The Feasibility of Using Recycled Rubber Tires in the Production of Asphalt in Alaska

A Research Project Report presented to the faculty of Alaska Pacific University in partial fulfillment of the requirements for the degree of Bachelor of Arts

by

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ABSTRACT

Research was conducted to determine the feasibility of using recycled rubber tires in the production of asphalt in Alaska. Employees of the Departments of Transportation in Arizona, California and Florida were contacted to determine the best practices of those states in the production of asphalt using crumb rubber, a product of ground recycled rubber tires. Because of the similarity of climate and topography in some areas of their states and Alaska, California and Arizona were the major focuses of the comparison study.

The report describes the various types of asphalt using crumb rubber and the advantages found in the use of this product. This study's findings indicate that crumb rubber modified asphalt is a viable product for Alaskan roads; Anchorage area roads in particular. It is the conclusion of this researcher that incorporating crumb rubber into asphalt oil using the wet process would be the most beneficial process for Anchorage.
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Chapter I - Introduction

In 1991, the U.S. Government mandated in the Intermodal Surface Transportation Efficiency Act (ISTEA) that tire rubber be used in asphalt pavement construction. Of the approximately 280 million tires discarded each year, only 55 percent are being recycled in some manner. The remainder go to already crowded landfills (User Guidelines for Waste, 1997). Besides retreading and as a fuel source, the most significant use of rubber tires is in the production of asphalt. Because of the cost of recycling in Alaska, virtually no tires are recycled here. One small entrepreneur is shredding tires and using them as playground cover, but this is only in the beginning phase. The purpose of this study was to discover whether using tires in asphalt is appropriate for Alaska. Using tires in asphalt pavement may use a large number of tires, thereby saving the landfill from excess rubber that is not likely to degrade. Furthermore, excess tires take up a great deal of landfill space. The industry's consumption of asphalt oil will also be diminished.

Purpose

The purpose of this project was to determine if using recycled rubber tires in the production of asphalt pavement in Alaska is feasible. Although mandated by the Federal Government in 1991, the mandate was eliminated in a short paragraph in Sections 205(b) and 327 National Highway System Designation Act of 1995. All penalties for non-
The feasibility of using recycled materials in road construction is an area of increasing interest. The primary reason for this is the desire to reduce the environmental impact of road building and to find alternatives to traditional materials. The use of recycled rubber tires in asphalt is one such alternative. This paper outlines the feasibility of using crumb rubber on the roadways and the benefits to the community.

Compliance with the mandate was eliminated; however, monies for research and technology transfer continued to be appropriated. The intent of the project was to determine if there are legitimate reasons for using crumb rubber on the roadways and if so what the benefits to the community are.

This researcher determined the amount of tires available in Anchorage to use on the roadways, and what the costs associated with the process of making crumb rubber asphalt are. Another objective was to find out if shredded or crumbed asphalt will make an asphalt product that will hold up during Alaska’s cold winters.

Anchorage Sand and Gravel Co., Inc. (AS&G) is one of the asphalt producers in Anchorage. There are several possible gains for this company if it can begin production of asphalt using recycled rubber tires. Since compliance with the mandate is no longer an issue, the government will not be giving monetary incentives for using the products. The rubber industry continues to do research on the viability of crumb rubber asphalt on our highways and hopes to get the mandate reinstated at a later date. AS&G will also promote a good public image in the community, since recycling any product is generally met with enthusiasm. This aspect may be even more important than the monetary incentives, because it is the people in the community who buy AS&G’s products. Also, some studies have shown that asphalt using rubber tires in its production can be stronger, last longer, and have more resistance to rutting than conventional asphalt.

The use of recycled rubber tires in asphalt is important for several reasons. The primary importance is the fact that millions of tires are finding their way into the country’s landfills every year. Since they will never degrade, these tires are taking up a
great deal of space that can never be reclaimed. Instead of going to the landfill, the tires can be recycled for other uses.

Rubber is also used in some areas for fuel, but this use is limited as well. From an environmental standpoint, recycling into asphalt pavement is a worthwhile venture. Gravel companies are often seen by the environmental movement as companies that are "raping" the earth by removing gravel and other materials. The use of rubber tires in materials will help remove some of the negative reactions to our business and develop a stronger public image.

**History and Background**

When technology was developed which allowed incorporation of rubber tires in asphalt, the process was tried in a couple of test spots on Anchorage streets. At that time, the asphalt community determined that this procedure was a failure, because deeper ruts were formed when the new product was used than when normal asphalt was used. Closer research shows, however, that the rutting was actually raveling, or coming off in thin strips; primarily caused by heavy trucks turning in the area. These test spots were done in the early 1980s. Since then much has been accomplished in the crumb rubber asphalt industry. Over the years, technology has changed and sturdier products developed. It is believed that the newer products will prove to be as durable and possibly stronger than asphalt without rubber tires incorporated. There are states that use crumb rubber asphalt products because the highways last longer and require less maintenance. This researcher found other benefits to using this product which are discussed later in this project.
Since AS&G did try this product many years ago, the company is resistant to working on the process again. This study looked at the benefits found in other states that use the product and have related it to the benefits that could be applied to Alaska, and specifically Anchorage.

**Scope**

This study concentrated on whether AS&G should convert to the use of tires in its manufacturing process. It was therefore limited to secondary sources of information and a comparison with AS&G’s current process of producing asphalt.

**Research Objectives**

There were several things that needed to be ascertained in order to determine if recycled rubber tires can be used in Alaska. These items were looked at in detail:

1. Determination of how many tires are required to produce a section of pavement.
2. Determine if there are sufficient used tires available in Alaska to recycle into asphalt.
3. Identify best practices used elsewhere.
4. Identify costs to convert current asphalt plant.
5. Determine cost/benefit of using tires in asphalt production.
Rubber tires are only one of the many different items that are recycled in this country. Many people think that using recycled products is substantially more expensive than more traditional products. Although this is true with some items, this is not always the case.

**The Case for Recycling**

In an article in the Wall Street Journal, Holt (1998) discussed various materials used in environmentally friendly homes. Among the items cited were carpet made out of recycled bottles, insulation made from recycled newspaper and homes made from recycled lumber. These items cost about the same amount as the products normally used. There are, however, homes that have been built from recycled products that are very expensive. One home, built into a hill in Colorado, uses recycled tires and cans and adobe for walls. This home is a $1 million dollar structure owned by Dennis Weaver, former star of "McCloud." The materials in this home were much costlier than non-recyclable materials, but illustrate the extreme measures that some people will take to be environmentally conscious consumers. The environmental issue has been active for more than thirty years. Many people advocate the use of recycled materials, but seldom to the extreme of Mr. Weaver. The question that needs to be asked is, "How much more will people spend to receive a similar product that is environmentally friendly?" For example, it is easier and cheaper to use recycled plastic bottles in carpeting than it is to build a home using recycled rubber tires and straw bales as a foundation. Although conservation
is an admirable goal to many people, the extra costs of some of the newer technology are not always economically feasible.

**Recycling Rubber Tires**

There are three major uses for used rubber tires. According to Blumenthal (1998), they are: 1. tire-derived fuel, 2. civil engineering applications, and 3. ground rubber applications.

Tire-derived fuel (TDF) is used primarily in cement kilns, pulp and paper mills and utility and industrial boilers. This use would not be very feasible in Alaska, because there is a lack of these types of facilities. This use, however, has increased over the past decade in other parts of the country. There has been a large amount of testing done on the emissions generated by TDF. At this point, there has been no negative impact discovered by the testing, but new regulations on particulate material by the Environmental Protection Agency may make it more difficult to permit these facilities.

Recycled tires are being used in many civil engineering projects, with varying levels of success. Among other uses, tires are used as construction materials in leachate collection systems and road bed support. As a negative example, there have been two notable locations in Washington state where deep shredded tire fills have developed hot spots. It is unclear what the cause of these spots is, but the market has suffered because of the inference that these products can spontaneously combust. Studies are currently being done to determine the cause of this problem.

Tires are ground for use in many products. There are three processes used to convert scrap tires to crumb rubber. According to information provided by the Scrap Tire
The Feasibility of Using Recycled 7

Management Council, the most commonly used method is the crackermill process (also known as ambient grinding). This process derives rubber pieces that are approximately 5 mm to 0.5 mm in particle size. The process consists of passing the material between rotating corrugated steel drums, this tears the rubber into uneven shaped pieces that have large surface areas. The process has various types of magnets to remove any steel from the tire chunks. There is also a fabric removal system incorporated in the procedure.

Another method is the granulator or micro-mill process, which uses steel plates to shear the rubber producing granulated crumb rubber particles. The final process produces a very fine ground rubber ranging in size from 0.5 mm to 0.075 mm.

Some processes freeze the rubber with liquid nitrogen, causing the rubber to become brittle and easily shattered. This process is sometimes used before final grinding. This is the cryogenic grinding process. After grinding processes are complete, the rubber is used for many products.

Running tracks incorporate rubber tires into their surfaces. This makes a more elastic and forgiving surface that could lead to fewer injuries. Recycled rubber is also made into mats for use on playgrounds, making a softer surface under swing sets, slides, etc. Loose rubber is also used under playground equipment. Six inches of loose rubber chips are placed under the equipment. The chips are long-lasting, soft and do not attract dogs or cats and water flows through them easily. This material does not incorporate asphalt in the mixture, but uses shredded tires that are fused together with other composites.
As technology advances, many other products are manufactured using recycled rubber tires. One of these products is manhole covers, which may be made in any shape to fit the configuration desired for the application. Each cover uses approximately seven recycled tires. This forms a long lasting, durable product that is easier to move and adjust than the normal concrete covers. Other products include household items such as brooms, car mats and soles for shoes. The environmental movement has encouraged entrepreneurs to devote their energies to finding quality items that use recycled products either as a percentage of or the total ingredient in common items.

Old tires are also reused to make new tires. The rubber is ground and incorporated with other rubber at a rate of 10 percent recycled content. According to Blumenthal (1998), this percentage is expected to increase in 1999 and should be sold on some new automobiles. A new dilemma with using this product, however, is that the recycled material causes the tires to have greater heat build up, increasing the rolling resistance. This leads to lower fuel economy and can lead to a shortened tire life. The Federal Government will be requiring light trucks, vans and sport utility vehicles to have better fuel economy, because of this, recycled rubber may not be a viable product for tires on these vehicles. It is unlikely that manufacturers will use two different processes to produce tires, when one will suit all vehicles.

Of the approximately 30 million tires that are not discarded each year, about one third are retreaded and returned to the marketplace (User Guidelines for Waste, 1997). There has been a decline in the use of retreaded tires for passenger cars, but truck tire
retreading is increasing, since these semi-truck tires may be retreaded three to seven times before needing to be discarded (Scrap Tire Management Study, 1995).

Crumb rubber modified asphalt is the product of choice in many areas of this country, as well as in Europe. There have been many positive results with this type of asphalt. A study by Rebala and Estakhri (1995) determined that certain rubber mixtures and methods may be more rut resistant and prevent cracking more than conventional asphalt processes. This is contrary to the beliefs of some asphalt companies and producers who believe that rubber incorporated into asphalt results in deeper rutting on road surfaces.

Another product that greatly enhances the rutting resistance combines carbon black (CB) from pyrolized tires with asphalt mixtures (Dekker, Lesueur & Planche, 1995). Carbon black is derived by heating tires to a very high temperature without oxygen. This causes the tires to pyrolize (decompose) into organic molecules. Seven to eight pounds of CB are derived from each tire.
**Processes for Incorporating Rubber Tires into Asphalt Mixtures**

Many processes are used to incorporate rubber tires into asphalt mixtures and there are many uses for the end products of these processes. A study by the Department of Transportation (DOT) in Minnesota defines an asphalt-rubber binder as a product used to patch or strengthen another surface (Allen, Kim, Newcomb, Stroup-Gardiner & Wattenhoffer-Spry, 1994). Rubber content in this wet process is at least 15 percent by weight of total binder and is fully dispersed in the asphalt cement. The product derived from this process can be used the same as conventional asphalt concrete or it is sprayed on the surface of the road as a seal coat, chip seal or stress absorbing membrane (SAM), depending on the purpose. After being sprayed on the surface, it is then rolled with a cover aggregate. This product is sometimes placed between layers of pavement and is then referred to as a stress absorbing membrane interlayer.

There are two processes for making the asphalt-rubber binder. One requires the use of vulcanized rubber (rubber which has not been chemically or thermally treated to alter its chemical composition), while the other uses devulcanized rubber (which has been treated in some manner to alter its chemical makeup). The two procedures require different amounts of asphalt and rubber and mixing requirements.

CRM (crumb rubber modified) asphalt concrete is composed of asphalt cement, recycled rubber tires, aggregates and miscellaneous additives, depending upon the use of the asphalt mixture. These materials are combined in different ways, but primarily in either the wet or dry processes.
The wet process blends asphalt cement and crumb rubber and then adds the mixture to hot aggregate as an asphalt binder. The mixture is blended for a long enough time to have a fairly stable consistency. To lessen the amount of blending time required, finer rubber or higher temperatures may be used. Two technologies are variables to the wet process. These are McDonald Technology and the continuous blending technology.

Ground rubber is incorporated at a rate of 15 to 22 percent of the total asphalt binder.

The following tables, provided by the DOT in Minnesota, show gradations necessary for both aggregates and rubber for the McDonald process used in experiments in that state. These products are mixed with asphalt cement, AC-10 or AC-20, and blended for one half to one hour. Table 1 shows rubber gradations for dense and open-graded mixtures. Table 2 shows two different aggregate gradations (Type I and Type II) that could be used in hot mix asphalt that incorporates crumb rubber.

<table>
<thead>
<tr>
<th>Sieve Size (mm)</th>
<th>Percent Dense-Graded</th>
<th>Percent Open-Graded</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.00 (#10)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>1.18 (#16)</td>
<td>98-100</td>
<td>75-100</td>
</tr>
<tr>
<td>0.60 (#30)</td>
<td>70-85</td>
<td>25-60</td>
</tr>
<tr>
<td>0.30 (#50)</td>
<td>10-40</td>
<td>0-20</td>
</tr>
<tr>
<td>0.075 (#200)</td>
<td>0-5</td>
<td>0-5</td>
</tr>
</tbody>
</table>

(Source: Allen, B. et al. (1994) Polymerized crumb rubber modified mixtures in Minnesota, Page 12).
Table 2. **Suggested Aggregate Gradations for Open-Graded CRM HMA Mixture**

<table>
<thead>
<tr>
<th>Sieve Size (mm)</th>
<th>Percent Passing</th>
<th>Type I</th>
<th>Type II</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.00 (3/4 in.)</td>
<td>100</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>12.50 (1/2 in.)</td>
<td>100</td>
<td>90-100</td>
<td></td>
</tr>
<tr>
<td>9.5 (3/8 in.)</td>
<td>85-100</td>
<td></td>
<td>75-95</td>
</tr>
<tr>
<td>4.75 (#4)</td>
<td>25-55</td>
<td>20-45</td>
<td></td>
</tr>
<tr>
<td>2.36 (#8)</td>
<td>5-15</td>
<td>5-15</td>
<td></td>
</tr>
<tr>
<td>0.60 (#30)</td>
<td>0-10</td>
<td>0-10</td>
<td></td>
</tr>
<tr>
<td>0.075 (#200)</td>
<td>0-5</td>
<td>0-5</td>
<td></td>
</tr>
</tbody>
</table>

(Source: Allen, B. et al. (1994) *Polymerized crumb rubber modified mixtures in Minnesota*, P.12)

The continuous blending technology differs from the McDonald technology in the amount of rubber used (5 to 20 percent) and in the type of asphalt cement (AC-5 or AC-10). The rubber used in this process is finer as shown in Table 3.

Table 3. **CRM Gradation for Continuous Blending Technology**

<table>
<thead>
<tr>
<th>Sieve Size (mm)</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25 mm (#60)</td>
<td>98-100</td>
</tr>
<tr>
<td>0.18 mm (#80)</td>
<td>88-100</td>
</tr>
<tr>
<td>0.15 mm (#100)</td>
<td>75-100</td>
</tr>
</tbody>
</table>

(Source: Allen, B. et al. (1994) *Polymerized crumb rubber modified mixtures in Minnesota*, Page 13)

The dry method adds crumb rubber to the hot aggregate before the hot aggregate and asphalt cement are mixed. This method was patented under the names “Rubit” in Sweden and “PlusRide” in the United States, after it was developed originally in Sweden in the 1960s. Generic dry technology is the other method of dry processing.
The PlusRide Technology uses aggregates of one uniform gradation (gap-graded), so that there is room for the rubber to fill in the gaps. In this process, the asphalt content is generally higher than in other mixtures. There is also a requirement of a 2 to 4 percent air void content so that there is room for the asphalt to fill in the holes during traffic. The following table, also from Minnesota’s DOT study, shows three different aggregate gradations that are recommended for different layer thicknesses for various traffic levels.

Table 4. Recommended Specifications for Rubber-Asphalt Mixture for Different Levels of Traffic for PlusRide Technology

<table>
<thead>
<tr>
<th>Mix Type</th>
<th>Mix Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Average Daily Traffic</td>
<td>2500</td>
</tr>
<tr>
<td>Minimum Thickness (mm)</td>
<td>25</td>
</tr>
<tr>
<td>Sieve Size</td>
<td>% Passing</td>
</tr>
<tr>
<td>19.0 mm (3/4 in)</td>
<td>100</td>
</tr>
<tr>
<td>15.9 mm (5/8 in)</td>
<td>100</td>
</tr>
<tr>
<td>9.5 mm (3/8 in)</td>
<td>100</td>
</tr>
<tr>
<td>6.4 mm (1/4 in)</td>
<td>60-80</td>
</tr>
<tr>
<td>2.0 mm (#10)</td>
<td>30-44</td>
</tr>
<tr>
<td>0.6 mm (#30)</td>
<td>19-32</td>
</tr>
<tr>
<td>0.075 mm (#200)</td>
<td>12-23</td>
</tr>
<tr>
<td>6.4 mm to 2.0 mm fraction</td>
<td>12 max</td>
</tr>
</tbody>
</table>

Rubber (% of Total Mix by)
- Weight | 3.00 | 3.00 | 3.00 |
- Volume | 6.70 | 6.70 | 6.70 |

Asphalt (% of Total Mix By)
- Weight | 8-9.5 | 7.5-9.0 | 7.5-9.0 |
- Maximum Voids (%) | 2.00 | 2.00 | 2.00 |

(Source: Allen, B. et al. (1994) Polymerized crumb rubber modified mixtures in Minnesota, Page 14)

The generic dry technology uses the same or slightly less CRM than is used in the PlusRide system. The CRM is also finer in the generic process. Dense-graded aggregate is used with CRM adjusted to suit the gradation. The coarse CRM replaces some of the
aggregate and acts as an elastic aggregate. This technology has been used in New York and several other states. CRM and aggregate gradations for a typical New York project are shown in the following two tables, derived from Minnesota’s DOT study on polymerized rubber mixtures.

Table 5. **CRM Gradation for Generic Dry Technology**

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Specified</th>
<th>Passing</th>
<th>Supplied</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.40 mm (1/4 in)</td>
<td>100</td>
<td>--</td>
<td>100</td>
</tr>
<tr>
<td>4.75 mm (#4)</td>
<td>--</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>3.20 mm (1/8 in)</td>
<td>75-85</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>2.00 mm (#10)</td>
<td>45-55</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>0.85 mm (#20)</td>
<td>30-40</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>0.425 mm (#40)</td>
<td>0-10</td>
<td>19</td>
<td></td>
</tr>
</tbody>
</table>

(Source: Allen, B. et al. (1994) *Polymerized crumb rubber modified mixtures in Minnesota*, Page 15)

Table 6. **Aggregate Gradation for Generic Dry Technology**

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.44 mm (1 in)</td>
<td>100</td>
<td>--</td>
</tr>
<tr>
<td>12.7 mm (1/2 in)</td>
<td>95-100</td>
<td>--</td>
</tr>
<tr>
<td>6.35 mm (1/4 in)</td>
<td>65-85</td>
<td>± 7</td>
</tr>
<tr>
<td>3.165 mm (1/8 in)</td>
<td>36-65</td>
<td>± 7</td>
</tr>
<tr>
<td>0.85 mm (#20)</td>
<td>15-39</td>
<td>± 7</td>
</tr>
<tr>
<td>0.425 mm (#40)</td>
<td>8-27</td>
<td>± 7</td>
</tr>
<tr>
<td>0.180 mm (#80)</td>
<td>4-16</td>
<td>± 4</td>
</tr>
<tr>
<td>0.075 mm (#200)</td>
<td>2-6</td>
<td>± 2</td>
</tr>
</tbody>
</table>

(Source: Allen, B. et al. (1994) *Polymerized crumb rubber modified mixtures in Minnesota*, Page 16)

The type or method of application is determined by assessing the location and use for the asphalt. Traffic patterns, climate, types of vehicles using roads, and availability
and source of aggregate supplies all contribute to the decision-making process. These variables are discussed later in this project.

Many states experimented with crumb rubber asphalt, in anticipation of the Federal mandate. The results varied depending on the process used. Because of these mixed results and the repeal of the mandate, most areas did not choose to use these products on their roadways.

Three states currently use large quantities of crumb rubber asphalt in the construction of their roads. These states are Arizona, California and Florida. These states have many climate dissimilarities, but have all found crumb rubber modified asphalt to be good for specific applications. Other areas have begun the use of crumb rubber in other asphalt production. Connecticut has some projects that utilize CRM on their bicycle trails and other states use crumb rubber on running tracks or playgrounds. Alaska has recently begun the use of this product on school running tracks in Anchorage.

**Arizona**

Arizona has been using recycled rubber tires in the production of their roadways since the 1950s. The procedures and specifications have changed over the years, enabling Arizona to develop a product that solves many of their road problems. According to Julie Nodes, Pavement Materials Testing Engineer with the Arizona Department of Transportation, the products are used because they provide a better ride, are quieter, provide greater durability, don’t age as rapidly as conventional asphalt products, and prevent reflective cracking. Reflective cracking in the winter is a common problem with asphalt, caused by cracking of the subsurface which reflects up to the
surface asphalt. This happens when the ground has thaw and freeze cycles that cause the ground to shift and eventually crack the surface.

Ms. Nodes mentioned that their success rate was so high with these products that an NBC “Dateline” show used pictures of roads in Arizona to depict advantages of recycled rubber products.

Ms. Nodes provided the following information on Arizona’s methods for using crumb rubber modified asphalt. Arizona generally uses a 1/2” overlay of crumb rubber asphalt on the final lift of the roadway during new construction. This overlay consists of 3/8” rock mixed with the asphalt binder. Their specifications call for 20% crumb rubber by weight of the asphalt binder content in the asphalt rubber asphalt concrete friction course (AR-ACFC). The mixture contains approximately 9 percent binder. The friction course is called for in Arizona because of the high speeds on the freeways, as well as the high air temperatures. Heat and sun damage normal asphalt by drying out the asphalt making it more prone to cracking.

Existing roadways are also resurfaced using this product. AR-ACFC has been found to be beneficial with both concrete and asphalt pavements. With concrete the joints are cleaned and resealed with asphalt rubber. AR-ACFC is used as the final surface to reduce cracking, provide adequate skid resistance and reduce noise. One inch of AR-ACFC is generally used when resurfacing. However, in instances of severe disrepair, two inches may be required. Although costs of rubber modified products are higher per ton, the thickness of this product is usually half the thickness of a regular
asphalt mix, thus the cost may be less overall for the crumb rubber modified product. Maintenance is also less with AR-ARFC than with asphalt.

One section of concrete pavement on I-40, around Flagstaff, was overlaid with AR-ACFC gap-graded for a distance of ten miles and was completed in four months (Way, 1998). The cost of the overlay was $10.00 per square yard including all associated costs. A similar 5-mile section of highway in close proximity to this 10-mile section was completely reconstructed and took two years to complete. The cost for this project was $45 per square yard, including paving, construction and detours. This was overlaid due to severe cracking and rough surface, after less than ten years of service. The adjacent overlay project was completed in 1990 and as of 1998 showed minimal signs of cracking, requiring no repair. This roadway is at an elevation of 7,000 feet and has a typical yearly rainfall of 25 inches and snow of 90 inches. Temperatures often fall below zero for extended periods. The cost savings on this project were estimated at $18 million when compared to the roadway on the same highway that was completely reconstructed.
I-40 SHRP test section
4" conventional AC placed in 1990
(photo taken in 1998)

I-40 SHRP test section
2" asphalt rubber hot mix
placed in 1990
(photo taken in 1998)


The I-40 project also contained several Strategic Highway Research program
(SHRP) and Arizona Department of Transportation test sections (Way, 1998). The
overlay using asphalt rubber in a gap-graded hot mix asphalt had the greatest success
with less reflective cracking. (See above photos). The mix used 12.5 mm (1/2") AR-
ACFC on top of (50 mm (1.95") AR-AC.

According to George Way (1998), the costs of asphalt rubber in Arizona have
deprecated steadily over the past decade. One reason for this is expiration of the original
patents. The patent usage greatly added to the cost of the rubber binder. The Arizona
Department of Transportation (ADOT) only uses AR-ACFC mixtures when it fits the
problem and is cost effective. Currently the AR-ACFC is used extensively in all parts of
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the State of Arizona. Ms. Nodes stated that Arizona was a pioneer in the development of
the asphalt rubber mixtures and continues to use the process, because of the performance
issues and the cost savings over the long term. An extra benefit to this process is that it
used over 5.5 million tires during the period of 1988-1998, keeping a non-biodegradable
material out of the landfills.

The following table from an Arizona report (Way, G. B., 1998) shows how the
price of asphalt rubber in Arizona has decreased from 1985 to 1998. This is partially due
to the expiration of patents in 1992, which provided opportunities for others to develop
processes.

Table 7. Asphalt Rubber Bid Prices and Usage

<table>
<thead>
<tr>
<th>YEAR</th>
<th>NUMBER OF PROJECTS</th>
<th>TOTAL METRIC TONS OF AR</th>
<th>AVERAGE LOW BID $/METRIC TON</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>3</td>
<td>900</td>
<td>506</td>
</tr>
<tr>
<td>1986</td>
<td>3</td>
<td>164</td>
<td>455</td>
</tr>
<tr>
<td>1987</td>
<td>1</td>
<td>274</td>
<td>482</td>
</tr>
<tr>
<td>1988</td>
<td>1</td>
<td>389</td>
<td>406</td>
</tr>
<tr>
<td>1989</td>
<td>6</td>
<td>3,533</td>
<td>443</td>
</tr>
<tr>
<td>1990</td>
<td>6</td>
<td>5,600</td>
<td>409</td>
</tr>
<tr>
<td>1991</td>
<td>6</td>
<td>3,248</td>
<td>449</td>
</tr>
<tr>
<td>1992</td>
<td>9</td>
<td>9,700</td>
<td>351</td>
</tr>
<tr>
<td>1993</td>
<td>18</td>
<td>16,050</td>
<td>325</td>
</tr>
<tr>
<td>1994</td>
<td>19</td>
<td>16,627</td>
<td>264</td>
</tr>
<tr>
<td>1995</td>
<td>41</td>
<td>28,761</td>
<td>255</td>
</tr>
<tr>
<td>1996</td>
<td>29</td>
<td>30,331</td>
<td>285</td>
</tr>
<tr>
<td>1997</td>
<td>31</td>
<td>28,710</td>
<td>277</td>
</tr>
<tr>
<td>1998</td>
<td>52</td>
<td>51,229</td>
<td>248</td>
</tr>
</tbody>
</table>


The table shows how the number of projects are increasing, along with the
number of metric tons of asphalt rubber being used. The tonnage has increased from 900
metric tons in 1985 to a high of 51,229 metric tons in 1998. The cost for the product has decreased from a high of $506 per metric ton in 1985 to a low of $248 in 1998.

**Florida**

David Webb, an engineer with Florida’s Department of Transportation, reported that in January 1994, Florida’s legislative body mandated that all friction course asphalt contain asphalt-rubber binder. This mandate applies to all interstate highways and other roads where the speed limit is above 45 mph and traffic is above 3,000 ADT (automobile daily traffic). The mandate was put into effect because Florida’s legislature believed that crumb rubber would add to the pavement life and improve the durability of the asphalt.

According to Pat Upshaw, an engineer with the Florida Department of Transportation, Florida uses recycled rubber for several reasons. He stated that Florida uses a thin asphaltic concrete friction course on the top lift of new highway construction. The top layer makes the asphalt more permeable, allowing water to go through the top layer and flow between the layers to the outside of the roadway. It is beneficial because it eliminates most hydroplaning caused by the high amount of rainfall found in some parts of Florida. Open graded mixtures are used on roads where the speed limit is over 45 mph or more than 3,000 ADT. These mixes have rock with fewer fines or small pieces in it. Because the fines are not in the mix to fill in all crevices, the water is able to penetrate through the top layer. Florida does not allow recycled asphalt pavement in their friction courses. Open graded friction courses (OGFC) have non-polished rock that is less than or equal to 3/8” with an asphalt binder containing 12% crumb rubber. Non-polished rock is used to increase skid-resistance. Limestone, generally found in
Southern Florida from the Oolitic formation, or crushed granite or lightweight aggregates are the aggregates usually called for because they are very hard and polish resistant.

The combination of small non-polished rock and rubber has increased the skid-resistance on Florida’s highways. David Webb mentioned that anytime there is a bad accident on a Florida highway, his department is dispatched with equipment to test the skid. They test to see if the friction course is working properly or if a mix design change is warranted. Because of the high amount of truck traffic on Florida’s highways, they are always trying to find improvements in their asphalt procedures. At this point they feel incorporating crumb rubber into their mixtures provides the most skid-resistance. There are new products in the developmental stages called “Super Pave” asphalt that Florida has been testing extensively. The specifications for Florida’s “Super Pave” mixes also use crumb rubber.

Florida’s highway department, according to Pat Upshaw, uses Dense Graded Friction Courses (DGFC) on roads that have maintained speeds under 45 m.p.h. The layer of friction course is thicker, generally 1”, but the amount of rubber incorporated into the asphalt binder is 5%. These roads are not as permeable as the interstates, but this aspect is not as important on roads that do not have heavy traffic on them. Because dense graded mixtures are not as bumpy when used, these roads have a smoother, quieter ride, which is often desirable. Dense graded mixtures have been found to cause less raveling at intersections. Most areas requiring dense graded mixes are in urban locations with many intersections. DGFC used as an overlay uses the same gradations as the structural asphalt and is similar to the structural layer in strength value.
Mr. Upshaw mentioned that the Florida DOT sometimes specifies a stress absorbing asphalt interlayer (SAMI). The surface of a roadway is milled so that an even surface is obtained. An application of ground tire asphalt binder is sprayed on the surface of the road. Immediately after spraying, the surface is treated with a layer of aggregate, which is rolled into the asphalt binder. This is called the crackerleaf layer. This process helps with reflective cracking and serves as a moisture barrier. Water from the surface will not get past the interlayer so damage cannot be done to the asphalt structure. After this process is completed, the regular asphalt layer is applied, according to specifications. The rock in the interlayer helps provide structural integrity of the roadway. When the top asphalt is placed, it heats the interlayer and causes all layers to bond together. Florida has found that this mill and resurface process can extend the life of the road 15-20 years.

There are other additives used in a similar manner, but contractors find the asphalt rubber binder to be easier to apply. At this point this product is the only one approved for use. One of the primary reasons for the use of recycled tire rubber in Florida is the environmental issue. Although other products could be used with similar outcomes, Florida believes in recycling the tire rubber instead of taking it to landfills. The Florida Department of Transportation uses approximately 25% of the waste tires generated each year. This amounts to approximately 1,600,000 to 2,000,000 tires that are used in Florida roads annually.

**California**

According to a report by Epps, Hanson, Hicks, Leahy and Lundy (1995), California began experimenting with crumb rubber in asphalt production in the 1970s.
They have used both wet and dry processes, but currently use primarily a gap-graded wet process. They no longer use the dry process, because of erratic pavement performance associated with this method. They had similar results to those found in the early 1980s in Anchorage. Depending on the application, California uses 14 to 23 percent CRM in their asphalt binder.

The climate and other environmental factors in California make Asphalt Rubber Hot Mix – Gap Graded (ARHM-GG) the product of choice for most of the state (Epps, et al. 1995). It has been found to be more crack resistant than dense-graded asphalt concrete (DACE). In California, the minimum allowable lift thickness (or layer) is 30 mm (1.2 inches). The maximum lift recommended is 2.4 inches, because of greater amounts of stability problems associated with lifts over that amount.

The state has modified some of their structural design procedures when using crumb rubber applications. One design specification calls for a reduction in the total asphalt usage when using a CRM mix. This specification decreases the DACE from 7.2 inches to 3 inches and places 2.4 inches of the CRM on top as the overlay. The total asphalt decreases from 7.2 to 5.4 inches, saving 1.8 inches of asphalt mix. This directly translates into a lower total cost for the project.

Gary Hildebrand, Maintenance Manager with the Maintenance Department at Caltrans (California’s Department of Transportation) relayed that 400,000 tons of asphalt containing crumb rubber were used in California last year. This is the equivalent of 2,000,000 tires. He believes that this amount will continue to increase. In 1995 and 1996 the highway department rewrote specifications for crumb rubber. Prior to that time they
used a mixture called Type I which was a combination of CRM and asphalt. In 1995 Type II was developed. This product incorporates extender oil, natural rubber (which can consist of chopped up tennis balls) and CRM. Type II's specification calls for installation at 55 degrees F. or higher, which is five degrees above the specification for Type I. There has been greater success with this product than with Type I, as it prevents reflective cracking better. It is more expensive than Type I, however, by about $.50 per ton. Although this doesn't seem like much money, it adds up when thousands of tons of binder are used on a project. Contractors are not allowed to use Type I anymore.

California uses the wet McDonald process in all applications.

Mr. Hildebrand reported that since 1995 there have been 113 projects completed using California's new specifications. After four years, 101 roads were in good condition, six in fair and six in poor, although two of the poor used dense graded mixes. Tests are being done to determine why some of the roads are not as successful as predicted. California has found that dense graded mixes do not fare as well as gap graded, so this might be the reason two of the highways failed. Most highways in California are now using gap graded products.

California has a variety of climates within its borders. Although this state is thought of as being very hot, there are also areas that have a great deal of snow. Portions of the Sierra Mountains are at an elevation of 6,500-7,000 feet. These mountains have a snowfall of 300-400" annually. In the early 1980s one of the roads in this area had a long truck climbing lane that was difficult to maintain. At this time they changed the lane to
an asphalt rubber material. The lane is still in good condition, according to Mr. Hildebrand.

ARHM-GG has not proven to be as reliable in preventing reflective cracking in cold climates. In the parts of the state that experience cold climates, for example the mountains of northern California, dense graded products are used. Asphalt Rubber Hot Mix – Dense Graded (ARHM-DG) has proven beneficial in mountain passes and other areas subject to snow chain and studded tire usage.

Advantages and Disadvantages of Using Recycled Rubber Tires in Asphalt

As mentioned previously, one of the major benefits of using recycled rubber tires in asphalt is the environmental aspect. The world’s landfills are filling with tires that will never degrade. Instead of taking up needed space, these tires could be used for products that are a benefit instead of a detriment. There are other positive reasons for using asphalt that is modified with recycled rubber tires.

According to an article in Rubber World (Coomarasamy, 1998), low and high temperature performance has improved with the use of recycled rubber tires in asphalt mixtures. This article mentioned a study in Clarkson, Ontario that compared asphalt with rubber modified asphalt. A rutting machine was used to determine the effects of rutting on both mixtures. The wheel tracking machine made 8,000 passes over the sample areas using a treaded tire. The results from this test showed that the resistance to rutting is significantly better when crumb rubber is used to modify the asphalt mixture. The improvement ranged from 37% to 60% and was felt to be accurate, since both samples were subjected to the same testing procedure.
Normal asphalt tends to rut in hot temperatures, especially if there is a lot of traffic use, or if heavy vehicles stay in one place for long periods of time, such as in a driveway. In cold temperatures, cracking may occur, allowing water to seep around the aggregates, causing pits, and eventually, holes in the asphalt.

This same study showed that the crumb rubber modified asphalt also had significantly better resistance to hot temperatures, although the cold temperature improvement was not as great. Cracking in hot weather was less frequent, giving a smoother surface to drive on. The mixtures containing smaller particles of the rubber performed better in the colder temperatures. If rutting and cracking are both to be prevented in cold climates, mix designs containing smaller particles of rubber may be the answer.

A study by the State of Alaska Department of Transportation (1985) found that sound reduction is another benefit of CRM asphalt. This study showed that noise was reduced by 10 decibels as compared to conventional asphalt (Hicks, McQuillen, Takallou, 1985).

Studies, including Alaska DOT studies conducted in 1979-83, compared traditional asphalt and crumb rubber modified asphalt under icy conditions (Esch, 1984). A test in Fairbanks, Alaska in 1982 compared two road sections, one with asphalt and one with CRM asphalt. These tests were in the middle of an icy road, not at a normal stopping area. A series of stops were made on each surface type, with measurements taken. This study showed results of 50 percent less distance required for stopping with
The feasibility of using recycled crumb rubber modified asphalt. It is believed that the protruding rubber particles are responsible for the reduction in stopping distances.

Another test section in Fairbanks in 1979-80 showed increased skid resistance (Esch, 1984). There were no skidding incidents on the corner tested during this winter, although it was commonly noted in previous years. Drivers noticed improved traction, even though they were not aware of the rubber asphalt test.

Studies are still being conducted to determine the actual cost/performance benefits of these products. Although the costs are generally higher when crumb rubber is incorporated into the asphalt mixture, the rubber often extends the life of the asphalt. The road surface may last longer with the crumb rubber mixture, possibly extending the life of the asphalt by several years. Also, as pointed out earlier, the thickness of the asphalt may be less, so the overall costs may be equal or less than with conventional asphalt.

The Federal Government originally mandated the use of recycled rubber tires in asphalt in 1991, as part of the Intermodal Surface Transportation Efficiency Act (ISTEA). The producers of crumb rubber pressured the government to use their product in asphalt mixtures. The lobbying worked and one part of ISTEA required that states use a designated percentage of rubber tires in their asphalt mixtures for highways by 1995. After pressure from state governments, the Act was rescinded before it took effect. According to Billy Conner, Statewide Research Engineer with the State of Alaska Department of Transportation and Public Facilities, one of the predominant problems with crumb rubber modified asphalt is that the states do not want to use the product. Many believed that the technology was not sufficient to produce a modified asphalt that
would work as well as the asphalt pavement already in use in this country. This is the image problem faced by the crumb rubber industry around the country. Besides technology, the other issue that caused the revocation was cost. The states believed that they were being forced to use a new product that would take more state funds, without any additional funding from the federal government.

In 1995, the government gave the states relief from the mandate. By rescinding this portion of the Act, all penalties for non-compliance were revoked and any incentive for states to use rubber tires in asphalt was virtually eliminated. The amendment to ISTEA did allocate approximately $2.1 million to research methods of using recycled rubber tires in asphalt. This study was conducted at Oregon State University (OSU) and included a pooled effort from 33 states.

According to Dr. Rita Leahy, a member of the research team at OSU, the project ended in late 1997, before being completed. One reason the project was not completed was that the project did not receive cooperation from the various states. Dr. Leahy stated that the mandate’s reversal provided the states with a good reason not to participate. If they did not have to use the product in their areas, there appeared to be no reason to participate in the study. Although the federal government allocated the money, there was no incentive for participation in the study.

The intent of the research contract was to design, construct and evaluate crumb rubber modified asphalt pavement. The asphalt would be made using different mixtures, various ingredients and gradients and be produced using various plant configurations under mixed conditions. According to Dr. Leahy, most states chose not to participate,
causing the research to fall behind schedule. Eventually the federal government cancelled the contract and reallocated the remainder of the grant into other unknown projects.

The producers of asphalt pavement, are not in favor of the use of crumb rubber in asphalt. The primary reason for this is cost. The product does cost more to produce, approximately 20% to 60% more than standard asphalt mixtures, according to Dr. Leahy. However, as shown by comparisons done in Florida, California and Arizona, the crumb rubber modified asphalt generally has a longer life and lower maintenance costs.

Figure 1.

**Materials Group ~ Pavement Design**

**Maintenance Cost $/lane - Mile**

--- ■ Overlays / Inlays — AR-ACFC


Figure 1 compares maintenance costs for both conventional asphalt and AR-ACFC. This figure shows the first five years having similar costs, however, after year five the AR-ACFC costs remain fairly constant while the conventional asphalt increases
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rapidly. Because of this, the final costs may actually be less in some instances than normal asphalt products. Part of the cost factor has been decreased since the patents on the process expired in the early 1990s.

The asphalt producers object to the loss of asphalt cement needed for this product. According to Dr. Leahy, an asphalt mixture that normally contains 5-6% asphalt cement would only require approximately 3-4% when using crumb rubber as an additional additive. This cuts the amount of asphalt cement needed in a project dramatically.

Another problem that has to be dealt with is past failures. A test patch in Anchorage in the 1980s showed excessive raveling at the intersection. The area for the patch was at the intersection close to Anchorage Sand and Gravel’s (AS&G’s) gravel pit, where there was continuous turning by heavy trucks. According to Herb Lang, then President of AS&G, the raveling necessitated repaving the intersection and proved to him that crumb rubber in asphalt was not a viable option. Technology has improved since the time of this test; however, it is difficult to convince someone who dealt with a failed area to consider the use of crumb rubber again.
Chapter III - Methodology

There have been many studies done regarding the use of crumb rubber modifiers in asphalt. This research project compared the information from the various studies to determine if the information, found in other areas that have similar climates to Alaska, is applicable in this location. There have been test projects done around the world. The researcher spoke with people from various locations to determine the advantages and disadvantages that were found with CRM. Some states do use CRM on a regular basis. California and Arizona have used CRM for many years with positive results. Florida has also used this product for years because of a state mandate. The mandate is in place because the state believes this modified asphalt has benefits as a friction course. The research includes information from those states as well as information from states that did use CRM and ceased production after the mandate was rescinded. The researcher investigated the practices used in California and Arizona to determine if their processes would work in the State of Alaska. Since these two states are not under any mandate, either federal or state, the information provided by them is especially useful. The research particularly looked at areas of these states that have colder climates, to see if the CRM is working as well in cold climates as in the hotter areas.
The research objectives were answered in the following manner:

1. **To determine how many tires are required to produce a section of pavement.** Dr. Rita Leahy, a member of a research team working on the crumb rubber topic, at Oregon State University, was contacted for information on the amount of tires needed to pave one lane mile using crumb rubber asphalt.

2. **Determine if there are sufficient used tires in Alaska to recycle into pavement.** Robert Larkey, owner of Alaska Tire Recycling, was contacted for information on availability of used tires in the Anchorage area.

3. **Identify best practices used elsewhere.** There are only a few states that still use crumb rubber in asphalt on a regular basis. These states were contacted to determine what works for them, what doesn’t, and if their best practices will work in Alaska.

4. **Identify costs to convert asphalt plant.** Manufacturers of asphalt plant equipment were contacted to determine additional pieces that would need to be purchased to convert AS&G’s plant to one that could use crumb rubber in the wet process. After contacting suppliers, Wes Vander Martin, Operations Manager for the Asphalt Division at AS&G gave his opinion on the cost of converting the plant.
5. **Determine cost/benefit of using tires in asphalt production.**

Various agencies were contacted for information regarding costs of asphalt crumb rubber. Reports were also read that contained information on costs of new pavement and maintenance of existing pavement.

After answering all of the research objectives, an analysis was made regarding the feasibility of using crumb rubber modified asphalt in Alaska. The determination was made after considering the answers to all of the objectives. If one answer provided negative feedback, the process might not work in this state. For instance, if best practices used elsewhere showed poor results in areas with similar climates to Alaska, the hypothesis, which is that using crumb rubber in asphalt in Alaska is feasible, would be proved false. This would also be true if there is no practical way to get enough crumb rubber for asphalt production, either by using available tires in Alaska, or shipping them in from other areas. The final results of the analysis considered all of the objectives and the answers received.
Chapter IV – Analysis

According to Dr. Rita Leahy, researcher at Oregon State University, 2-6 tires are required in the production of 2,200 pounds of asphalt hot mix. The North Carolina DOT provides information on the amount of asphalt needed to cover a given area at a specified rate of application (QMS Manual, 1999). Their computations show that a stretch of highway that is 2,800 feet long by 12 feet wide and 4 inches deep, requires approximately 840 tons of asphalt. In this example, 1,527 to 4,581 tires are needed as an additive. Using this computation, a lane mile would take 1,584 tons which includes approximately 2,879 to 8,637 tires. This figure could be much less, since most states use between one and two inches of crumb rubber asphalt on their highways. These figures also will vary depending on the specifications required by the contractor or highway department.

Through contact with various agencies, this project determined the optimum amount of rubber needed on a street in Anchorage to provide for a long lasting surface that prevents rutting. A 1-mile divided highway, with two lanes each way, could use 11,516 to 34,548 tires. Therefore, a 4-mile stretch on the Seward Highway might use 46,064 to 138,192 tires. These figures are estimated using a 4-inch thick overlay.
Table 8. **Amount of Tires Needed in Specified Area**

<table>
<thead>
<tr>
<th>Area covered</th>
<th>2 tires per MT</th>
<th>4 tires per MT</th>
<th>6 tires per MT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,800' x 12' x 4''</td>
<td>1,527</td>
<td>3,054</td>
<td>4,581</td>
</tr>
<tr>
<td>5,280' x 12' x 4'' (1 lane mile)</td>
<td>2,879</td>
<td>5,578</td>
<td>8,637</td>
</tr>
<tr>
<td>5,280' x 48' x 4'' (1 mile, divided 2 lane highway)</td>
<td>11,516</td>
<td>23,032</td>
<td>34,548</td>
</tr>
<tr>
<td>21,120' x 48' x 4'' (4 lane miles, divided 2 lane highway)</td>
<td>46,064</td>
<td>92,128</td>
<td>138,192</td>
</tr>
<tr>
<td>21,120' x 48' x 2 1/4''</td>
<td>25,911</td>
<td>51,822</td>
<td>77,733</td>
</tr>
</tbody>
</table>

The number of tires used in a metric ton is dependent on the specifications required by the engineer. This same four mile two lane divided highway could use much less, depending on the thickness of the asphalt. These computations are figured on asphalt that is four inches thick. Other states do not use more than 2 1/4" on a similar road. This would substantially decrease the amount of tires needed. This same four mile road would require between 25,911 and 77,733 tires as shown in Figure 8.

According to Robert Larkey, owner of Alaska Tire Recycling, there are approximately 300,000 tires that could be recycled annually in the Anchorage Mat-Su areas. Currently his company receives 25% of that amount, primarily from the various tire stores in Anchorage. People who leave their tires with the dealers for disposal pay between $1.50 and $2.00 per tire for this service. Mr. Larkey said that many people prefer to take the tires home and dispose of them at a later date. He currently has 70,000 tires in the stockpile on his company’s premises. He has not been able to promote products in Alaska using recycled tires, so he is not utilizing his facility as much as he would if there were job prospects in the future. He has bid on projects with the Anchorage School District that used recycled crumb rubber in the production of ground
covers on the elementary school playgrounds. He lost the bid to a company in New York who could provide the entire process, including additives, which he did not have experience with at the time. Mr. Larkey believes that a good use for the crumb rubber would be on the many bicycle paths that are being developed in South Central Alaska. This process has been used extensively in some states with positive results.

Mr. Larkey stated that the cost of the crumb rubber varies according to the gradation of the specification. He estimates that crumb rubber used for highway production would cost between $200-$600 per ton, depending on the gradation of the rubber. According to Donna Carlson with the Rubber Pavements Association, the cost of crumb rubber in Arizona averages between $.12 - $.15 per pound, which is $240 to $300 per ton. If rubber needed to be shipped to Alaska by barge from Seattle, an additional cost of $150-200 per ton for shipping would need to be included in the total costs. If Alaska Tire Recycling had a large job they could probably decrease their costs and pass those savings on to the customer.

It would not be possible to pave all of Anchorage's streets with crumb rubber mixes, unless we purchased some of the rubber from outside of the state of Alaska. Even if all tires in the area were recycled there would only be enough for approximately 8.5-26 miles of divided highway, two lanes each direction, depending on the mix design. This figure is derived using a 4" thick overlay. Using a 2 1/2" overlay, as is used in other locations, the figure would increase to 15.5 to 46.5 miles. An overlay on an existing highway would take much less, especially if the specification called for a one inch overlay. It has to remembered, however, that high traffic roads, i.e. the Seward Highway,
Minnesota Bypass, Glenn Highway, to name a few, experience the deep rutting and other problems that could be remedied by crumb rubber asphalt. All roads in the Anchorage area can have problems with icing and skid resistance, so a determination would need to be made regarding what roads to use this product on.

Converting the plant at Anchorage Sand and Gravel will have some costs. The existing plant was used during the trials in Anchorage in 1980 and 1981. The equipment consisted of the asphalt plant and the Hazemag, a piece of equipment that crushes used asphalt to use in recycled asphalt pavement. The conveyor system that is part of this equipment was used to carry the crumb rubber to the hopper on the asphalt plant for incorporation into the mixture. This procedure was used when Anchorage Sand and Gravel used the dry process. This process is not used in any of the states currently using crumb rubber asphalt. To prevent the problems that occurred in the early 1980s, it will be necessary to use the wet process being used in the other states using CRM successfully. Because of this, there are additions that need to be made to AS&G’s existing plant.

According to Epps et al. (1995) a possible choice of equipment is a similar system used in Tempe, Arizona and manufactured by CE Enterprises. There is a separate asphalt-rubber mixing system and a tank used exclusively for agitating the mixture of asphalt oil and crumb rubber. The mixing tank holds 300 gallons and consists of a shaft with blades at the bottom and midway. The tank must have thick coils in it to withstand the increased temperatures required for this process. A circulation pump sucks the crumb rubber into the mixing tank and blows it around the coils and circulates the mixture. The
asphalt oil is kept at 400°F, but will decrease to approximately 350°F when the crumb rubber is incorporated. Conventional asphalt oil is generally kept at 300°F. After blending, it is moved into a 15,000 gallon tank. The mixture is then agitated for approximately 45 minutes before adding to aggregates to produce the crumb rubber asphalt mixture. This system can produce approximately 28 tons of asphalt rubber binder per hour, which would be enough to produce 400 tons of rubber-modified asphalt in that same period.

Through discussions with a supplier of a similar system and with Wes Vander Martin, Operations Manager for the Asphalt Division at Anchorage Sand and Gravel, it is believed that the additional equipment needed would cost between $50,000 and $60,000.

Although the states using crumb rubber modified asphalt are basically hot weather areas, they do have areas that have climates with cold temperatures. California and Arizona were contacted for information on cold temperature asphalt usage. These areas also were able to provide information on the most efficient laydown procedures and preventative measures for cracking, rutting and raveling. Since California and Arizona are both using crumb rubber on a voluntary basis, these states are good examples of areas that have tried different practices and are now using these materials cost effectively.

Life cycle cost analysis studies have been conducted on various mixes of asphalt in different locations. These studies were compared with studies done on the life cycle of asphalt mixes that incorporate crumb rubber into their production. Besides these comparisons, data was also analyzed comparing the various types and sizes of crumb rubber, as well as the amount used in the mixtures. These were compared to asphalt
mixtures that have similar properties. Besides the life of the asphalt, other costs/benefits were examined, i.e. environmental benefits, including the savings of disposal fees for tires at landfills. Non-monetary benefits were also analyzed, i.e. the public's interest in having low maintenance highways. Another benefit looked at was the safety factor. The purpose was to determine if shorter stoppage distances on ice convert to less accidents and lives saved. Studies cited previously determined up to fifty percent less stoppage distances are possible. Another benefit is less sand and chemicals used on the roads because of the partial elimination of ice cover on the roadways. This would also have to be weighed against the loss to the aggregate supplier of sand to the departments.

Another factor looked at was the cost/benefit of producing crumb rubber in Anchorage, as compared to bringing the product already shredded, here by water or truck. The small business located in Palmer that deals with recycled rubber tires was contacted. It was found that 75,000 tires are recycled here each year. If there was a need for more product, this number could be increased to as much as 300,000. Alaska Tire Recycling could provide enough recycled rubber to do a significant number of miles annually.

Caltrans has conducted studies on the cost benefits of using rubberized asphalt concrete in comparison to conventional asphalt. The following examples show information they have compiled in the State of California (Figure 2). The costs per ton shown in the examples are typical to Southern California. These examples are provided by the Rubberized Asphalt Concrete Technology Center, which is a cooperative effort of the County of Los Angeles and the California Waste Management Board whose mission
is to promote the use of crumb rubber from scrap tires by providing education within California.

Figure 2.

<table>
<thead>
<tr>
<th>Project Design Example No. 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil/deflectometer testing indicates that a 4-inch overlay of conventional AC is required.</td>
</tr>
</tbody>
</table>

Cost Per Lane Mile Using Conventional AC:

\[
\begin{align*}
1,584 \text{ tons} @ \$30.00 \text{ per ton} &= \$47,520 \\
\text{Pavement Prep} &= 7,000 \\
\text{Total} &= \$54,520
\end{align*}
\]

Cost Per Lane Mile Using 2-inch RAP (recycled asphalt pavement)

\[
\begin{align*}
754 \text{ tons} @ \$42.00 \text{ per ton} &= \$31,668 \\
\text{Note: RAP weighs 5% less than AC}
\end{align*}
\]

Savings per lane mile: $54,520 - $31,668 = $22,852

<table>
<thead>
<tr>
<th>Project Design Example No. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil/deflectometer testing indicates that a gravel equivalent of 26 is required.</td>
</tr>
</tbody>
</table>

Solution No. 1 is Reconstructing the Structural Section with 4” AC/17” CAB (Crushed Asphalt Base).

Cost Per Lane Mile

\[
\begin{align*}
\text{Excavation} - 4,107 \text{ CY} @ \$25/\text{CY} &= \$102,675 \\
\text{CAB} - 3,324 \text{ CY} @ \$20/\text{CY} &= \$66,480 \\
\text{Asphalt} - 1,584 \text{ TN} @ \$30/\text{TN} &= \$47,520 \\
\text{Total} &= \$216,675 \\
\text{Advantages:} &\text{ New roadway elevation will be the same as existing} \\
\text{Disadvantages:} &\text{ High cost, long-term disruption of traffic during construction}
\end{align*}
\]

Solution No. 2 is resurfacing with 4” of Conventional Asphalt

Cost Per Lane Mile

\[
\begin{align*}
\text{Same as Example No. 1} &= \$54,520 \\
\text{Advantages:} &\text{ Minimal disruption to traffic} \\
\text{Disadvantages:} &\text{ Adding 4 inches to the existing roadway elevation may not be practical.}
\end{align*}
\]
Solution No. 3 is resurfacing with rubberized asphalt concrete — cold mix 1 inch, add 2 ½ inches RAC.

Cost Per Lane Mile

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost (in $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold Mill — 63,000 sq. ft. x $0.10</td>
<td>$6,336</td>
</tr>
<tr>
<td>RAC = 942 tons @ 42 per ton</td>
<td>$39,564</td>
</tr>
<tr>
<td></td>
<td>$45,900</td>
</tr>
</tbody>
</table>

Advantages: Roadway elevation is only raised 1 ½ inches. Minimum disruption to traffic.
Disadvantages: None.

Summary of Costs Per Lane Mile

<table>
<thead>
<tr>
<th>Solution No.</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$216,676</td>
</tr>
<tr>
<td>2</td>
<td>54,520</td>
</tr>
<tr>
<td>3</td>
<td>45,900</td>
</tr>
</tbody>
</table>

Note: If the cost of RAC exceeds the cost of AC, its appropriateness for the project should be evaluated against the advantages/disadvantages of the other solutions.

(Source: Rubberized Asphalt Technology Center, 1998. Pages 1-3. Reprinted by permission of Rubberized Asphalt Technology Center)

The majority of the information for this project was provided by secondary sources. Previous studies were reviewed so that a comparison could be made between other areas and climates and the State of Alaska. People in other areas were interviewed so that more information could be garnered regarding past and present trials and/or asphalt in use on highways in their areas. A determination was made as to the viability of using this product in Alaska, either in Anchorage or other areas.

This report concentrated on the best practices used in other states that use recycled rubber tires in the production of asphalt pavement. During the literature portion of this project, areas with similar climate and topography to Anchorage were specifically targeted for study. Anchorage was chosen as the focal point of the project because a majority of the state’s population and roadways are located there. Because of the impact
of climate, especially temperature, on asphalt products, comparisons with areas with similar climates are very important. It is also important to look at the reason a certain area uses a specific asphalt mixture. If the mixture is used solely for skid resistance, the product will most likely be different than a product used to prevent reflective cracking caused by cold temperatures. Florida’s friction courses are used primarily for skid resistance and permeability to prevent hydroplaning. This is important in Florida, because of the high truck traffic on their interstate highways. The mixture they use works well with the high temperatures experienced in Florida most of the year. The thin layer of asphalt rubber used on the interstates prevents most of the standing water problem that was previously experienced. Florida does not have any areas that have similar climates or temperatures as Alaska.

California also has hot temperatures in some of its regions most of the year. California, however, does have areas that have very similar climates to Alaska. The High Sierras have a great deal of snow and experience temperatures that can get as cold as Anchorage. Their snow cover averages 375 inches annually. This area compares to Thompson Pass, which is near Valdez, Alaska. More important than snow, however, may be temperature. Temperature has more of an impact on asphalt than snow or rain.

Many vehicles in Anchorage are equipped with studded tires in the winter. An engineer with the Alaska Department of Transportation (DOT) stated that he believes that one of the problems with Anchorage’s roads is that studded tires are damaging the surface. It is feared that the wet process of incorporating crumb rubber will not alleviate
this problem, so the Alaska DOT is considering doing experiments with the dry process again.

California uses the wet process in the High Sierras with good success. According to Gary Hildebrand, vehicles, including heavy trucks, put snow chains on their tires before driving the snowy roads. Those not using chains generally use studded tires. They have found no significant damage to the roadways caused by either.

California has found that using gap graded asphalt rubber helps to cut down on reflective cracking in the mountain regions. By using the best practices of California’s mountain regions, Alaska may be able to develop a product that will work well under similar conditions.

Tests regions in Arizona have shown that asphalt rubber friction courses are more beneficial in preventing reflective cracking than either concrete or asphalt concrete (Way, 1998). Figure 3 shows the differences between conventional asphalt and AR-ACFC in regards to reflective cracking. The figure shows a similar percentage of cracking during the first four years, but while cracking in conventional asphalt percentages increase, the rubber modified product remains fairly constant.

Arizona has found that asphalt rubber products last as much as three times as long as conventional asphalt. Arizona’s DOT often specifies half the thickness of asphalt rubber on a project as they would conventional concrete, greatly decreasing the costs of the project. By using less asphalt rubber than asphalt, a project will often cost less using asphalt rubber than it would if using conventional asphalt mixtures. Areas in northern Arizona, specifically around Flagstaff, have a similar climate to Anchorage, generally
having 90 inches of snow and temperatures dipping to 20 degrees below zero in the winter. The products used in this region should also prove useful in the Anchorage area.

Figure 3.

Materials Group ~ Pavement Design
Percent Cracking

CHAPTER V – CONCLUSION

Anchorage has a great deal of problems with its roadways. Among the more noticeable of these problems are the deep ruts found on most highways, potholes that develop with regularity and ice cover caused by the climate.

Similar areas in California and Arizona have been using crumb rubber modified asphalt on their roadways for many years. Because of the similarities, it is believed that a product using specifications from either of these areas should prove beneficial here.

An added aspect of the use of crumb rubber in asphalt production, not before entertained, is the fact that the Department of Transportation (DOT) of the state has to use the product in its specifications. For this to happen, the DOT must believe that the product is going to be beneficial on the roadways. The three states currently using these products are specifying the products in many of their roadways. As stated previously, Florida’s mandate requires friction courses to use recycled rubber, and therefore write their specifications using the product. Although California and Arizona do not have mandates, specifications are written using these products in many locations. If Anchorage Sand and Gravel is going to begin to use crumb rubber in its asphalt production, the Alaska Department of Transportation will need to write specifications using the product.

It is this researcher’s opinion that asphalt mixtures containing crumb rubber would be a viable option for Alaska, particularly for the Anchorage area. There are several mixtures that can work in cold temperatures, however, according to Mr.
Hildebrand of Caltrans, the mixture California calls Type II, incorporating dense-graded aggregates appears to be a good mix for our cold climate.

**Recommendations**

There are several things that will need to occur before Anchorage Sand and Gravel can begin to produce asphalt mixtures containing crumb rubber. The primary obstacle at this point is the State of Alaska’s Department of Transportation. It will be necessary to convince this department that crumb rubber will improve the quality of our roadways. An engineer with the Alaska DOT has been approached to determine the Department’s receptiveness to this product. He stated that the DOT has been thinking about doing some new test spots in Anchorage using crumb rubber. His belief was that Anchorage needed to use the same process that was used previously, the dry process. It is this researcher’s opinion that this process will not prove to be beneficial in this location. It will be necessary to show supporting information that will persuade the DOT’s engineers to consider using the wet process for incorporating crumb rubber into asphalt. The research contained in this report, along with contact names for people in other states, will be presented to the DOT so that they have access to available information.

In addition to convincing the Alaska DOT of the viability of the product, management at AS&G will also need to be informed of the available processes and the possible benefits to the company of using crumb rubber. If the wet process is approved for use, AS&G will need to modify the asphalt plant to produce the new mixture. It will be important for AS&G to have all necessary information on equipment and processes, so
that equipment can be ordered and the plant converted if the State of Alaska begins to specify this product.

AS&G needs to look at the crumb rubber industry in Alaska. At present the only company dealing with recycling of used tires is Alaska Tire Recycling. To gain a competitive edge in the crumb rubber asphalt business, AS&G will need to have access to the rubber products needed to produce this type of asphalt. The company can form a partnership with Alaska Tire Recycling, buy that company, or purchase equipment to grind tires. Since Alaska Tire Recycling has the equipment and agreements with tire companies to pick up their used tires, it seems logical for AS&G to form a joint venture with that company. AS&G will need to form a relationship with Alaska Tire Recycling, who will also need to extend contracts with the various tire retailers, so that there is an access to crumb rubber for a definite period of time. AS&G can gain a competitive advantage in the asphalt market if the company has the information and technology available when new products and processes are specified by the Alaska Department of Transportation.

Suggested Additional Research

This researcher did not look at the various mix designs that may or may not be usable in the State of Alaska. An engineer should look at specifications used in the states of California and Arizona to determine if their ingredients will work in this state, or if one of their designs needs to be modified.

It would be beneficial to have a test pavement placed in the Anchorage area using the wet process of incorporating the crumb rubber into the asphalt. The test should be
placed in a location that has a great deal of traffic, for instance the Seward Highway. If a control area is done nearby using conventional asphalt, a determination can be made if this product will work in this city.
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References


Appendix A

Glossary

**Ambient ground rubber** – product that is obtained by passing rubber through rotating corrugated steel drums, tearing into uneven shaped pieces. Magnets remove steel from rubber chunks.

**Asphalt rubber** – asphalt cement modified with crumb rubber modifier (CRM).

**Crumb rubber modifier** – general term tire rubber that is used in asphalt paving materials.

**Cryogenically ground rubber** – process that freezes rubber with liquid nitrogen causing rubber to become brittle and shatter easily.

**Devulcanized rubber** – rubber that has been chemically altered after grinding to change properties of the material.

**Dry process** – a method that mixes aggregates and rubber before hot asphalt oil is added.

**McDonald technology** – wet process of modifying asphalt, rubber is mixed with hot asphalt oil, mixed for an hour, and then blended with aggregates.

**Micro-mill** – process that shears rubber with steel plates, reducing it to particles .5 mm to 0.075 mm.

**PlusRide** – process developed in Sweden using coarse rubber particles added with gap-graded aggregates to form a dense grading of the final product. This is one of the dry processes.

**Reaction** – the process between the asphalt cement and the crumb rubber that involves absorption of aromatic oils from asphalt cement into the crumb rubber.
Reflective cracking – cracking of the subsurface that reflects up to the top.

Stress-absorbing membrane (SAM) - consists of spraying asphalt rubber blend on existing pavement and then applying uniform aggregate, which is then rolled into the binder layer. Generally ¼” to 3/8”.

Stress-absorbing membrane interlayer (SAMI) – a membrane between layers of asphalt designed to keep reflective cracking from going through top layer. Similar to SAM, but covered with an additional layer of asphalt or asphalt rubber.

Vulcanized rubber – rubber that is not treated by heat or chemicals to alter properties.

Wet process – any method that blends crumb rubber with asphalt cement before mixing with aggregates.