As a result of Mr. Charles McDonald's early work, the City of Phoenix in 1970 made the decision to go ahead with application of asphalt rubber as a binder in the annual preventative maintenance chip seal program. Based upon Mr. McDonald's research, a contract was written with a special provision to include asphalt rubber. This special provision spelled out the proportions to be used, mixing time and temperatures and application method. The special provision also recommended the type and size of rollers to be used, how many times the application would be rolled, and it specified the type and rate of aggregate applications. It also specified exact surface temperatures along with ambient conditions.

In 1972 Phoenix set up a standard specification for Hot Asphalt Rubber Seal Treatment. This standard has been modified and improved over the past years to allow competition, improve the product and reduce costs. The current standard appears in the Appendix. The industry also has improved and modified the equipment to be competitive and has made definite contributions to improvement of the product over the last decade.

Phoenix began using asphalt rubber with a bang. In fact, the city was placing it on runways, roofs, lake liners, under runways, and of course using it in the chip seal program, and in cracks. Asphalt rubber chip
seals also were included in new construction in 1973 to build an inexpensive pavement in small neighborhood improvement districts. This was the Stress Absorbent Membrane, (S.A.M.) as it was later named. The pavement section consisted of 4.5 inches of soil cement and 1.5 inches of asphaltic concrete followed by 0.55 gallons per square yard of asphalt rubber and \( \frac{1}{4} \) -inch precoated aggregate. ASTM, Special Technical Publication 724, dated December 12, 1979, provides more detail on this development.

Due to the lack of advance public relations both on the part of the city and the contractor, the City Council quickly began to hear from the public on the use of asphalt rubber. This was because, in our ignorance, no speed restrictions were placed immediately after application and flying stone chips caused damage to cars. The negative public reaction slowed up the rubber development program and, in fact, almost stopped it. However, these conditions were corrected and Phoenix is currently applying in excess of five miles of rubber chip seals annually on a selective basis. Areas are chosen for application based on need, paving surface condition, the alternatives and the costs.

The reasons for selecting asphalt rubber chip seals will become obvious from the data to be presented at this conference. These reasons are the same as those for selection of surface treatments using the standard AR's, penetration grades, cutbacks and emulsions; and which include:
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1. Provides a low-cost all-weather surface
2. Waterproof paving
3. Provides a skid-resistant surface
4. Gives new life to dry, weathered surfaces
5. Reinforces pavement strength
6. Guides traffic
7. Improves visibility.

However, the asphalt rubber seal now offers added advantages, such as:
1. Prevents crack reflection
2. Prevents spalling at pot hole edges
3. Provides a truly flexible surface
4. Eliminates need for maintenance for at least eight full years
5. Adds to life of pavement by as much as two times
6. Delays need for reconstruction.

QUALITY CONTROL
CONSTRUCTION MATERIALS

The aggregate used in asphalt rubber chip seals must be as close to uniform size as is economically practical so the surface treatment will have only a single layer of aggregate. It also is absolutely necessary to obtain a 50% embedment of the aggregate into the asphalt rubber. This can be accomplished by using the correct asphalt rubber application rate of not less than 0.5 gallon per square yard, the proper application viscosity, the right aggregate application rate
and by immediate rolling of the aggregate surface. In our experience in Phoenix if the aggregate is not immediately 50% embedded, the chip is lost due to traffic scatter.

Asphalt rubber can be placed at application rates of over one gallon per square yard without occurrence of the problems experienced with asphalt cement or cutbacks. During the first year after construction it tends to self-correct any problems such as stickiness, chip tear-out and scatter. It then continues to improve. By comparison, during the first year after a chip seal has been placed using a conventional asphalt, the surface will be at its best. During the second, third, and perhaps the fourth year the surface begins to deteriorate and gradually returns to the original cracked and worn conditions. At some time between the fifth and eighth years, the surface must be resealed.

Asphalt rubber chip seals in the first year often cause concern, especially to those who are trying to impress the taxpayers. Traffic tends to tear out and scatter the chips. The cure is slow, causing the surface to remain sticky, and the appearance is poor. However, asphalt rubber, improves with age and use until it reaches its eighth year. Phoenix has asphalt rubber chip seals 10 to 12 years old that are just beginning to show distress.

CONSTRUCTION EQUIPMENT

The application equipment for asphalt rubber outwardly appears the same as that required for conventional surface treatment: a distributor,
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a spreader and rollers. The train of application equipment is shown at work in Figure 1. However, asphalt rubber application has required improvements and modifications. The asphalt rubber distributor now has evolved into a sophisticated boot truck with automatic controls, continuous monitoring devices and larger capacities. Figure 2 shows nozzle array and controls.

Early in the history of asphalt rubber application the sizes of spray bars, pump pressures, and nozzles were specified. Today the only specification is that 0.6 gallons of asphalt rubber be placed uniformly on the pavement surface. This illustrates dramatically the improvements that have accrued in asphalt rubber technology.

Aggregate spreaders also have improved, however not necessarily due to the asphalt rubber or to the degree of the boot trucks. Phoenix specifies a highly efficient self-propelled spreader with maximum speed specified to prevent aggregate rolling. The spreader appears in Figure 3.

For best results, rollers should be self-propelled with a minimum of 5,000 pounds on each wheel and equipped with pneumatic tires inflated to a minimum of 100 PSI in each tire. This, by definition, is a large roller and this size is needed to obtain the 50% embedment of the aggregate chips into the asphalt rubber. It is essential that the rollers follow immediately behind the distributor. Phoenix specifies a minimum of three roller coverages per unit area. Three rollers are used to keep up with production, as shown in Figure 4.
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The street is swept of loose chips within 24 hours and examined to insure that 50% embedment was accomplished. If the chips are not properly embedded, the surface is flush coated with a SS-1h emulsion to insure bond integrity. In applying asphalt rubber Phoenix does not normally use a tack coat unless the application is made to a surface under very poor condition, such as a new road mix skin patch, etc. A tack coat is used for the conventional chip seal.

TRAFFIC CONTROL

Traffic flow continues during the chip seal application, as shown in Figure 5. Therefore, the moment that the aggregate has been rolled, traffic is using the new surface. Police are stationed at major intersections for traffic control and to maintain traffic speed at 25 MPH until the surface has been swept. All major intersections require sanding to prevent pickup from quick starting cars. The sand is applied after the aggregate chips have been rolled. The greatest damage to asphalt rubber seals is experienced at intersections and behind the signal light. However, after a year's use, even that heals.

As reported (ASTM), Phoenix has twelve years of asphalt rubber use with traffic counts of over 38,000 vehicles per day and the surface continues to perform. An airport runway has had no maintenance since the rubber application in 1972. The fully cured asphalt rubber seal is shown in Figure 6.
Cost comparisons were made in Phoenix and these may or may not be applicable over the other parts of this country. Since 1971 asphalt rubber cost has gone from 97¢ to $1.40 per square yard, including aggregate in place, a 5.4% annual increase (See Figure 7). The cost remained stable at 97¢ until 1978 and then rose very rapidly with the price rise of asphalt.

By comparison, conventional chip seal cost in the past ten years has gone from 15¢ to 72¢ a square yard, including aggregate in place. This represents a 38% annual increase (See Figure 7). The primary ingredient in the seal, of course, is asphalt cement, which has increased from $4.9 per ton in 1971 to $26.5 per ton today. This represents a 46% annual increase, and the cost still appears to be going up (as shown in Figure 8). As a comparison, for the past ten years, cost of asphaltic concrete in place has risen from $9.25 per ton to $27.50, a 20% annual increase. This can be seen in Figure 9.

In 1971 three miles of conventional chip seal could be placed for every mile of asphalt rubber. It is necessary to point out here that asphalt rubber has not been used explicitly for preventative maintenance. Asphalt rubber was used to salvage surfaces in the last stages of disrepair, or where virtual "Basket" cases needed help. Today we can place less than two miles of a conventional chip seal for every mile of asphalt rubber. This comparison is based upon the initial cost.
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After installing and observing asphalt rubber applications for the past twelve years, observations indicate that ten to twelve years life can be expected from an asphalt rubber seal. Normal life expectancy using a conventional chip seal is six to eight years.

Also, the asphalt rubber has not required maintenance except for utility problems for at least ten of the twelve year life. The conventional chip seal normally requires some maintenance such as crack filling and pot hole repairs by the fifth year of its life. Sufficient cost data are not available on the amount of per mile maintenance expenditures to make a just comparison. However, street maintenance crews report that no maintenance is being performed on the asphalt rubber seal, while maintenance of the conventional chip seal coatings is required.

By doubling life expectancy and reducing maintenance costs, asphalt rubber becomes very cost-competitive with other seal coats. Phoenix has 3,000 miles of streets and each year budgets enough money to chip seal 300 miles. This means that we can chip seal each mile only once every ten years which simply does not maintain our street investment. Use of asphalt rubber seal coats offers the means to improve on this situation through the extended life of the rubberized seal.

ADVANTAGES

As originally viewed, it was thought that one of the greatest advantages of asphalt rubber was to save the roadway until reconstruction monies
became available. The extent of paving deterioration that can be arrested with asphalt rubber sealing is shown in Figure 10. With time and experience other advantages have become apparent.

Among them are:
1. Stops reflective cracking in paving materials with less than 0.25-inch cracks.
2. Water proofs the structure to stabilize the unit.
3. Stops spalling of asphaltic concrete around pot holes and larger cracks.
4. Eliminates maintenance due to items one, two and three.
5. Renovates and retains characteristics of the existing asphaltic concrete needed to retain life and which are normally lost by oxidation, exposure and use are retained by an asphalt rubber seal.

CONCLUSIONS

Asphalt rubber chip seals have performed well in Phoenix and original installations still are working well. The cost of asphalt rubber is 1.5 times the cost of the conventional seals. However, it lasts up to twice as long. It has reduced general street maintenance to a point that street maintenance crews can take care of other problems.

Phoenix has used asphalt rubber seals on selected streets that were particularly in need of immediate help, but has not used it for a general
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overall preventative maintenance due to its cost. Its excellent performance leaves no question that asphalt rubber has earned its place in the world of highways and streets and should be used or considered as an alternative for paving maintenance.
717.1 GENERAL:
Hot asphalt-rubber seal shall consist of a mixture of hot paving grade asphalt and ground tire rubber combined with heat into a visco-elastic composition. After application it shall be covered with cover aggregates.

717.2 MATERIALS:
717.2.1 The Asphalt shall be AR-1000 grade as per Section 711.
717.2.2 The granulated rubber shall meet the following requirements:
The specific gravity of the material shall be 1.15±.02 and shall be free from fabric, wire, or other contaminating materials except that up to 4 percent of calcium carbonate may be included to prevent the particles from sticking together.
717.2.3 The cover aggregate shall conform to the requirements of Section 716. The grading of cover aggregate shall comply with Table 716-1 for light traffic use and Table 716-2 for heavy traffic use. Cover aggregate shall be either hot precoated chips in accordance with Section 331 or cold uncoated chips.

Except where materials are being obtained from a previously approved source, the Contractor shall furnish samples for testing in accordance with Section 725.
SECTION 335

HOT ASPHALT - RUBBER SEAL

335.1 DESCRIPTION:
This item shall consist of the placing of a hot paving grade asphalt and ground tire rubber combined with heat into a visco-elastic composition. After application, it shall be covered with a cover aggregate.

The work involves furnishing and placing all materials on existing pavement surfaces in accordance with the following specifications.

335.2 MATERIALS:
The asphalt, granulated rubber and cover aggregate shall comply with Section 717.

335.3 EQUIPMENT:
The equipment used by the Contractor shall include a power broom for sweeping joint edges and a self-propelled aggregate spreading equipment equipped with a classifying screen for dust control that can be so adjusted as to spread accurately the given amounts per square yard. Three pneumatic-tired rollers shall be used. Each roller shall carry a minimum of 5,000 pounds on each wheel and a minimum of 100 PSI in each tire, and shall not travel in excess of 8 miles per hour. There shall also be a self-powered pressure distributor tips, full circulation spray bars, and equipment for heating bituminous material. Distributor equipment shall include a tachometer, pressure gages, volume measuring devices, and a thermometer for reading temperatures of tank contents. The spray bars on the distributor shall be controlled by one or more boatmen, as required,
riding at the rear of the distributor in such a position that operation of all sprays is in full view and accessible for unplugging tips and controlling spread widths. The Contractor shall satisfy the Engineer by actual demonstration, at a location designated by the Engineer, that his spreading equipment will produce the intended results.

The method and equipment for combining the rubber and asphalt shall be so designed and accessible that the Engineer can readily determine the percentage by weight of each of the two materials being incorporated into the mixture.

335.4 MIXING:
There shall be not less than twenty (20) percent of rubber by weight of the total mixture.

335.5 SPREADING:
Prior to placing the hot asphalt-rubber seal coat, soil and other objectionable materials shall be removed from the pavement surface and a tack coat applied, if necessary, consisting of 0.05 gallons per square yard of SS-lh emulsified asphalt, diluted 50-50 with water.

The application rate of the hot asphalt-rubber mixture (based on 7½ pounds per gallon) shall be 0.55 to 0.60 gallons per square yard unless otherwise specified.

The cover aggregate shall be preheated immediately prior to application and precoated with not more than 0.75 percent of aged residue asphalt.
The temperature of the precoated chips at the place of application shall be between 290 degrees Fahrenheit and 350 degrees Fahrenheit. Stockpiling or reheating of cover aggregate after precoating will not be permitted. Truck bed covers will be required as necessary to maintain the temperature of the cover aggregate prior to placement. Canvass, or similar covers, that completely cover each load shall be used whenever it is found that the temperature of the top 3 inches of the chip load is dropping below the minimum requirement at the time of application.

Hot asphalt rubber seal with hot precoated cover aggregate shall be placed only when the pavement temperature is 70 degrees Fahrenheit, or above and rising.

The rate of application of the cover aggregate shall be from 27 to 35 pounds per square yard of the \( \frac{3}{8} \) inch nominal size of 37 to 39 pounds per square yard for the 3/8 inch nominal size as directed by the Engineer. A minimum of 4 complete coverages shall be made with the pneumatic rollers. The rolling of the cover aggregate shall proceed immediately after application in order to insure maximum embedment of the aggregate.

The Contractor shall sweep all joint edges clean of overlapping cover material prior to adjacent application of asphalt-rubber material. All reasonable precautions shall be taken to avoid skips and overlaps at joints and to protect the surfaces of adjacent structures from being spattered or marred. Correction of any such defects will be required at no additional cost to the Contracting Agency. All transverse joints
shall be made by placing building paper over the ends of the previous applications and the joining application shall start on the building paper used. Once the application process has progressed beyond the paper used, the paper shall be removed and disposed of to the satisfaction of the Engineer.

Traffic will not be permitted on the surface except under pilot car until the cover aggregate has set. Traffic control will be covered in Section 401 and the special provisions where required.

At signalized intersections, an application of 5 to 10 pounds per square yard of sand shall be applied after rolling, and before opening a lane to traffic, through the intersection and for a distance of 200 feet each way from the near curb returns.

After a final sweeping, and prior to striping, a flush coat may be applied, except for 200 feet either side of signalized intersections, to the asphalt-rubber treatment consisting of 0.04 to 0.10 gallons per square yard of undiluted SS-1h emulsified asphalt. The application of the flush coat may be delayed to facilitate curing or to avoid placement under unfavorable high temperature conditions. The flush coat may be deleted if the Engineer determines sufficient chip embedment has been attained.

335.6 MEASUREMENT:
Certified weight slips of all materials shall be delivered to the Engineer before the materials are applied.
Certified weight slips of any bituminous material being weighed back in for credit, shall be delivered to the Engineer before starting the next day's work.

Quantities of materials for this work will be paid for at the contract price per unit of measurement for each of the following pay items actually ordered and used on the project:

(A) Hot Precoated Chips
(B) Asphalt-Rubber
(C) SS-1h Emulsified Asphalt

335.7 PAYMENT:
Quantities shown in the proposal are for bidding purposes only. Payment will be full compensation for furnishing and placing all materials ordered and used, with no allowance for waste, and shall include labor, equipment, tools, and incidentals necessary to complete the work as prescribed and as directed by the Engineer.

Asphalt cement for precoating chips will be included in the price per ton for hot precoated chips, except that if the Engineer orders precoating material in excess of 0.75 percent of the combined weight of the bituminous material and the chips, the additional asphalt required will be paid for at the unit price bid for the item under aged residue asphalt.

No payment will be made for materials rejected due to improper placing, improper proportions of materials, or materials found to be defective.
716.1 GENERAL
Precoated chip seals shall consist of one or more applications of bituminous or asphalt-rubber material, followed by an application of precoated stone chips, smoothed and compacted, on existing roadway in accordance with this specification.

716.2 MATERIALS:
716.2.1 Bituminous Materials: The bituminous binder for precoating shall be asphalt cement, of any standard paving grade as specified in Section 711.

716.2.2 Stone Chips: The cover material for the paving asphalt binder shall be stone chips having a percentage of wear not to exceed 40 at 500 revolutions when tested in accordance with AASHTO T-96.

Sodium sulphate soundness test shall be in accordance with AASHTO T-104 and shall not show a loss in excess of 12 percent. A minimum of 75 percent of the material, by weight, retained in the No. 8 sieve, shall have at least one fractured face produced by crushing.

Grading of the stone chips when tested in accordance with AASHTO T-11 and T-27 shall comply with the following. When sealing low-volume traffic street only, the grading shall be \( \frac{3}{4} \) inch nominal size as follows:
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**TABLE 716-1**

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
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<td>100</td>
</tr>
<tr>
<td>1/4&quot;</td>
<td>80-100</td>
</tr>
<tr>
<td>No. 8</td>
<td>0-5</td>
</tr>
<tr>
<td>No. 200</td>
<td>0-2</td>
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</table>

When sealing high traffic volume streets only, the grading shall be 3/8 inch nominal size as follows:

**TABLE 716-2**

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<thead>
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<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>3/8&quot;</td>
<td>70-100</td>
</tr>
<tr>
<td>1/4&quot;</td>
<td>0-10</td>
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<tr>
<td>No. 8</td>
<td>0-5</td>
</tr>
<tr>
<td>No. 200</td>
<td>0-2</td>
</tr>
</tbody>
</table>
Figure 1. Asphalt rubber chip seal equipment train at work. Distributor truck in foreground left spreads hot asphalt. Aggregate spreader follows with three rollers bringing up the rear.

Figure 2. Nozzle array, controls and monitoring devices on rear of asphalt rubber tanker.
Figure 3. Improved aggregate spreader at work.

Figure 4. Three large rollers follow immediately behind distributor.
Figure 5. Traffic drives on the seal immediately. Speed must be maintained at 25 MPH, or less.
Figure 6. Fully cured asphalt rubber seal. This seal was installed on Washington Street, one of the city's busiest.
Figure 7. Cost increases of conventional chip seal and asphalt rubber chip seal.
Figure 8. Increase in cost of asphalt cement during the past ten years.
Figure 9. Annual increase in cost per ton of asphalt concrete in place.
Figure 10. Extent of asphalt pavement deterioration that can be arrested with asphalt rubber seal application.