Tire Recycling Contributions to Safety, Noise Reduction, and Long Term Performance in Highways Using Asphalt-Rubber

H. Barry Takallou, Ph.D., P.E.
President
CRM Company
15800 S Avalon Blvd
Los Angeles, CA 90220 USA
hbtak@aol.com

Cliff Ashcroft
Vice President California Operations
FNF Construction
810 Arroyo Place
Fullerton, California 92833 USA
cliffa@fnfinc.com

Douglas D. Carlson
Executive Director
Rubber Pavements Association
1908 South Jentilly Lane Suite A-2
Tempe, Arizona 85281 USA
Doug.carlson@rubberpavements.org

ABSTRACT: Recent research within the United States has provided data demonstrating the enhanced safety, decreased tire noise generation and long term performance of bituminous mixtures that use scrap tire rubber (crumb rubber) as a modifier.

In the state of Texas, rubberized permeable friction course (PFC) reduced weather accidents over 50% and in some cases fatalities have been significantly reduced after the placement of PFCs.

The Quiet Pavement Pilot Program initiated by the United States Federal Highway Administration (FHWA) allowed a state of Arizona to control traffic noise by using a rubberized surface for the first time. Twelve dBA reductions are reported when measuring tire noise at the pavement contact. New noise measuring methods are being developed to quantify and measure tire/pavement noise in order to control it. The new method has allowed a standardized measurement of quiet pavements in locations around the world. The rubberized surfaces used in the U.S. have ranked very close to the quietest pavement designs in Europe.

The US FHWA evaluated modified pavement mixtures using the Accelerated Loading Facility. This device simulates real loading of pavements expected to bear heavy truck traffic. At the experiment completion, all sections had cracked and most had failed with the exception of the asphalt-rubber. This verified the performance of the asphalt-rubber materials in the reduction of reflective cracking and maintenance in field applications. The experiment will also provide materials engineers in the US a predicted performance grade (PG) of the asphalt-rubber which previously was not possible due to testing equipment constraints related to the 2 mm rubber particles in the liquid asphalt.

This research provides pavement designers with compelling rationale to select asphalt-rubber materials which can consume over 1500 tires per lane/kilometer of roadway. By selecting asphalt-rubber materials in pavement construction, maintenance and rehabilitation, governments may achieve safer, quieter and longer lasting roadways that also help reduce the amount of scrap tires that are not beneficially re-used.
1. Introduction

There are a few ways in which asphalt-rubber is manufactured for use in road paving applications. Primarily, asphalt-rubber is the combination of liquid bitumen (asphalt) and granulated scrap tire rubber or crumb rubber modifier (CRM) in a 4:1 ratio, (80% bitumen and 20% rubber) and held in agitation and elevated temperatures for 45-60 minutes. The CRM is used in a 2 mm minus particle and does not dissolve during the process. [TAK 03] Common CRM particle size can be noted in the Figure 1.

![Figure 1. Common rubber size 2 mm minus, rubber remains undissolved](image)

The resulting A-R material is highly viscous and flexible and stays flexible for longer periods of time than conventional, unmodified bitumen. The material can be used in spray applied applications commonly called chip seals or stress absorbing membranes and in hot mix asphalt concrete. This paper will focus upon the hot mix asphalt materials.

Asphalt-Rubber has been routinely used in some parts of the United States for many years. Pavement design engineers in cities, counties and states have been selecting the material due to its performance and durability, providing a more crack resistant and longer lasting pavement surfaces which in turn decrease maintenance costs. [WAY 99] Originally developed in the state of Arizona in the 1960s, the material was limited in use due to the limited capacity of the asphalt-rubber industry and limited supply of quality scrap tire rubber. Although scrap tire use was a compelling reason to develop the technology, the scrap tire problems were not recognized at the time and regulations and scrap tire programs were not introduced until the late 1980s and early 1990s.

Following the expiration of patents on the technology in the mid-1990s, many road building and materials supply companies invested in the industry primarily in the states of Arizona, California and Texas where the material was regularly specified. Growth has ebbed and flowed in various countries and states since the 1990 including a brief introduction to Europe. Also, whole scrap tire processing did not develop in the USA until the mid 1990s. Many agencies did not have the specifications or expertise needed to implement the technology or a well develop local industry to
support and sustain the continued use of the material. Considering the somewhat recent expiration of patents and development of whole tire processing equipment and facilities, the industry is just now entering a significant growth phase from it’s infancy and years of early development. Only 12 years have passed since the last of the patents expired.

The key to growth is within every community. Two key champions are needed for asphalt-rubber technology development with a region. The champions needed are the innovative pavement or highway design engineer within a department of transportation and the pioneering industrial champion willing to invest in the equipment and technology and to take the first risk when asphalt-rubber projects are specified. Typically, road builders will never invest in equipment before the material is routinely specified in projects.

Some specialized equipment is needed to manufacture asphalt-rubber material. Equipment manufacturers have responded to growth and provide a variety of machines that can be used to blend the CRM and bitumen and mix the material or react it on site before it is supplied to the hot mix asphalt facility. It is very important that the equipment has precise weighing and metering capabilities as well as heavy duty pumps to move the high viscosity material. Also, most of the equipment is mobile or trailer mounted to respond to distant locations within a region and sometimes sporadic requests for use within the domain of paving agencies that do not use the material routinely. A typical equipment configuration is provided in the Figure 2 below.

![Figure 2. Bitumen Tank and Baghouse before A-R blending Equipment is Added and After](image)

The latest equipment is computer controlled and easily managed through touch screen displays or keyboard commands. The blending and mixing equipment is fully integrated with standard hot mix asphalt facilities and simply provides a by-pass in the normal piping used to supply the regular bitumen. A large production blending unit commonly used in the US is pictured in Figure 3.
Figure 3. A common large production, mobile asphalt-rubber blending unit.

No special equipment is needed to place the material on the roadway. Conventional paving equipment will suffice. Steel wheeled rollers are needed since the tire rubber in the asphalt can stick to the tires on rollers or other equipment. The material can stiffen quickly, like other polymer modified bitumen, and is recommend to be placed at ambient air temperatures of 12° C or higher. Cooler temperatures may be allowed based upon the prevailing weather conditions and the contractor’s material heat management practices such as covered loads during hauling and material transfer devices. Figure 4 provides some paving applications from recent projects in Alberta, Canada.

Figure 4. Standard paving equipment is used to apply A-R.

The presence of undissolved CRM in the paving mixtures has required the development of aggregate gradations that were not commonly used within the United States. Common aggregate gradations were designed to have a uniform distribution of rock sizes so that the rocks would fit together in the most compacted space possible, with a thin coating of bitumen to hold them all
together. These are called dense graded mixes. A program was initiated in the 1990s by the US Federal Highway Administration to develop a uniform and standard mix design procedure within the state departments of transportation using the dense graded mixtures and non-particulate modified bitumen. Mixtures using asphalt rubber need to have some of the fine dust and sand removed to make room for the scrap tire rubber particles. These mixes are called gap or open graded. See Figure 5 for a comparison of the dense, gap and open graded mixes.

![Figure 5. From Left to Right, Open Grade, Gap Grade and Dense Grade Aggregate](image)

This change in mixture design was one reason why new areas within the US were reluctant to try or use the material. The rubberized material did not fit into their standard mix designs and procedures. Some extra engineering is required. Typically, engineers are cautious by nature and slow to change, especially without a compelling reason. European states have mixtures where asphalt-rubber would fit in and work very well, they are the Stone Matrix and Porous Asphalts. See Figure 6.

![Figure 6. A porous pavement in the Netherlands (left) and SMA mix (right) in Belgium could be easily modified with scrap tire rubber to extend the service life, the porous asphalt is similar to the open grade and SMA is similar to the Gap Grade in Figure 5.](image)
Recent developments and research provides more information to the US engineering community that will allow them to make the changes needed to make the use of asphalt-rubber routine. Compelling findings with respect to highway safety, tire noise reduction and long-term performance will bring about more growth in the US and provides a new opportunity for European engineers to introduce the material for use in their regions of influence.

2. Recent Research

Many barriers have existed to limit the growth of the asphalt-rubber industry. The barriers are being removed in unconventional manners stemming from the need to rehabilitate aging highway infrastructures, high occurrences of vehicle collisions, increased highway traffic noise, public involvement in environmental impact of road construction, and remarkable performance of asphalt-rubber materials in areas that are easily accessible to the highly mobile society. Highway users from other areas or states observe and experience the very favorable performance and then ask their departments of transportation or public works to have the same pavement types in the areas near their homes.

2.1 Safety

Safety has become a very high concern of the Federal Highway Administration with over 40,000 fatalities recorded each year in the US as a result of accidents upon the nation’s highways. According to the National Transportation and Safety Bureau, the number of fatalities as a result of automobile accidents by 1950 had exceeded the number of Americans killed in action during both World Wars. To improve highway safety, the US FHWA encouraged the states to implement the use of friction courses in the year 1980 under the Skid Action Reduction Program Technical Advisory T 5040.17 and T 5040.13 for the Open Graded Friction Course. Friction courses provide greater traction to vehicle tires, resisting skid. However, because the materials available for use in the friction courses did not have adequate durability, lasting only 5-7 years before needing replacement, and the funding for the maintenance and replacement was not given to the states, the states moved away from the open graded technology.

The state of Arizona continued to use the friction courses because it had developed durable mixtures with asphalt-rubber binders that lasted 10-15 years before needing maintenance or replacement. [MOR 01] States now use many different materials and devices in highway construction to improve safety. For example significant expenditures are made to install and maintain bridge rails, guard rails, rumble strips, shoulders, median barriers and crash cushions. With materials like asphalt-rubber that can provide a more durable binder due to the presence of recycled tire rubber, safety improvements in the pavement surface are being reconsidered.

In the state of Texas, a rubberized permeable friction course (PFC) was used for the first time to place a thin, 38 mm (1.5 in), surface treatment on an aged continuously reinforced concrete pavement (CRCP) that was built in the late 1970s. By 2002, the existing structure of the CRCP was sufficient, but the surface was badly deteriorated due to prolonged exposure to heavy truck traffic and weather. The project is located in San Antonio Texas on Interstate Highway 35 which serves as a major North/South commercial truck route for the North American Free Trade
Agreement (NAFTA) between Canada, USA, and Mexico. The pavement surface was considered extremely rough, in the range of 3.3 m/km (209 inches/mile) on the International Roughness Index (IRI). This measurement indicates the amount of up and down movement experienced by a vehicle as it travels along a given length of highway. A marker traces the up and down motion on a scroll of paper similar to a seismograph. Measurements above an IRI of 2.7 m/km (170 in/mi) are considered to be Poor. Measurements in the range of 1.5-2.7 m/km (95-170 in/mi) IRI are fair and IRI rating of 1.5 m/km (95 in/mi) and below are good.

According to the Texas State Bituminous Materials Engineer, Dale Rand, asphalt-rubber is selected as the binder of choice for a permeable friction course overlay of concrete because it is so “sticky”. Also, the Arizona experience with good performance interested the engineer. No other binders in the state inventory allow the PFC material to stick to the aged concrete underneath. When other binders have been selected, the PFC material de-laminates, or detaches in large sections 0.3-0.6 m² (1-2 ft²) in a short period of time, most likely due to water intrusion in the bond between the PFC and the Concrete below. [RAN 04] Therefore, without the durable A-R material, friction courses will not be used on top of concrete because of their extremely poor durability and high maintenance costs.

During construction, after one direction of travel had been paved with the asphalt-rubber PFC, a rain shower occurred and the reduced splash and spray on the A-R PFC compared to the pre-existing surface was captured in a photograph. See Figure 7.

Figure 7. Reduced spray from vehicles on the A-R permeable friction course on right
After the project was completed in both directions, a noticeable decrease in wet weather accidents was also observed. Gary Fitts of the Asphalt Institute’s regional office in San Antonio, Texas, collected the weather station information for the year leading up to the A-R PFC overlay and the year after the A-R PFC overlay was completed. Accident data within the boundaries of the project were also collected from the San Antonio Police Department. [FIT 04] See Figure 8.

| Climatic & Accident Data IH 35 San Antonio Before and After Asphalt-Rubber Overlay |
|---------------------------------|-----------------|-----------------|------|
| Precipitation                   | 80.7 cm 31.78”     | 82.9 cm 32.63”     | +2.2cm +0.85”  |
| Days with Precipitation         | 69               | 99               | +30   |
| Major Accidents                 | 85               | 48               | -37   |
| Major Accidents on Days with Precipitation | 39             | 19               | -20   |

Climate data obtained from National Oceanographic and Atmospheric Administration
Accident Data collected from San Antonio Police Department
Major Accidents Involve Emergency Medical Response (Ambulance)

Figure 8. Accident and Climate data before and after placement of A-R PFC.

In the year before the placement of the A-R PFC, July 01, 2001 to June 30, 2002 there were 69 days with measurable precipitation for an accumulation of 80.7 cm (31.78”). During that time, the San Antonio Police Department responded to 85 major accidents. A major accident is defined as one where emergency response vehicles, such as an ambulance or paramedic unit, are dispatched to treat potential injuries on site. Of the 85 major accidents, 39 occurred on days with precipitation. In the year following the completion of the A-R PFC, from November 01, 2002 to October 31, 2003, 82.9 cm (32.63”) of precipitation was recorded over 99 days. The number of major accidents was reduced to 48 and the number of major accidents occurring with precipitation was cut in half to 19.

Even though the number of wet weather days had increased, the number of major accidents had decreased significantly. It is easy to hypothesize that the increased visibility (reduced splash and spray noted in Figure 7) during wet weather by using the permeable friction course had enhanced
the public safety of the roadway. This would not have been accomplished without the tough and durable addition of recycled tire rubber in the permeable mix.

The state of Texas has also examined other projects for similar before and after data where permeable friction courses have been placed. In one example, on a Farm to Market (FM) road number 1434 near the state capitol city of Austin, a two mile stretch of roadway that had numerous curves and intersections, a PFC was placed under an emergency contract because of numerous fatalities in the year 2003. The existing surface was a traditional dense graded asphalt concrete. The climatic conditions and accident data were examined before (years 2001-3) and after (2004-5) the PFC overlay. The findings are presented in Table 1 below. [RAN 06]

<table>
<thead>
<tr>
<th>Accident Data: FM 1431 - Travis County - Near Jonestown</th>
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<tbody>
<tr>
<td>(PFC mixture was placed in February 2004)</td>
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<td><strong>Total # of accidents</strong></td>
</tr>
<tr>
<td>Dry weather accidents</td>
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<tr>
<td>Wet weather accidents</td>
</tr>
<tr>
<td>Fatalities</td>
</tr>
<tr>
<td>Total injuries</td>
</tr>
<tr>
<td>Incapacitating injuries†</td>
</tr>
<tr>
<td>Non-incapacitating injuries</td>
</tr>
<tr>
<td>Annual rainfall (inches)</td>
</tr>
<tr>
<td>Total rain days (&gt;0.1 in.)</td>
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</tbody>
</table>

† Some of these injuries later became fatalities

Source: Cedar Park Police Department & Austin Mabry Weather Station

Table 1. Climate and accident data before and after a permeable friction course was placed

In the example above, the differences a very striking. Prior to the overlay, an average of 21 wet weather accidents were recorded, 20 injuries and an average 2 fatalities. Following the overlay, with very similar weather conditions recorded, the average number of wet weather accidents had dropped to 1.5, injuries to 4, and fatalities to 0. Figure 9 shows pictures taken from the cab of a vehicle following a typical pick up truck as it transitions from the dense graded material onto the FM 1431 PFC project.
Clearly, public safety is tremendously enhanced through the use of permeable friction courses. With the aging concrete highway infrastructure in many urbanized area, the use of scrap tire rubber will offer the highway engineer an alternative for greater safety. Of the quality of life issues that highway engineers contemplate, safety is number one.

The San Antonio A-R PFC project generated a great deal of public interest, but not due to the enhanced safety. The public noticed the quiet ride. According to Dale Rand, some motorists commented that they had thought their vehicles had “fallen off of a cliff” as they drove onto the A-R PFC surface because it had gotten so quiet. [RAN 04] It is the quality of life for those living near the highway that is driving the use of A-R friction courses in the greater Phoenix, Arizona area.

2.2 Noise Reduction

Scrap tire rubber has been used by the Arizona Department of Transportation (ADOT) in highway paving applications since the mid 1970s. The first application of an asphalt-rubber friction course on concrete was in 1988 near the city of Tucson on Interstate 19. The application was done to improve the ride and skid resistance, but again the public noticed the quiet ride. The department measured the noise levels using the standard “way-side” technique where a microphone is placed 15 m (50 feet) from the edge of the roadway and the traffic noise is recorded and measured using a noise meter. A five dBA reduction was recorded. [HEN 96]

Much later, in 2002, a major freeway, US 60, near Phoenix, Arizona was expanded to accommodate the area growth in population. Several new lanes were added, using Portland cement concrete, to match the existing lanes which were built in the 1970. A thin A-R friction was applied to the entire width to ensure a uniform surface without any skid differential between the new and old surface, and to avoid lane closure to the old surface through the surface grinding. Again, the noise reduction was noted by the public and recorded in a large volume of news media, both in local newspapers and television. [SOU 04]
Every city in the Phoenix metropolitan area wanted the freeways within city limits to be covered and they were willing to provide the funding to do it. The success and tremendous public support of the A-R friction course led the Governor of the State, Jane D. Hull, to announce the adoption of the Arizona Quiet Pavement Pilot Program in partnership with the US FHWA. The 185 km (115 mile) project started in 2003 should be completed in 2007. Several other new highway construction projects will have the A-R friction course included as the surface before the projects are ever opened to traffic. By the end of 2008, all of the regional freeway system [ADOT 03]

The US FHWA has implemented the QPPP to gather data in order to create a model that will be used to provide values for surface type changes in the Traffic Noise Model. The Traffic Noise Model is used by environmental engineers in the US when considering the potential noise impact of new highway and expansion projects. Through this pilot research program, other states will be able to gather information about the sustained noise reduction achieved through the use of tire rubber modified asphalt pavements. A map of the QPPP is available as Figure 10.

![Figure 10. Original configuration of the 185 Km (115 mi) Quiet Pavement Project in Phoenix, AZ](image)

Much information is available on the ADOT website at [www.quietroads.com](http://www.quietroads.com) and the FHWA website at [http://www.fhwa.dot.gov/environment/noise/qpppmem.htm](http://www.fhwa.dot.gov/environment/noise/qpppmem.htm) The potential to avoid
building or rebuilding costly noise walls to block highway noise with new surfaces that actually reduce the noise at its source is very appealing to highway engineers, but most importantly the communities they serve.

The standard way-side measurement has been refined in research grade sites into a pass-by method for traffic noise monitoring. In the pass-by method, only a single vehicle at a time is allowed to pass in front of the noise meters placed at specific distances from the highway to record the sound levels. This does capture all of the noise generated by the vehicle, but is limited to provide the noise levels in only one location along the length of the roadway and it is difficult to limit traffic to the degree that only one vehicle is within measuring range of the meter at a time. An example of the pass-by method is provided in Figure 11.

![Tire/Pavement Source Level to “Passby” Comparison](image)

**Figure 11.** The Pass-By method of measuring traffic noise. Note the dBA level at the tire (0 m), 15 m, and 50 m.

In most agencies where test sites have been constructed, the values are reported using a variety of methods and compared to a variety of base or reference surfaces. In the literature, the values are generally reported as a reduction in dBA from the reference surface or pre-existing surface. It is very difficult to compare the results of one highway noise report to another because of the high degree of variability.

According to acoustical engineers working with the automotive industry, 78% of highway traffic noise generated from passenger vehicles originates at the tire pavement interface. [DON 05] An example is provided in Figure 12.
Figure 12. Tire Noise Dominates at Highway Speeds.

With the introduction of surface types to highway maintenance engineers, new testing devices are needed to easily record and monitor the entire length of a quiet pavement project. Through the use of General Motors tire noise monitoring devices, the state of California is developing an On Board Sound Intensity (OBSI) device to provide pavement maintenance engineers a noise profile very similar the profiles of other pavement performance criteria such as cracking, rutting and skid testers. [RYM 06] The OBSI device is easily mounted on any vehicle and can be used to compare a multitude of different test sites anywhere in the world. See Figure 13

Figure 13. On Board Sound Intensity (OBSI) Device under development by California DOT
Through the use of the device many different surface types test sections in Arizona and California have been profiled and ranked according to the amount of tire noise they generate. Figure 14 below provides the differences measured at the tire/pavement contact.

![Figure 14. Ranking of Test Sites in AZ and CA, USA in dBA using the OBSI](image)

In Figure 14, the asphalt-rubber surfaces are ranked the lowest in tire noise generation at 96.6 dBA. Some of the original or common concrete surfaces used in the Arizona system with a random transverse tined texture were ranked among the loudest at 109.2. Although the public had used their own noise meters, their ears, to understand the value of turning down the volume of noise at it’s source, engineers require numerical values in order to understand and calculate the noise reductions that can be expected or predicted when using different surface types.

European countries have had more progressive policies on highway noise control that include many more tools for noise reduction besides the construction of sound walls or barriers. Pavement types have been recognized and allowed for use to reduce traffic noise since the 1980s. [BER 06] Recognizing Europe’s lead in this area, the US FHWA organized a Quiet Pavement Technology Scan to allow members of the US government and industry interested in noise control to visit several test sites and host agencies in Denmark, England, France, Italy and the Netherlands. It was clear the governments of the European nations had invested a great deal of resources to improve the quality of life of people living and working nearby highways through extensive research ion quiet pavement research and development. It was also clear that standard methods of measurement
and reporting highway noise did not exist and it is very difficult to compare or use the data collected by the many nations.

Interest in the European Quiet Pavements and the introduction of the on board sound intensity device lead to a research project to help correlate the finding from the diverse quiet pavement reports in Europe and the USA. The device was recently used to compare quiet pavements that were designed and built in Europe to those in the US. The testing allowed the first standardized comparison of the quiet pavement test sites around the world. The project was called “Noise Intensity Testing Europe” (NITE) and took a team of researchers to several of the quiet pavement test sites visited by the Scan Team, and other sites that were of interest. [DON 05] The findings indicated that the quietest pavements with respect to passenger car tire noise were found in The Netherlands using a double layer porous asphalt system and a single layer Porous Asphalt in a German test track. Neither pavement included scrap tire rubber in their sophisticated designs. However, the next quietest pavement was a standard A-R friction course in Arizona that was not designed to be quiet, but to be durable and long lasting. Only one decibel of separation existed between the most advanced quiet pavement technology and a standard technology. The ranking on the pavements and the comparison of the quietest are presented in Figures 15 and 16.

![European Pavements at 97 km/h](image)

**Figure 15.** Ranking of Quiet Pavements in Europe Using OBSI
Although the European double layer porous asphalt design were extremely quiet, their lack of durability, lasting 5-7 years in the first generation of design, is an obstacle to widespread use. Expensive modifiers need to be used in order for the pavements to be cost effective. Since tire rubber has demonstrated very favorable results in reducing traffic noise and provides a very durable surface, it may provide European quiet pavement designers a valuable tool in materials selection.

This research is encouraging for the scrap tire recycling community in that it shows that particulate scrap tire rubber can have tremendous contributions to the quality of life of highway users and neighbors with respect to highway noise in both the EU and the US. With the flexible European policies that allow surface type to be used to control traffic noise, scrap tire rubber can be easily incorporated into the quiet pavement technologies. Likewise, the expertise in quiet pavement design in Europe can be used in the US to develop even quieter surfaces using the slightest of modifications to the existing asphalt-rubber friction course designs that still provide a durable and long-lasting surface. Research in durability is the final data set that will help convince pavement design engineers to select scrap tire rubber as a modifier to asphalt pavement systems.

**2.3 Durability and Long Term Performance**

During the 1990s, the US FHWA developed a standardized mixture design procedure and bitumen performance tests to help the states design bituminous pavements more appropriately for traffic,
loading and for the various climates from cold and wet to hot and dry and everything in between. The system was called the Superior Performing Asphalt Pavements System, or Superpave in an abbreviated name. By the year 2000, most of states adopted the Superpave system. Unfortunately, the bitumen testing procedures were developed in such a way that the presence of a 2 mm rubber particle would interfere with the test and provide confounding results. The tests were required to provide the Performance Grade (PG) of the bitumen in order to predict the bitumen performance at the low and high pavement surface temperatures experienced on the highway. For example, a PG 70-22 is expected to perform well in a climate where the pavement surface temperature would be above 70°C and the below -22°C only 10% of the time. Since the scrap tire rubber did not fit into the system, most state chose to leave it out. However, the states that had adopted the Superpave System, still used various modifiers such as scrap tire rubber, that did not fit into the testing procedures. The modifiers were kept in the materials inventory because the materials had demonstrated very satisfying field performance to the user agencies. Scrap tire rubber was one of the favorable modifiers.

In the year 2000, the US FHWA began a field experiment on pavements containing modifiers that did not fit into the bitumen performance grade system. The modified pavements would be compared to a performance graded pavement so that the value added by the modifier through extended pavement life could be graded using mathematical models instead. The Turner Fairbank Highway Research Center, near Washington, D.C., set up an Accelerated Loading Facility to subject test pavements to tire loadings expected on the highway. The loading is accomplished through repeated passes of a truck tire attached to a beam with an automated rolling mechanism. The device can be seen in Figure 17.

![ALF testing device and close up of loading wheel.](image)

Through the use of this machine pavement loadings are accelerated to 35,000 passes per week in a tightly controlled manner and condition. Although the experiment is ongoing, some results have been recently published related to the sections with scrap tire rubber modifiers. [XIC 06] In the first phase of the experiment, 7 lanes with 100 mm of pavement thickness were constructed. An asphalt-rubber section had been built according to the Arizona DOT specifications in Lane One but it was only a 50 mm section placed on the 50 mm of the control material. Another scrap tire rubber modified section had been built but had used a newer process developed by bitumen
refineries that dissolves the scrap tire rubber, commonly called a terminal blend. A diagram describing the pavement design and thickness is provided in Figure 18.

![Figure 18. ALF sections built in 100 mm thickness.](image)

The seven test sections and a description of the modifiers is provided in Table 1

<table>
<thead>
<tr>
<th>Lane</th>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>CR-AZ</td>
<td>Crumb Rubber (Asphalt-Rubber) binder, ADOT specifications</td>
</tr>
<tr>
<td>2</td>
<td>PG 70-22</td>
<td>Unmodified Asphalt Binder Control</td>
</tr>
<tr>
<td>3</td>
<td>Air-Blown</td>
<td>Binder subjected to high pressure hot air prior to shipment</td>
</tr>
<tr>
<td>4</td>
<td>SBS LG</td>
<td>Styrene-Butadiene-Styrene Modifier with Linear Grafting</td>
</tr>
<tr>
<td>5</td>
<td>CR-TB</td>
<td>Crumb Rubber Modified, Terminal Blend</td>
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<tr>
<td>6</td>
<td>Terploymer</td>
<td>Ethylene Terpolymer Modifier</td>
</tr>
<tr>
<td>7</td>
<td>Fiber</td>
<td>Unmodified PG 70-22 with 0.2% Polyester Fiber by mass of the aggregate</td>
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Table 1. Descriptions of ALF test sections.

Results are reported after 100,000 passes. For materials that did not obtain 10 meters of cumulative fatigue cracking, loading was continued to 200,000 passes and 300,000 passes. A chart of the results and picture of cracking is provided in Figures 19 and 20.
The asphalt-rubber section did not experience any cracking after 300,000 passes where the control section had experienced 90 meters of cumulative cracking after 100,000 passes. The dissolved tire rubber material had over 20 meters of cumulative cracking after 100,000 passes. Interestingly, the polyester fiber modified bitumen also performed well with only 5 meters of cumulative cracking.
after 250,000 passes, however it was built as a 100mm thick section compared to the 50 mm A-R section. This indicates that the presence of large particle modifications assists in the prevention of reflective cracking. Core samples were taken from the asphalt-rubber section and it was discovered that the PG 70-22 material underneath was completely cracked, similar to the control section of greater thickness. See core samples drawn from lane one in Figure 21.

Figure 21. Pavement Cores from A-R section, Lane 1 showing cracking in bottom 50 mm.

According some newer models developed to predict cracking, this test section would have to subjected to 700,000 to 900,000 passes before any cracking would appear on the surface. [SOU 06]

The Accelerated Loading Facility data provides engineers in the US familiar with the Superpave System and Performance Grade binders with correlating data that can be used in new pavements designs. The performance on the material in the experiment is also reflected in real life on the highways in the states that regularly use the highly engineered scrap tire rubber components in bituminous pavements. It also demonstrates that reduced thickness designs using asphalt-rubber are well validated.

3.0 Conclusions

The asphalt-rubber materials have performed very well for the agencies that regularly use them to provide safe, quiet and durable highways. The recent research discussed in the paper adds to the mounting body of data that will reassure material and pavement design engineers that their communities will benefit in many ways if they make the decision to use scrap tire rubber. Scrap tire rubber is a very valuable resource to the pavement design community. The decision is easy to make especially with pressure to use less material in thinner layers and with rising cost for energy, oil, and material transportation. Great advantages can be gained with respect to the greater use of recycled tire rubber. Each tonne of asphalt-rubber mix uses about 15 kilograms of scrap tire rubber. A lane-kilometer of rubberized mix can beneficially reuse over 1500 scrap tires. It is easy for engineers to add up the results and provide their community with a closed loop system by using their scrap tires in their roads.
4.0 References

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