Twenty-Year Study of Asphalt Rubber Pavements in Phoenix, Arizona

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The details of asphalt rubber application on city streets pioneered by the city of Phoenix, Arizona, since the mid-1960s are outlined. Problems encountered in the early use of this material are noted. Various guidelines and specifications developed by the city for the successful use of asphalt rubber are summarized. Viscosity of asphalt cement with and without an asphalt rubber seal was determined, and the importance of these results on the aging phenomenon are discussed. Many of the city's original streets with asphalt rubber application were not evaluated because they have been reconstructed. The remaining streets were inspected, and the pavement conditions for each were observed. Detailed observations of all the street pavements are summarized, and the important findings from this 20-year historical survey of asphalt rubber pavements are discussed. Conclusions on the use and advantages of asphalt rubber as a maintenance treatment for the city's streets are noted. In spite of the advantages and good engineering characteristics of asphalt rubber chip seal, there was mounting public opposition to its continued use because loose chips caused damage to cars. The city therefore developed a special asphalt rubber hot mix. This alternative surface treatment has proven to be as effective and reliable as asphalt rubber chip seals. Details of the design of this mix and its advantages are discussed in depth.

The city of Phoenix, Arizona, has an extensive network of streets with more than 550 mi of major streets and 3,500 mi of collector and residential streets. These streets are constantly monitored, and appropriate maintenance and rehabilitation are provided on a routine basis through a pavement management system. In the mid-1960s, the city of Phoenix pioneered the use of asphalt rubber chip seal. Asphalt rubber is a mixture of 75 to 80 percent hot asphalt cement and 20 to 25 percent ground recycled tire rubber, mixed at a temperature of 300°F to 400°F to cause a reaction. A small amount of additive is added to the mixture to improve its flow characteristics for spray application.

EARLY USE

The earliest application of asphalt rubber was in 1964, followed by more extensive field testing at Sky Harbor International Airport taxiways in 1965. Success and experience of using asphalt rubber at the airport led to its routine use on city streets. A number of terms used in relation to pavements and rehabilitation are summarized in a later section. Phoenix has used asphalt rubber in two types of surface treatments: (a) stress absorbing membrane (SAM), in which a hot asphalt rubber chip seal is applied to the distressed cracked surface, and (b) stress absorbing membrane interlayer (SAMI), in which hot asphalt rubber chip seal is applied to the surface, followed by a 1½- to 2-in. asphalt concrete (AC) overlay. SAMIs were generally used in major streets with a great number of utility cuts in addition to extensive cracking. Asphalt rubber application has allowed the city to incorporate existing pavements that have been evaluated as structurally inadequate, resulting in substantial savings.

One of the earliest applications of asphalt rubber chip seal was placed on Indian School Road from Central Avenue to 7th Street in 1971. The surface of the pavement was in poor condition and was badly cracked. Application of an asphalt rubber chip seal was a temporary measure to prevent the street from complete deterioration and failure. It was then scheduled for total reconstruction in 2 years. However, the street has performed satisfactorily with little maintenance for the past 19 years. The current condition of the street is shown in Figure 1. The traffic count on this street has increased from 30,000 average daily traffic (ADT) in 1971 to 60,000 ADT in 1990. This section will be totally reconstructed in 1991. Another application was on the I-17 frontage road and offramp at Van Buren Street in December 1968. This pavement was removed because of the major interchange improvements for I-10 and I-17 in 1989. A SAM consisting of hot asphalt rubber followed by an application of hot precoated ⅜-in. aggregate was used at this site. Diluents were not used in the asphalt rubber seal. The 1967 surface was scheduled to be replaced; however, the asphalt rubber seal saved it for 21 years.

Since 1967, this treatment has been applied to more than 3,000 lane-mi in Phoenix in addition to the main runway at Sky Harbor International Airport, lake liners, and lagoon ponds.

The principal problem encountered early in the asphalt rubber construction was chip loss in low- or nontraffic areas. Some bleeding and loss of the asphalt rubber resulted. The problem was solved by increasing the asphalt rubber application and by applying a flush coat to the seal in a timely manner. A flush coat is recommended when ⅜-in chip seal is used.

With this extensive use of asphalt rubber chip seal over a span of almost 30 years, the city has developed considerable experience in the use of this method (*1–4*).

GUIDELINES AND SPECIFICATIONS FOR USE OF ASPHALT RUBBER CHIP SEAL

The following guidelines and specifications have been developed for the use and application of asphalt rubber chip seal on city streets:

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- Asphalt rubber is produced with 80 percent hot asphalt cement and 20 percent coarse ground recycled tire rubber, mixed at a temperature of 300°F to 400°F.
- Aggregates used are ⅜- or ¼-in. nominal and are hot precoated.
- Asphalt rubber is generally applied at a rate of 0.6 gal/yd^2.
- Hot precoated chips are applied at a rate of 37 to 40 lb/yd^2.

The chip seal produced a unique paving material with superior engineering properties. The main advantage of the asphalt rubber treatment has been virtually complete cessation of surface maintenance for 12 years, except for utility cuts. Cracks have not reflected through the seal on aged pavements. Continued observations of treated streets confirm the significant advantage of this method in preventing reflective cracking. Long-term studies have indicated that cracks less than 0.25 in. wide generally do not reflect through the seal for 8 years and, in some cases, for as many as 12 years. For the occasional cases in which reflection cracking occurred, there was no spalling or deterioration into potholes.

Transverse cracking has not been totally stopped by asphalt rubber SAM or SAMI. However, secondary cracking that normally radiates off a primary transverse crack does not normally occur. Secondary cracking usually causes potholes at major cracks.

The greatest advantage in stopping reflective cracking has been in alligator-type cracks and shrinkage cracks. Any crack greater than 0.3 in. should be prepared and filled.

VISCOSITY

Another unique advantage of asphalt rubber is that it does not bleed in hot weather or crack in cold because its viscosity is much less temperature-dependent than that of asphalt cement. Asphalt rubber has a 35° to 50° higher softening point than standard asphalt. When using asphalt rubber, the choice of base asphalt may be reduced by one to two grades to improve the cold properties of the asphalt rubber mix.

Observations of viscosity-time relationships at the Sky Harbor Airport are shown in Figure 2. The asphalt viscosity graph reflects the apparent trends for the two asphalts on the basis of the average of five samples taken between 1972 and 1985. The section with conventional asphalt was rehabilitated with reclamite 3 years after it was placed, which affected the viscosity of the asphalt (see Figure 2). The literature (*5*) indicates that a logarithmic relationship exists between viscosity and time for nonrubberized asphalt. The viscosity should approach an upper level as oxidation progresses and its volatiles are removed. From these observations, viscosity of asphalt cement with an asphalt rubber seal has exhibited no increase. In the same period, the nonrubberized sealed asphalts increased in viscosity more than 20-fold.

Effects of the asphalt rubber seal on the aging phenomenon also become apparent from various observations. The asphalt rubber layer acts as a sealant, preventing the loss and reaction of the asphalt's more volatile components. This sealing action preserves the viscosity of the pavement and maintains much of the flexibility of the treated surface.

An earlier study (*4*) also indicated that sealed concrete retains its original properties for 12 years or more.

Although hardening of regular asphalt with time is well documented, the hardening, or lack of it, for asphalt rubber–sealed asphalt is the important result of this study. The asphalt rubber–sealed AC has exhibited no appreciable increase in viscosity after 13 years. As mentioned, in the same period the nonrubberized asphalt has increased in viscosity over 20-fold. With such well-maintained viscosity, the durability of the surface is greatly increased. The reduction in oxidation an aging has been proven by the longer life of asphalt rubber applications. Hot AC mixtures with crumb rubber placed since 1972 have shown major reductions in aging. The 3,000 lane-mi of SAMs in Phoenix have retarded aging to extend the pavement life by a factor of 2 to 3.

FIGURE 1 Condition of Indian School Road after 19 years.

ECONOMICS OF ASPHALT-RUBBER

Economics must be considered when deciding whether or not to apply asphalt rubber. The cost of asphalt rubber in 1971 was three times the cost of conventional chip seal. Today the actual cost of the asphalt rubber is approximately two times that of conventional chip seal.

Asphalt rubber chip seals have performed well in Phoenix for 20 years over soundly cracked pavements. It was found that 12 to 15 years of maintenance-free life can be expected from asphalt rubber seals. Normal life expectancy using the conventional chip seal over very poor pavement is about 2 years, and more than 6 to 7 years over reasonably sound pavements. Asphalt rubber about doubles the life of the pavement and reduces maintenance. Thus, over a 12-year period, asphalt rubber costs will equal conventional chip costs.

OBSERVATIONS OF ASPHALT-RUBBER PAVEMENTS

Almost 70 percent of the streets studied in the previous report (*4*) were not evaluated this time because these streets have been reconstructed. The remaining 30 percent of the pavements were inspected and their conditions noted. The complete observations of the pavement conditions of these streets

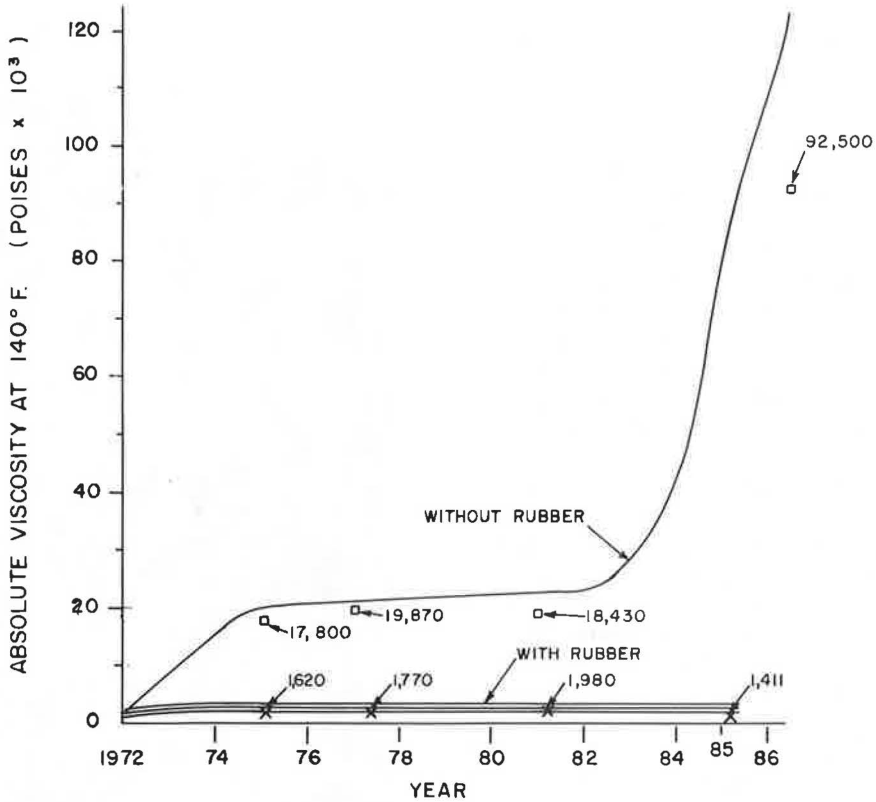

FIGURE 2 Absolute viscosity versus time for Phoenix Sky Harbor Airport asphalts.

are available from the authors, but the highlights are shown here in the appendix. The important findings drawn from these observations are as follows:

- Most of the street pavements inspected showed severe cracking and fatigue failures over the years. The pavements had suffered deterioration due to traffic, weather, and age. In most cases, there were signs of rubber that was still elastic, but at other locations the rubber had become dry.
- Inspections of the subgrade at a number of locations revealed no sign of soil-cement. It appeared that cement was either washed out or in some way chemically altered, because the materials showed no cohesion or strength. Also, shrinkage cracks reflected in all cases after 15 years.
- Chip loss was observed from pavements at various locations, including both low- and heavy-traffic areas. As observed earlier, asphalt rubber loses its flexibility with time and does not retain the chips. Chip loss on a typical street edge is shown in Figure 3.
- Cracking caused by fatigue-type failure, characterized by alligator cracking followed by potholes in the original pavement, was stopped for 15 years due to the use of asphalt-rubber chip seal. Although asphalt rubber cannot bridge wide cracks, it reduces crack width and prevents spalling at the edges for 10 to 12 years. However, recent observations indicate that there is complete deterioration after 20 years. In some cases, wide cracks that were almost 1-in. deep occurred when using the cement-stabilized soil base concept.
- The continuing effect of asphalt rubber on the aging phenomenon could not be evaluated because the pavements placed at Sky Harbor Airport have been reconstructed to meet the FAA geometric design.

FIGURE 3 Chip loss on street edge.

- After 20 years, an estimated 20 percent of the asphalt rubber seal (SAM) still remains and is still functioning.
- Several miles of pavements received a standard seal coat (mini-SAM) between the 12th and 16th years.
- A few miles were overlaid with a standard hot AC on a SAMI after 8 years or more as a SAM.
- Several projects held the existing street in place up to 20 years until reconstruction could be accomplished.

- Samples taken after 17 years indicate a very flexible surface as compared with the standard hard, brittle surfacing after 6 years.
- As indicated in the 15-year study by Schnormeier (*4*), cracking developed about 12 to 15 years after application. At 15 years, little or no secondary cracking had developed. Secondary cracking did develop on most streets after 15 years, causing some potholes. Many of the cracked surfaces were reflected soil-cement base shrinkage cracks.
- The survey indicated that the surface needed a rejuvenation by a fog seal, reclamite, or some rejuvenating sealer. The 52nd Street project is a good example of obtaining three or four times the pavement life with timely treatment.
- The soil-cement base designs have developed large (1½-in.) transverse cracks and some longitudinal cracks that the asphalt rubber has not stopped.
- Many of the original SAM applications are currently being overlaid with 1 in. of asphalt rubber hot mix.
- The design comparison on 13th Street and Camelback illustrates the life expectancy of asphalt rubber. The street was constructed in 1974 and butted against a street constructed in 1972. The 1974 construction was 4½ in. of soil cement, 1½-in. of AC, and SAM. The 1972 section was 6 in. of aggregate base with 2 in. of AC. The 1974 construction was less than half the cost of the 1972 section. The asphalt rubber SAM has not cracked after 17 years, whereas the aggregate asphalt section exhibits 99 percent cracking. The boundary between the two sections is shown in Figure 4.
- Pavements with high traffic volumes performed better than those with low traffic volumes. It appears that traffic helped keep the pavement sealed and slowed the rate of deterioration.

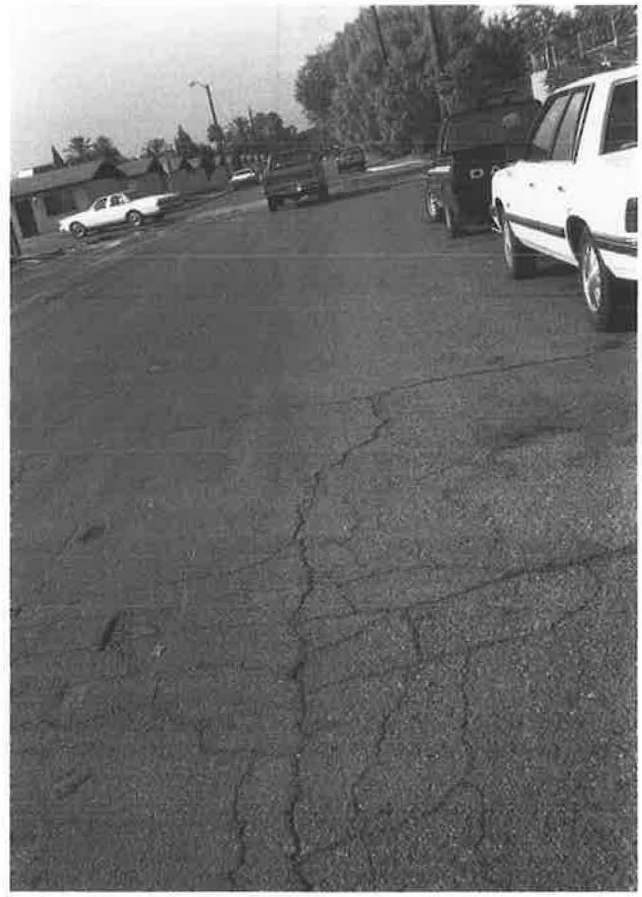

FIGURE 4 Boundary between two sections on 13th Street and Camelback.

CONCLUSIONS ON USE AND ADVANTAGES OF ASPHALT RUBBER

Chip seals have been a dependable maintenance treatment for Phoenix streets. They have added extra life to the pavements and enabled the city to delay reconstruction of streets. Asphalt rubber seal coats—SAMs and SAMIs—have given the pavement management system a number of advantages, as summarized:

- The seals retard reflective cracking in paving materials with less than 0.25-in. cracks for 8 to 12 years.
- They stop secondary cracking up to 15 years.
- They retard spalling of AC around potholes and larger cracks.
- They waterproof the structure to obtain maximum stability.
- They seal and preserve the in-place original quality of asphalt cement and the asphalt concrete.
- They considerably reduce maintenance due to the factors just mentioned.
- They seal the subgrade to minimize volume changes that take place because of moisture changes.
- They serve as a stress-absorbing interlayer to reduce future maintenance.
- They function as an excellent crack-filling material and joint sealer.
- They last 2 to 2½ times longer than most standard seals in Phoenix. If preventive seals were applied at proper times, the seals would last 2 to 5 times longer.
- Rubber particles separate from asphalt cement because the rubber absorbs the light fraction, causing it to lose flexibility and requiring maintenance. If another asphalt rubber seal, fog seal, or rejuvenation seal is applied at the proper time, the pavement life can be extended by the type of reseal selected.

Despite the successful use of asphalt rubber, it must be used with careful consideration of the pavement's structural condition, size of cracks, and intended use, as well as the absorption properties of the asphalt material. Although asphalt rubber does absorb pavement stresses and does seal, it does not stop cracking or failures in the existing pavement or subgrade. The cracks are still present; however, they do not come to the surface to cause problems. When used as a SAMI, the minimum overlay thickness should be 1½ in. to prevent reflection.

PROBLEMS WITH CHIP SEAL

Despite the sound engineering properties, economic advantages, and success of chip seals, the public suffered considerable aggravation by the inconvenience of the chip seal process. In addition, loose chips were often scattered by the leading cars, resulting in a number of shattered windshields and unhappy motorists.

Due to mounting public pressure, the Phoenix City Council directed the Street Transportation Department to discontinue the use of chip seals. Thus, the city was forced to develop an alternative surface treatment that was as economical and reliable as the chip seal.

DESIGN OF MIX

As an alternative to chip seals, the Street Transportation Department developed a special asphalt rubber hot mix (*6*). The mix was designed with a gap gradation to incorporate a large amount of asphalt rubber binder. Gradation limits of the mix are shown in Figure 5, together with the line of maximum density. Details of the rubber in the mix are available from the authors.

The use of asphalt rubber mix with 10 percent asphalt-rubber binder was chosen on the basis of the authors' experience with tests on mixes with as much as 13 percent asphalt rubber binder in 1985. The concept was to design a mix with a high asphalt rubber content and large voids, as much as 24 percent, in the mineral aggregate (VMA). This procedure results in a dense mix that would seal the badly cracked pavements and prevent moisture from getting into the subgrade. The stability of the mix was obtained from the aggregate interlock.

In order to examine the effects of light- and heavy-traffic conditions, both a 100-blow and a 75-blow Marshall were run on mixes with asphalt concrete binder of 8.5 and 9 percent. The results of various parameters are presented in Table 1. The modulus of the mix is a function of stability and flow. The values in Table 1 indicate that the mixes have low stability and high flows, resulting in low values of the modulus. Thus, the mix behaves as elastic material.

During the initial paving, the asphalt mix began to be picked up on tires because of the nature and physical properties of the mix. To keep the temperature of the rubber mix down so that it would start to stabilize, a water truck had been used to spray the pavement. By spraying the pavement, the water actually stripped the tack coat in those areas that were deficient in asphalt thickness (less than ½ in. in some cases). Thus, small sections of asphalt came up. It was proposed that the contractor spread sand on the pavement to stabilize the mix, which worked well. A chip spreader was used to disperse the sand at the rate of 2 to 3 lb/yd^2.

From field and laboratory tests, it was decided that 8 percent asphalt rubber binder was suitable for streets with heavy traffic and 9 percent asphalt rubber binder was appropriate for streets with light traffic. Furthermore, to prevent rubber from sticking to tires, it is necessary to spread sand over the overlay areas when the ambient temperatures exceeded 100°F.

ADVANTAGES OF ASPHALT RUBBER HOT MIX

Approximately 3,000 t of recycled tire rubber was used in the 600 lane-mi of asphalt rubber–concrete overlaid during the past 2 years. This process required grinding of about 600,000 old tires and helped eliminate the waste disposal problems that would have otherwise occurred. The use of old tires in the mix helped in preventing pollution and maintaining a good quality environment. Since 1971, Phoenix has paved almost 3,600 lane-mi using almost 3.6 million scrap tires.

It is anticipated that the new mix overlay will be more durable and will perform better than the chip seal because asphalt rubber retards oxidation and deterioration of the

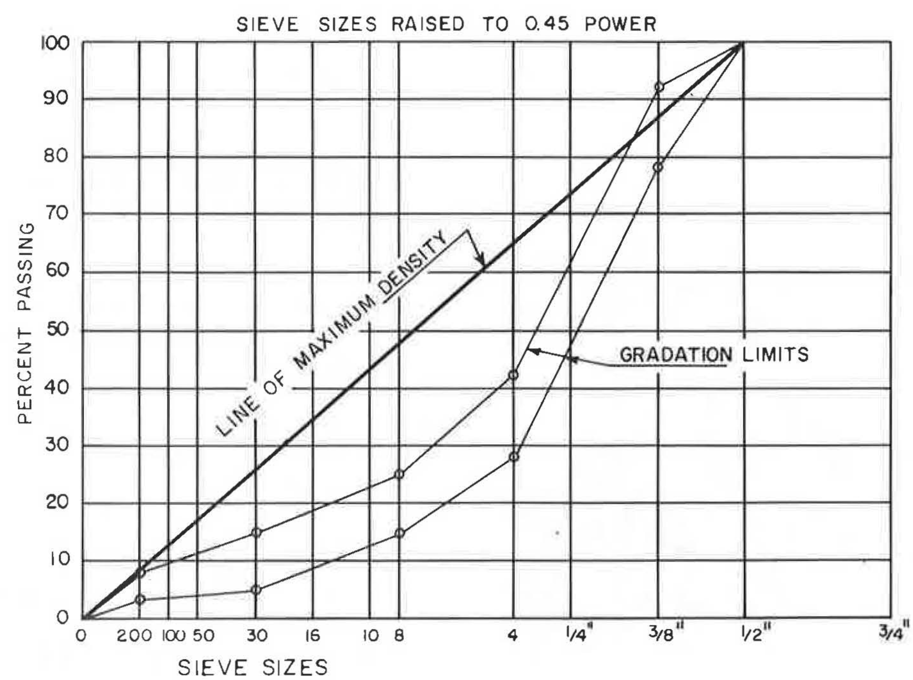

FIGURE 5 Asphalt rubber surface course mix gradation limits.

TABLE 1 DESIGN PARAMETERS FOR ASPHALT RUBBER MIX

	Marshall 75 Blows		Marshall 100 Blows	
% AC	8.5%	9.0%	8.5%	9.0%
% Aggregate Voids	23.3	24.2	22.4	23.6
% Voids in Comp. Mix	5.2	5.1	4.0	4.3
Unit Weight	138.8	137.8	140.3	138.8
Stability	955	1082	998	1176
Flow	19	22	21	22

pavement. On the basis of the performance of the test sections, it can be concluded that a 1-in. asphalt rubber–concrete overlay will resist cracks from reflecting through the existing worn out pavement.

The skid resistance of the surface is not reduced by rubber. There are significant improvements in two other areas. First, the surface provides a much improved riding surface. Second, there is a marked decrease in traffic noise. Reports from residents near a major street overlaid with this mix confirm this observation.

A photograph showing the typical condition of the street being overlaid with asphalt rubber hot mix is shown in Figure 6.

GLOSSARY

Asphalt-rubber: a blend of asphalt cement, reclaimed tire rubber, and certain additives in which the rubber component is at least 15 percent, by weight, of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles.

Asphalt rubber chip seal: application of hot asphalt rubber followed by an application of hot precoated ¼-in. (6.3-mm) nominal, or ⅜-in. (9.5-mm) nominal, aggregate.

FIGURE 6 Overlay with asphalt rubber hot mix: condition before overlay (*left*); completed half (*right*).

Standard or conventional chip seal: application of hot asphalt cement (AC-20 or AC-40) followed by an application of hot precoated ¼- or ⅜-in. nominal aggregated.

Flush seal: application of emulsified asphalt mixed 50–50 with water and applied at 0.1 to 0.2 gal/yd^2 (0.45 to 0.91 L/m^2).

Stress-absorbing membrane (SAM): application of hot asphalt rubber chip seal to a distressed surface.

Stress-absorbing membrane interlayer (SAMI): application of a hot asphalt rubber chip seal to a distressed surface followed by an AC overlay.

Mini-SAMI: application of a hot asphalt rubber chip seal to a surface followed by the application of a conventional chip seal.

Asphalt rubber gap-graded concrete (ARC): gap-graded asphalt rubber hot mix that incorporates a high asphalt rubber content and large voids in the mineral aggregate, placed with standard lay-down equipment and rollers.

Reflective crack: any crack that has developed in the pavement and has passed through the overlay.

APPENDIX

Twenty-Year Historical Survey of Pavement Conditions

WESTWOOD NEIGHBORHOOD IMPROVEMENT DISTRICT, CONTRACTOR—BENTSON (CONSTRUCTED 1972)

West half of 24th Avenue from Thomas Road to alley south of Pinchot Avenue (0.285 mi)

1976: Good surface; good texture; asphalt concrete slippage on soil-cement on south end.
1979: Slippage has healed; some longitudinal cracks at Earll Drive; shrinkage cracks that have developed in untreated area stop at rubber treatment; good surface and texture.
1985: Pavement resealed (mini-SAMI); good condition.
1990: 1986 standard chip; severe cracking; new treatment required.

23rd Avenue from Thomas Road to Catalina Drive and east half of 23rd Avenue to Avalon Drive (0.201 mi)
1976: Good surface texture; some slippage on south end.
1979: Some soil-cement cracks have developed; slippage has healed; good condition.
1985: Resealed (mini-SAMI); soil-cement cracks reflected.
1990: Severe cracking; rubber has lost elasticity; oxidized; needs rehabilitation.

24th Avenue from Indian School Road to Grand Canal (0.268 mi)
1976: Severe chip loss from 23rd Drive to the Grand Canal; slippage of asphalt concrete surface on cement-treated soil at Indianola Avenue and Indian School Road intersection.
1979: Slippage areas have been patched and have stabilized; severe chip loss has stabilized; slight loss continues.
1985: Resealed (mini-SAMI); good condition.
1990: Fair to good condition; some cracking.

Indianola Avenue from Black Canyon Highway to 24th Avenue (0.121 mi)
1976: Good textured seal; asphalt concrete slippage on soil-cement by Mardian Construction Co. parking lot exit.
1979: Slippage has stabilized; good texture and surface.
1985: Soil-cement cracks have reflected through; some shrinkage cracking; texture remains good.
1990: 1986 standard chip seal; good condition.

Fairmont Avenue from 24th Avenue to Grand Canal (0.10 mi)
1976: Good textured seal; asphalt concrete slippage on soil-cement severe at 24th Avenue and 23rd Drive.
1979: Slippage still severe; areas have been patched; beginning to stabilize.
1985: Patched areas have slipped; same condition as 1979.
1990: 1986 standard chip seal; severe cracking; rubber still flexible; needs rehabilitation.

Glenrosa Avenue from Black Canyon Highway to 23rd Avenue (0.23 mi)
1976: Good surface texture; some chip loss from oil drippings on cracks; some slippage of asphalt concrete on soil-cement at 23rd Avenue. Portions of asphalt concrete cracked by reflection from soil-cement base before rubber seal in 1972; these cracks did not come through asphalt-rubber seal.
1979: Good surface texture; slippage has healed; still no cracks through asphalt-rubber seal.
1985: Surface has been resealed (mini-SAMI); major construction on both sides by developers; original pavement good.
1990: Some cracking; newer pavement on north side without rubber is more cracked; scheduled for ARC overlay in late 1990.

Turney Avenue from 23rd Avenue to 22nd Drive (0.067 mi)
1976: Good condition and texture; some chip loss next to curb.
1979: Same condition.
1985: Reconstruction for new development.
1990: Severely cracked; needs reconstruction; scheduled for ARC overlay in late 1990.

22nd Drive from Turney Avenue to Campbell Avenue (0.127 mi)
1976: Good condition and texture.
1979: Some raveling; 10 percent chip loss.
1985: Reconstruction for new development.
1990: New on east side; west side severely cracked; needs reconstruction; scheduled for ARC overlay in late 1990.

South side of Turney Avenue from 21st Avenue west approximately 300 ft (0.057 mi)
1976: Severe chip loss, up to 90 percent in areas; pavement shows reflective cracks from soil-cement.
1979: Street has been resealed with standard chip seal; cracks through the reseal.
1985: Reconstructed for new development.
1990: Scheduled for ARC overlay in late 1990.

South side of Turney Avenue from 20th Drive to 19th Avenue (0.188 mi)
1976: 25 percent chip loss on south side; asphalt concrete slippage on soil-cement at 19th Avenue with some reflective cracks.
1979: Resealed; cracks showing on north side after seal; no cracks showing in rubber treatment; good surface texture; slippage has healed; only a few cracks showing.
1985: Fewer cracks on south side; same condition as 1979.
1990: Scheduled for ARC overlay in late 1990.

20th Avenue from Turney Avenue south to dead end (0.10 mi)
1976: 75 percent chip loss; appears to be insufficient asphalt-rubber; 30 percent chip embedment; some cracks developing.
1979: Same condition with cracking in chip loss areas; needs resealing.
1985: Resealed surface looks very good.
1990: Scheduled for ARC overlay in late 1990.

Highland Avenue from 23rd Avenue to 23rd Drive (0.054 mi)
1976: Okay with good texture.
1979: Loss of chip at dead end area; little or no traffic.
1985: Surface has cracked and has developed potholes; major construction areas for new development.
1990: Severely cracked; needs rehabilitation; scheduled for fabric and 1½-in. overlay in late 1990.

23rd Avenue from Highland Avenue to Pierson Avenue (0.10 mi)
1976: Varied 10 to 20 percent chip loss; fair to good texture surface; not much traffic.
1979: Still raveling; some cracking; needs reseal or flush coat.
1985: Resealed (mini-SAMI); good condition.
1990: Rubber SAM (double) in 1986; good condition; some cracks.

Pierson Avenue from 23rd Drive to 23rd Avenue (0.05 mi)
1976: Raveling at corners and parking areas.
1979: Continues to ravel in same areas.
1985: Trench work has caused need for resealing; very good condition.
1990: Good condition; some cracks; scheduled for fabric and 1¼-in. overlay in late 1990.

Pierson Avenue from 23rd Drive to 22nd Avenue (0.134 mi)
1976: 10 to 20 percent chip loss; fair to good textured surface; severe slippage of asphalt concrete on soil-cement in entire area; some patching in slippage areas.
1979: Chip loss continues; slippage areas have been patched and have stabilized; new slippage developing.
1985: Slippage has stopped; new construction on portions for development; good condition.
1990: Severely cracked; some wide cracks; scheduled for ARC overlay in late 1990.

East half of 26th Avenue from Pierson Avenue to Highland Avenue (0.121 mi)
1976: Chip loss in parking lane; fair to good textured surface.
1979: Same condition with a few cracks.
1985: Same condition.
1990: Scheduled for ARC overlay in late 1990.

Coolidge Street from Black Canyon Highway west to dead end (0.20 mi)
1976: 40 percent chip; not much traffic.
1979: Same condition; needs to be resealed.
1985: Surface resealed (mini-SAMI); good condition.
1990: Very low or no traffic; severely cracked; loss of chips; alligator cracks; completely stripped; scheduled for ARC overlay in late 1990.

North half of Hazelwood Avenue from Black Canyon Highway west to dead end (0.008 mi)
1976: Okay; good surface; has a shallow chip embedment; 10 to 15 percent chip loss; needed to be flushed after construction.
1979: Same condition; needs reseal because of new construction in area; essentially no crack reflection in asphalt-rubber originating from underlaying soil-cement base wherever chips remained in place.
1985: Surface resealed because of construction; cement-treated soil shrinkage cracks have reflected through almost all rubber applications except in highly traveled areas.
1990: Scheduled for ARC overlay in late 1990.

ST. FRANCIS NEIGHBORHOOD IMPROVEMENT DISTRICT, BOUNDED BY 7TH TO 16TH STREET, INDIAN SCHOOL TO CAMELBACK ROAD, CONTRACTOR—TANNER (CONSTRUCTED 1974)

11th Street from Meadowbrook Avenue to Campbell Avenue (0.12 mi)
1979: Good condition.
1985: Good condition; new construction on west side.
1990: Standard chip seal in late 1985.

Minnezona Avenue from 9th Street to 7th Street (0.18 mi)
1976: 20 percent chip loss; severe loss near 7th Street.
1979: Same condition.
1985: Over 50 percent chip loss; needs resealing.
1990: Standard chip seal in 1988.

8th Place from Grand Canal to Highland Avenue (0.22 mi)
1976: Some chip loss with cracking near post office.
1979: Same condition.
1985: Severe chip loss south of Minnezona; large soil-cement shrinkage cracks; no secondary cracking.
1990: Standard chip seal in 1985.

8th Street from Grand Canal to Meadowbrook Avenue (0.07 mi)
1979: Same condition.
1985: 30 percent chip loss to Minnezona; 80 percent loss to Canal; no traffic for kneading surface.
1990: Standard chip seal in 1985.

8th Place from Camelback Road to Pierson Street (0.12 mi)
1979: New construction on east side; rubber seal okay.
1985: New construction due to development.
1990: Standard chip seal in 1985.

Pierson Street from 8th Place to 10th Street (0.05 mi)
1976: Roped surface.
1979: Surface has smoothed out; condition has stabilized.
1985: Good condition.
1990: Standard chip seal in 1985.

10th Street from Pierson Street to Highland Avenue (0.12 mi)
1976: 40 to 50 percent chip loss early; roped surface that has been resealed.
1979: Same condition.
1985: Fair condition; severe cracking needs reseal with rubber.
1990: Poor condition; severe cracking; chip lost; standard chip in 1985.

Highland Avenue from 7th Street to 15th Street (0.87 mi)
1976: 10 to 40 percent chip loss early; some areas have been resealed; chip loss problem in shaded areas.
1979: Same condition; no cracks.
1985: Same condition from 10th to 15th; poor condition 7th to 10th; several cracks; severe raveling at intersection.
1990: Resurfaced; standard chip seal in 1985.

15th Street from Meadowbrook Avenue to Highland Avenue (0.13 mi)
1976: Small early chip loss; good surface remaining.
1979: Very good condition.
1985: Same condition; some raveling at driveways; no cracks.
1990: No seal coat; same condition; some cracks and raveling at driveway.

14th Place from Meadowbrook Avenue to Highland Avenue (0.12 mi)
1979: Good condition.
1985: Small reflective cracking; good condition.
1990: Original rubber surface; some cracking and chip loss.

Pierson Street from 14th to 12th Street (0.25 mi)
1976: Okay except for embedded chips causing a black surface; some slippage of asphalt concrete on soil-cement at 12th Street.
1979: Fair condition with about 40 percent chip loss in parking area.

1985: Fair condition; little or no cracks.
1990: Original asphalt-rubber surface; some cracking and chip loss; considerable chip loss in parking lane.

13th Street from Pierson Street to Highland Avenue (0.12 mi)
1976: Roping has worked out in center area; roping severe and remains the same as placed in 1974 in parking areas; looks like a bleeding pavement.
1979: Pavement has stabilized; no cracks; roping is smoothing out; bleeding not a problem.
1985: Very good condition on north end with very heavy traffic; overall good surface with little cracking.
1990: Original asphalt-rubber surface in fair condition; some cracking and roping.

14th Street from Campbell Avenue to Glenrosa Avenue (0.24 mi)
1976: Chip loss at construction joint; good surface.
1979: Very good condition.
1985: Same condition.
1990: No seal coat; surface in fair to poor condition.

Deveonshire Avenue from 12th Street to Longview Avenue (0.12 mi)
1976: 20 to 30 percent chip loss.
1979: Same condition.
1985: Pavement resealed; very good condition.
1990: Nothing done; no seal coat; no maintenance for past 16 years; fair surface.

Minnezona Avenue from 12th to 13th Street (0.13 mi)
1976: Considerable chip loss in shaded areas.
1979: Very good condition.
1985: Good condition; some soil-cement crack reflection.
1990: Nothing done; no seal coat; fair surface.

Elm Street from 13th to 12th Street (0.012 mi)
1976: 20 percent chip loss.
1979: Same condition; no cracks.
1985: More chip loss on outside edges; no cracks.
1990: Nothing done; no seal coat; good to fair surface.

STREET MAINTENANCE, CONTRACTOR—BENTSON (CONSTRUCTED 1971)

52nd Street from Van Buren to Roosevelt Street (0.5 mi)
1976: Alligator cracking in center portion with some chip loss; texture good; area has little or no subgrade support with high water table; very high pavement deflections under traffic.
1979: Severe alligator cracking over entire project; very weak subgrade with very high deflection.
1985: 1983 rubber chipped again; no cracks; very good surface.
1990: Rubber chip seal in 1983; very good condition after 19 years.

STREET MAINTENANCE, CONTRACTOR—TANNER (CONSTRUCTED 1973)

Buckeye Road from Central Avenue to 3rd Street (0.2 mi)
1976: Some cracking; overall condition good.
1979: Some large shrinkage cracking; some alligator cracking at Central Avenue; good condition.
1985: 1982 asphalt rubber reseal; good surface; poor ride.
1990: Severe cracking; needs rehabilitation.

Thomas Road from 19th Avenue to 12th Street, 10-ft strip, both sides (2.5 mi)
1976: Some chip loss on inside edge; good texture; comparing existing pavement in center portions, asphalt rubber has stopped cracking.
1979: Asphalt rubber portion in very good condition considering preexisting conditions; standard area in center severely cracked and needs maintenance.
1985: Fair condition with nothing being done since 1973 from 19th Avenue to 7th Avenue; 7th Avenue to 17th Street overlaid in 1983.
1990: Severely cracked in non-asphalt-rubber area; reconstruction summer of 1990.

52nd Street from Thomas Road to McDowell Road (1.0 mi)
1976: Some chip loss in southbound lane with alligator cracking on north end.
1979: Same condition.
1985: Rubber sealed again in 1983; very good condition.
1990: Fair to good condition.

52nd Street from Roosevelt Street to entrance of Motorola (0.30 mi)
1976: Alligator cracking in center portion with chip loss; traffic indicates very large deflection on soft subgrade.
1979: Entire area has alligator cracks with very high deflections; pavement has not developed potholes due to rubber particle properties.
1985: Rubber sealed again in 1983; excellent condition.
1990: Fair to good condition.

SPECIAL PROJECTS FOR STREET MAINTENANCE, ASPHALT-RUBBER ON PRIMED SUBGRADE OF NATURAL SOIL, CONTRACTOR—CITY OF PHOENIX (CONSTRUCTED 1970)

55th Avenue from Claredon Avenue to 600 ft north on east half only (0.1 mi)
1976: Very good condition except for two potholes on east side of street (*1*).
1979: Total street resealed in 1976 with standard chip seal, making the surface a mini-SAMI. West half cracked; east half not cracked. East half in good condition with some depressions from subgrade conditions. Rubber molded to depressions. The 1-ft overlap on the conventional pavement has stopped cracks. Treated berm has deteriorated, causing potholes on east edge.

1985: After 15 years of use and some additions by new development, pavement is failing because of lack of subgrade support; pavement should be reconstructed or overlaid with another asphalt rubber chip seal.
1986: Nominal chip seal.

It is of interest that the potholes mentioned stood unrepaired for several years and showed little tendency to expand into the roadway, which they would most certainly have done in a conventional light surface treatment over a clay loam soil (plasticity index 18, passing #200 sieve, 80 percent). Procedure definitely has promise for low-traffic-volume roads. Traffic count on street is 4,500 average daily traffic (ADT).
1990: Alligator-cracked surface; little or no surface movement; good surface after 21 years.

SPECIAL PROJECT, CONTRACTOR—TANNER (CONSTRUCTED 1971)

Indian School Road from Central Avenue to 7th Street (0.75 mi)
1973: Very good condition; excellent surface; 25,000 veh/day.
1976: Good condition; some chip loss at intersections; 30,000 veh/day.
1979: Fair condition with cracks; very good texture; Central Avenue intersection 75 percent raveled away; 37,000 veh/day.
1985: 1981 resealed (mini-SAMI); very good condition with 48,000 ADT; unable to find manholes; rubber sealed system.
1990: No reseals; pavement has cracked but doing well; 1991 planned reconstruction.

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