalt rubber from Pensacola, Florida (8 hours away).

At the asphalt plant, quality testing was conducted at regular intervals to determine mix properties. Initial tests of the rubber modified HMA indicated

Paper from: *Waste Management and the Environment*, D Almorza, CA Brebbia, D Sales & V Popov (Editors).
ISBN 1-85312-907-0



binder contents that were higher than specified, which subsequently caused other volumetric properties such as the air voids to not meet the requirements of the job mix formula. Once adjustments were made at the asphalt plant to correct the binder problem, all other criteria also fell within acceptable limits.

## 3 Conclusions

South Carolina municipalities are responsible for the disposal of approximately 3.5 million tires each year. There are many environmental hazards associated with tires left in landfills including fires and a breeding ground for mosquitoes. Many researchers and private companies are investigating for ways to recycle scrap tires into viable resources rather than sending the millions of tires that are discarded annually to landfills. There are many uses for the scrap tires including rubberized asphalt, other civil engineering applications (e.g., embankments, fill material), as a fuel source, and various other ways. One of the primary goals of ARTS is to make scrap tire recycling sustainable in South Carolina.

The six rubberized asphalt projects completed to date have been widely successful and even in the early stages of the overall grant project, several conclusions can be made. For the materials used, ARTS has successfully used the Superpave mix design process to develop a formula that utilizes asphalt binder containing 10% ground tire rubber by weight of binder. Crumb rubber can effectively be blended using the "wet method" at a rate of 10% by weight of binder, on-site at an asphalt plant. In addition, the same mix can effectively be blended at the binder supplier's terminal and shipped to the contractor's asphalt plant. In both cases, minimal plant modifications may be necessary to incorporate the mix into the asphalt plant. This may include an additional valve to the asphalt pump and an electrical breaker to accommodate a pre-blended terminal mix. Another important issue involved with this process is the calibration of the asphalt plant. Calibration of the asphalt pump for the asphalt rubber is recommended prior to starting production of the rubber-modified mix.

The costs of mixtures used for a couple of the projects were approximately 19% more than conventional asphalt mixes. These costs are highly dependent on several factors including materials, project location, and more importantly, project size. The project that utilized the terminal blend was more costly (39% compared to a conventional mix). The higher cost of this pavement was due largely to the transportation of the blended mix from far away (i.e., Florida) and then from the local asphalt plant to the project site. Although more expensive than conventional mixes using unmodified asphalt binders, the cost of this rubber modified asphalt mix is very similar to those using common polymer modified binders such as PG 76-22.

## 4 Acknowledgements

The author wishes to extend his appreciation to the South Carolina Department of Health and Environmental Control (SC DHEC) for sponsoring and funding

Paper from: *Waste Management and the Environment*, D Almorza, CA Brebbia, D Sales & V Popov (Editors).
ISBN 1-85312-907-0



this project. Special thanks to Anderson County and Pickens County School District, as well as private consultants and contractors for their assistance throughout each project.

## 5 References

[1] Amirkhanian, S.N., *Asphalt-Rubber Technology: Waste Tires Cut Costs of Building New Highways*, BioCycle Magazine, pp 46-47, December 2000.