Cost Considerations of Asphalt-Rubber Hot Mix

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MATERIAL DESCRIPTION AND PROPERTIES

Asphalt-rubber (A-R) is produced by reacting ground reclaimed tire rubber with asphalt cement to produce a binder with improved temperature susceptibility and flexibility. The antioxidants and carbon black in the tire rubber also reduce ageing of the binder.

Hot mixes using A-R binder will generally be more flexible at low temperatures and stiffer at high temperatures than conventional asphalt concrete (AC). This results in a mix that is less susceptible to thermal cracking and rutting. The increased film thickness and reduced ageing of the A-R binder will normally result in a more durable mix.

HISTORY

Initial Development: Asphalt-rubber was developed by Charles H. McDonald in the early 1960s. The first applications, called "band aid" treatments, were hand placed for patching asphalt concrete pavements.

SAMI: The use of A-R for stress absorbing membrane interlayers (SAMIs) began in the early 1970s. The ADOT placed its first SAMI as part of a two layer system in 1972 and subsequently placed an A-R SAMI as part of a three layer system in 1975. These SAMI’s are used to retard reflective cracking for overlays of AC and portland cement concrete (PCC) pavements.

Dense-Graded Hot Mix: The use of dense-graded asphalt-rubber concrete (ARC) began in the late 1970s. CalTrans has been using dense-graded ARCs since 1978. Because the ARC sections were out performing equal thicknesses of standard asphalt concrete (AC), CalTrans, in 1983, constructed test sections to investigate using thinner ARC overlays. Based on the success of these tests, CalTrans continues to construct test sections to evaluate the thinner ARC layers. Dense-graded ARC is currently being used to increase ride quality, structural support and skid resistance on pavements where a thick overlay or reconstruction would be the standard solution.

Open-Graded Hot Mix: Asphalt-rubber has been used as a binder in open-graded hot mixes since the mid 1970s. The ADOT placed its first A-R open-graded hot mix in 1975. Since this time the open graded hot mix has been used as surface course or overlay on AC and PCC pavements to improve ride quality and skid resistance. Open-graded mixes using A-R are normally produced at binder contents of 8 to 10 percent, which result in a more durable and
flexible mix.

**Gap-Graded Hot Mix:** The use of gap-graded ARCs began in the City of Phoenix in 1988. This mix is placed one inch thick at binder contents of eight percent for arterial/collector streets and nine percent on residential streets. This type of mix has proven to be highly resistant to reflective cracking on badly cracked streets in Phoenix and other areas where it has been used.

**COST FACTORS**

Asphalt-rubber concrete is produced, transported and compacted in the same manner as standard AC mixes, with very little variation. In order to understand the similarities and variations between ARC and AC the following presents a summary of how ARC is produced:

**Blending:** The asphalt used in the blend is brought to a temperature of about 400°F in a portable heated storage tank or in a heater/blender unit. The asphalt is blended with the rubber and transferred to a nurse truck where it is kept heated and agitated for a specified reaction period (usually 45 to 60 minutes). The addition of the rubber will typically drop the temperature of the blend to a standard reaction of 350°F.

**Mixing:** The A-R binder is transferred to the plant using one of the following connections:

**Batch Plants:** A separate connection from the plant’s standard asphalt feed is made to the pug mill mixer. This allows the plant to produce other mixes without unnecessary delays.

**Drier-Drum Mixers:** Standard connections are as follows:

1. For plants fitted with separate cement and asphalt feeds the connection is made to the cement feed. This allows the plant to switch between standard AC and ARC.

2. For plants with a single feed the connection can be made to the asphalt feed line near the drum by either: (1) a direct connection where only ARC mixes can be produced; (2) a three-way valve that allows the plant to manually switch between ARC and AC.

The actual mixing of the ARC is the same as for AC. Plant emissions, where tested; have been comparable to those for standard mixes, in spite of higher mixing temperatures.

The costs for the asphalt cement, rubber, blending, and plant connections are included in the price for asphalt-rubber binder. The only costs, other than the A-R binder, are the aggregate and mixing which should be the same as for an AC mix. Therefore, the difference in cost between AC and ARC, at this point, should be equal to the cost difference between the A-R binder and asphalt cement.

**Hauling:** Hauling of the ARC is the same as for AC except that soapy water or a silicone emulsion should be used for a releasing agent. Diesel or solvents should not be used. This difference should result in no cost differential between AC and ARC.

**Placement and Compaction:** As with the hauling, the placement and compaction of ARC is generally the same as for AC. The placement temperature for ARC should be between 275 and 325°F which is somewhat higher than for AC. Pneumatic rollers cannot be used for compacting ARC. Instead, vibratory (for breakdown rolling) and static steel wheel rollers should be used.

When given a choice the use of vibratory and static steel wheel rollers seems to be the preference of contractors. Therefore, the compaction of A-R should be no different for equal thicknesses of ARC and AC. The elevated pavement placement temperature should normally result from the addition
of the A-R binder at the normal reaction temperature of 350°F.

The purpose of this discussion to this point as been has been to show that the only cost difference between ARC and AC should result from the difference in costs between A-R binder and asphalt cement.

**MATERIAL COST DETERMINATION:**

The following presents a method that can be used to determine the cost per ton of an ARC based on local AC, asphalt cement and A-R binder costs. Values need to be assumed or estimated for:

- AC cost/ton (in-place)
- AC binder content (by wt. of total mix)
- Asphalt cement cost/ton
- A-R binder content
- A-R binder cost/ton

The costs for the first three items can be acquired from local bid results and contractors. Asphalt-rubber binder contents and costs can be acquired from an asphalt-rubber supplier. A simple and conservative formula to determine this cost is:

\[ \text{Cost}_{ARC} = \text{Cost}_{AC} - (\text{Cost}_R \times P_R) + (\text{Cost}_{A-R} \times P_{A-R}) \]

**Example:** At the time this paper is being prepared the cost of asphalt cement is about $165/ton. Asphalt-rubber binder costs will vary from a low of about $350/ton for a local project to more than $500/ton for a small job due to increased mobilization costs.

The following costs were developed assuming: $35/ton for AC; 5 percent binder content for AC; $165/ton for asphalt cement binder; and $400/ton for A-R binder.

- ARC Dense-Graded: + 0.5% of dense graded AC binder content
- ARC Gap-Graded: 8% by weight of total mix. (range 7% to 9%)
- ARC Open-Graded: 9% by weight of total mix. (range 8% to 10%)

Asphalt-rubber mixes will generally have higher binder contents than conventional AC mixes. A good estimate of the binder contents for ARC mixes is as follows:

**MATERIAL QUANTITY:**

One mistake that is commonly made in determining quantities of ARC mixes, partic-
ularly gap-graded mixes, is that the unit weight of the material is often assumed to be equal to that of AC. However, because of the higher binder contents of gap-graded ARC mixes the unit weight of the mix is typically 5 to 7 pounds per cubic foot (pcf) less than dense graded mixes.

The unit weight of ARC mixes can be estimated based on average values for the compacted unit weight, binder content and percent air voids \( P_a \) of local AC mixes. The first step is to calculate the maximum specific gravity \( G_{mm} \) of the mixture and then determine the effective specific gravity \( G_{se} \) of the local aggregate using average binder contents, compacted unit weights and assumed in-place air voids. The equations for determining these values can be found in the Asphalt Institute’s MS-2 and due to limited space will not be presented in this paper. After the \( G_{se} \) of the aggregate is determined the unit weight can be determined for any A-R binder content and assumed in-place air voids using the following equation:

\[
\text{Density}_{ARC} = 62.4 \times G_{mm} \times \left(1 - \frac{P_a}{100}\right)
\]

Assuming an AC with a unit weight of 145 pcf at 6 percent voids and 5 percent asphalt cement by weight of total mix the following values for ARC mixes are computed:

\[
\begin{align*}
\text{ARC Dense-Graded} & \quad 145 \text{ pcf} \\
(5.5\% \text{ A-R, 6}\% \text{ P}_a) \\
\text{ARC Gap-Graded} & \quad 140 \text{ pcf} \\
(8.0\% \text{ A-R, 6}\% \text{ P}_a) \\
\text{ARC Open-Graded} & \quad 117 \text{ pcf} \\
(9.0\% \text{ A-R, 20}\% \text{ P}_a)
\end{align*}
\]

The specific gravity of the asphalt cement and A-R binder are assumed to be 1.01 and 1.05, respectively.

The following presents a cost comparison of AC and ARC mixes on a $/sq.yd.-inch basis using the costs and unit weights previously developed:

\[
\begin{align*}
\text{AC Dense-Graded} & \quad $1.90/sq.yd.-in. \\
\text{ARC Dense-Graded} & \quad $2.65/sq.yd.-in. \\
\text{ARC Gap-Graded} & \quad $3.08/sq.yd.-in. \\
\text{ARC Open-Graded} & \quad $2.75/sq.yd.-in.
\end{align*}
\]

REHABILITATION STRATEGIES

The major use of ARC mixes at this time is in the rehabilitation and maintenance of existing road surfaces. The flexibility and improved temperature susceptibility of the mixes result in improved fatigue, rut and reflective crack resistance.

The following discussion presents possible rehabilitation alternatives using asphalt-rubber materials. These alternatives will vary considerably from the standard rehabilitation practices and therefore are a significant cost consideration.

PCC Rehabilitation: The purpose for rehabilitation of PCC pavements is generally to improve ride quality and/or skid resistance. Standard solutions will vary according the pavement condition and may include: (1) grinding and grooving; (2) thick overlay; (3) three-layer system using fabric; (4) un­bonded or bonded concrete overlay. Asphalt-rubber alternatives would vary from a 1-inch open or gap-graded ARC overlay to improve skid and ride quality to a three-layer system for more distressed pavements. A-R may be used in the interlayer only or for all three layers. The thickness of the layers may often be decreased if A-R is used for all of the layers.

The rehabilitation alternative being evaluated can often have other costs which are sometimes ignored in a cost evaluation. Examples of this include: thicker overlays may require raising guardrails and/or grinding under bridges; grinding and grooving of pavements may require resealing of joints;
alternatives which require longer construction times will result in increased traffic control costs and inconvenience to the public.

**Asphalt-Concrete Rehabilitation:** Standard rehabilitation practices for AC pavements which have reached a state of distress such that conventional surface treatments are not viable may include: (1) thick AC overlays; (2) AC overlays with fabric; (3) recycling; (4) surface reconstruction; (5) complete reconstruction. Asphalt-rubber solutions will vary. For pavements with significant thermal and alligator cracks and little or no evidence of subgrade failure an A-R SAM or 1-inch gap-graded ARC overlay are considered appropriate. For severely distressed pavements which may require structural improvements a 2 or 3-layer A-R system may be required.

Other costs that are associated with the various overlay alternatives may include: edge grinding at curbs and gutters; manhole and utility vault adjusting; raising guardrails; Traffic control should be a cost consideration for all alternatives. These other costs can have a significant impact on the analysis when an A-R SAM is being considered as an alternative since the primary other cost is traffic control. Traffic control is probably less for the A-R SAMs than the other alternatives since traffic can normally be let on the street within one hour of placement.

**DISPOSAL COST SAVINGS**

A cost savings may be considered when using A-R materials. This cost savings is equal to the amount that would normally be paid for the disposal of the tires that will be recycled into the pavement in an A-R mix. This cost savings can be determined based on: (1) the normal disposal cost for tires; (2) rubber content of the A-R binder (16% to 25%); (3) an average weight of rubber per tire of 10 pounds.

**SUMMARY**

The concepts presented in this report can be summarized as follows:

1. The difference in cost between a standard asphalt concrete (AC) and asphalt-rubber concrete (ARC) should result from the difference between the costs and percent binder of the asphalt cement and asphalt rubber (A-R) binder.

2. Based on the above concept the costs for ARC mixes can be estimated based on the costs for AC, asphalt cement and A-R binder.

3. When evaluating alternative rehabilitation strategies other costs such as manhole adjusting, raising guardrails, traffic control and life cycle costs should be considered.

4. A cost savings may be considered for A-R mixes since scrap tires are recycled in the ARC mixes.

Using the concepts presented in this paper, the agency/engineer will find that A-R systems are often less in initial costs when compared to conventional mixes. The cost effectiveness of A-R systems will be even greater using life cycle costs.

**REFERENCES**