Specification Requirements for Asphalt-Rubber

SCOTT SHULER

Asphalt-rubber has been used in the United States to fabricate seal coats and interlayers since 1967. Current estimates put the amount of asphalt-rubber in service at approximately 10 000 lane miles of both highway and aircraft pavements. Specifications used since 1967 are a result of experience gained with materials applied. Empirical results from paving projects traditionally have provided the engineer with information necessary to devise a descriptive account of proper construction procedures. Information is provided regarding knowledge gained since 1967 on proper practices in asphalt-rubber construction. Some of the tempting variances to recommended procedures are cited as well as predictable results if specified descriptions are not adhered to.

Current specifications for asphalt-rubber mixtures are derived from descriptions of materials produced by companies involved in asphalt-rubber construction. Through many years of empirical development, asphalt-rubber membranes have evolved from the combination of a limited source of ground scrap tires and asphalt cement to a sophisticated art and science that uses many sources of raw materials. This empirical development led to increased understanding regarding potentially beneficial asphalt and rubber combinations, effective concentrations, and methods of fabrication that include enumerable preparation techniques. This technology allows the leaders in asphalt-rubber production to gain expertise in order to improve their products and consequently enhance pavement quality. However, current specifications remain a description of the products from a few suppliers of asphalt-rubber.

Research activities have been under way in asphalt-rubber development since its inception in 1964. Experimentation has been helpful in determining physical and chemical characteristics that might be used to describe the differences in mixtures, beneficial attributes, and properties desirable for field use. Developing specifications has been the goal of many researchers, but difficulties encountered with a new hybrid engineering material such as asphalt-rubber provided much challenge in their development. Initially, laboratory tests had to be developed for a material that behaves neither like asphalt cement nor like tire rubber. Research and development activities aimed at identifying adequate laboratory and field tests continue. Later, after a few promising laboratory procedures were discovered that could differentiate between rubber mixes, interpretation of results was necessary to provide meaning to these new tests.

The mechanism that allows asphalt-rubber or any other low-modulus interlayer to provide for crack attenuation is understood in principle; however, the solution to the problem that describes how the mechanism operates is extremely complex. An understanding of this mechanism is required before any phenomenological or mechanistic specification can be prepared. This specification would not be a description of an empirical product but a rational procedure for the preparation and construction of a new engineering material.

SUMMARY OF ASPHALT-RUBBER SPECIFICATIONS

Asphalt-rubber as defined in this paper is the combination of hot asphalt cement and recycled passenger-car or truck tires. It is understood that uses for this product are numerous and include applications other than pavement interlayers and surface treatments. However, this paper is concerned with the latter applications only, and references to specifications included here deal specifically with membrane construction. Asphalt-rubber as defined includes between 18 and 24 percent by total weight of dry rubber in an asphalt cement matrix. The methods of combining these two principal ingredients vary, and distillate additives are allowed in current specifications, but the component composition of the various types of mixtures is essentially equivalent. The product obtained after the two principal components have been combined, however, varies so dramatically between various mixtures that methods for controlling fabrication are essential.

The first mixtures of asphalt and rubber as defined here included only the two principal ingredients. Rubber was added to hot asphalt cement and mixed for various time periods at temperatures considerably higher than those customarily used on paving projects. Results of these early projects varied, but the concept was sound and from these early experiments came the first specifications for a new paving material.

The proceedings of the 45th Annual Meeting of the Highway Research Board document a specification by C.H. McDonald (1) that called for use of 33 percent by weight of rubber and the remaining proportion occupied by 85-100 penetration-grade asphalt cement. The asphalt was heated to 420°F and the rubber added and mixed until a jell consistency was acquired. Ths composition was applied to the pavement in amounts of 1 gal/yd^2 by using squeegees. Then approximately 45 lb/yd^2 of aggregate chips were applied to complete the membrane. Some experimentation was done with varying proportions of rubber to asphalt by using mixes with 25 percent rubber by total weight.

Later, slurry seal equipment was used to apply the mixtures. Asphalt temperatures were raised to 445°F prior to mixing with rubber, but proportions remained at two parts 85-100 asphalt to one part rubber. Difficulties getting uniform application of the final asphalt-rubber mixture led investigators away from this form of construction.

After early work that used slurry seal equipment to construct membranes, use of conventional seal-coat distributor equipment began. The success of this process was mixed, since the conventional equipment had application difficulties with the very high viscosity material (2). These difficulties led to the addition of kerosenes to the hot asphalt-rubber during the mixing process. This process aided uniformity during distribution, and experimentation began by using various types of diluents. One major difference between modern specifications and previous ones is the provision for diluents.

As the technology of asphalt-rubber applications progressed, so did the descriptions of the materials, fabrication techniques, and application processes. The most recent specification (3) to date provides a description of major differences among the various types of asphalt-rubber membranes. The differences among these specifications are due to several types of rubber currently available for use in membrane production. These types include possible combinations of vulcanized and devulcanized rubber materials. Included in these specifications in addition to rubber differences are details that surround the use of various principal ingredients. As field experience indicates, use of one of the rubber types means using a specific method for fabrication and application of the membrane. Current

specifications are considerably more complex than previous ones and allow more flexibility and consequently more margin for error in inexperienced hands. Several rubber gradations, types of rubber, rubber manufacturing differences, asphalt sources, diluent types, and fabrication processes make the construction of asphalt-rubber membranes a highly refined technique that requires considerable experience by the applicator. Clearly, the need for comprehensive specifications is implicit in successful production by contractors who have had little or no previous experience with asphalt-rubber.

REQUIREMENTS OF SPECIFICATIONS

Specifications for asphalt-rubber have through necessity been designed as specific component and method outlines aimed at describing in detail every aspect of fabrication. Performance specifications to date do not exist, due to an insufficient knowledge that relates field performance with laboratory test results. The aim of many researchers in asphalt-rubber technology is to develop such specifications. This type of specification appears worthy of development for a material as complex as asphalt-rubber. It seems unlikely that the relatively few asphalt-rubber formulations in use are the only potentially successful combinations available. Indeed, performance attributes that the successful mixtures have in common should also be available in some yet-undiscovered method of combining raw materials.

These ideal performance attributes that combinations of asphalt and rubber should display will in the future be the basis for specifications. Research in progress is dedicated to determining what engineering properties these mixtures should display and what techniques may be used to measure them. Only by developing this type of construction specification will the seemingly insurmountable task of combining the myriad of asphalts and rubber be simplified. However, the knowledge necessary to establish such a specification remains in the future, and until adequate information becomes available regarding materials properties, the recipe specification is essential to competent construction.

The most concise specification to date has been fabricated based on proven materials, manufacturers, and construction methods. It seems of interest to note some of the more important aspects of this specification. It is understood that as soon as a performance-oriented specification becomes available, many items necessary in the asphalt-rubber recipe specification may not be required. However, until more-mechanistic methods are discovered, the current technology will dictate the procedures and components for use.

Generally, a specification, for whatever use, is designed to guide an agency through the construction process by indicating the types of materials and methods of fabrication required to produce the desired result. Asphalt-rubber specifications are no different in this respect and consequently begin with definitions essential to understanding the specialized terminology of asphalt-rubber technology. Examples of terms that may be included in this type of glossary are listed below:

1. Ambient ground rubber: Tire rubber ground or processed at ordinary room temperatures.
2. Asphalt-rubber: A mixture of paving-grade asphalt and recycled vehicular tire rubber and certain additives. The rubber component is at least 15 percent by weight of the total mixture and is reacted in the hot asphalt sufficiently to cause swelling of the rubber particles.
3. Automobile tires: Tires that have an outside diameter less than 26 in and are used by automobiles or light trucks.
4. Cryogenically ground rubber: Tire rubber that has been subjected to temperatures below the embrittlement temperature of the rubber during the grinding process.
5. Devulcanized rubber: Tire rubber that has been subjected to treatment by heat, pressure, or the addition of softening agents to alter properties of the recycled material.
6. Reclaimed tire rubber: Rubber obtained by processing and recycling used automobile, truck, and bus tires. Solid tires, fork-lift, aircraft, earth-moving equipment, and other nonautomobile (truck) tires and non-tire-rubber sources are excluded.
7. Tread rubber: Tire rubber that consists primarily of tread rubber or peel with less than 5 percent sidewall rubber.

Descriptions of the materials to be used are an essential part of the job specification. Asphalts available around the country vary considerably, and experience with different asphalts, although considerable, pales in comparison with the number available. Therefore, the type of bitumen to be used should be described in some detail to avoid confusion. Rubber types and manufacturing methods differ much less abundantly than do asphalts. However, several choices of rubber types are available. Depending on which rubber is used, the method of combining rubber with asphalt will vary. For example, the rubber types available from the recycling industry are numerous. Even after all sources other than tires have been discounted, choices remain. Finally, after the choice has been limited to pneumatic tires from passenger cars and heavy trucks and earth-mover tires, aircraft tires, or pneumatic industrial-machinery applications have been eliminated can the final selection be made.

The difference between mixes made from automobile versus truck tires is due in part to the chemical balance in the rubber. One constituent of tire rubber known to affect asphalt-rubber behavior is the natural rubber component. Whole truck tires contain approximately 18 percent natural rubber compared with 9 percent for whole automobile tires and 2 percent for automobile tire tread (4).

Rubber-recycling methods are different. Some processes produce a totally vulcanized product, whereas others produce a chemically treated rubber tire product known as devulcanized or depolymerized rubber. Combinations of the two products are also readily available. Some recyclers grind up tires in shredders and put the whole tire through the mill in successive passes until the desired gradation of ground rubber is produced. Some recyclers put only the tread rubber through the grinder; the resultant rubber product has virtually no sidewall material and consequently different properties than the particulate whole tire. Some producers use cryogenic methods to fabricate the particulate tires, whereas others grind at relatively ambient conditions. All these processes result in different particulate rubber materials.

Sizes of rubber particles may differ in asphalt-rubber mixtures. The most recent specification includes four gradations. The type of rubber to be used in the asphalt-rubber mix dictates which gradation or gradations to choose. The four gradations currently in use appear in Table 1. Types I, II, and III are used with vulcanized rubber products. Type IV is used when devulcanized materials are present in the mixture.

The third constituent used in asphalt-rubber production is a viscosity-reducing agent. This mater-

Table 1. Gradations of particulate tire rubber for use in asphalt-rubber.

	Percent Passing			
Sieve No.	Type I	Type II	Type III	Type IV
8	100	100		100
10	95-100	95-100		
16		70-80	100	
20			95-100	
30	0-10	5-15	60-80	60-80
40	0-5	0-5		
50			0-10	15-40
100				0-15

ial can be either a kerosene-type diluent or a high-molecular-weight aromatic asphalt extender oil. These materials are used with vulcanized and devulcanized products, respectively.

Although constituent analysis of rubber products is routine and the separation of various components includes identification of natural and synthetic rubber, ash content, carbon black, etc., only a requirement for the natural rubber content has been cited to date in specifications. This value has been set at 30 percent of total rubber weight.

Combining asphalt and rubber is the next step in the specification process after the materials description. This segment of the specification describes the method of bringing the three raw materials together. Two procedures are possible depending on whether vulcanized or devulcanized rubbers are used. The major differences between the two procedures include the proportions of asphalt and rubber, the introduction of viscosity-reducing agents, and the time and temperature of mixing. In general, however, the two procedures are alike regarding the product desired. This product is described as a homogeneous mixture, uniform throughout, that will not separate into constituent components when mixed or applied.

Much of the difficulty in producing any satisfactory paving product appears during construction. This is not necessarily the fault of the contractor. It is this stage of a project in which the greatest number of variables are introduced that can thwart success. In most paving construction, weather is generally the single variable that can make or break a given project. In asphalt-rubber construction, this is also true. Unlike conventional seal coats, asphalt-rubber membranes provide no room for obvious errors made during construction. Where moist or wet aggregate would be marginally acceptable in a conventional seal coat, this condition will lead to debonding with an asphalt-rubber membrane almost without exception. This may not be a problem if the membrane is to be used as an interlayer, but as a surface course, it should be avoided. The distance between the aggregate chip spreader and asphalt distributor truck is critical in asphalt-rubber construction. It has been suggested that the chip spreader be physically attached to the asphalt-rubber distributor. This may not be practical, but the implication is clear. The chips should be embedded in the hot binder before too much cooling occurs in the asphalt-rubber binder. The closer the chip spreader is to the asphalt-rubber distributor, the better the aggregate retention will be. Application rates for asphalt-rubber mixtures are approximately twice those of conventional seal coats. At 0.55-0.60 gal/yd^2 of hot asphalt-rubber, the quantity of aggregate chips required to cover this membrane is proportionately higher than conventional amounts. This increase in quantities of materials sometimes leads conscientious or well-meaning employees to reduce specified application rates on site. Obviously, this situation should be guarded against, since reduction in asphalt-rubber application rates will jeopardize the effectiveness of the membrane.

The roller train used in membrane construction usually numbers three pneumatic types. Tire pressures are required to be 100 lbf/in^2 with a minimum 4000 lbf/wheel. Rollers must follow the chip spreader closely to achieve proper embedment. Various methods to ensure chip retention have been used with much success. On occasion, when maximum retention is required, precoated chips have been used with much success. Other times, when initial retention has been marginal, a light application of emulsified asphalt (5) applied to the compacted surface is often effective in reducing chip loss. Preheated chips may also be included in specifications when cool weather threatens or ensurance of low moisture content is desired.

SUMMARY

An outline of some of the factors involved in producing an effective specification for asphalt-rubber has been presented. A description of the constituents involved and the methods of combining and applying asphalt-rubber to pavement surfaces were discussed. The component and procedure type of specification currently in use may be replaced with a specification based on performance attributes in the future. Research and development efforts now under way are aimed at producing such a specification but complexities associated with composite and hybrid materials make identification of desirable materials properties difficult. A performance specification is a desirable method for identifying this product. Complex combinations of potential materials make the recipe specification inefficient and potentially wasteful. By calling for unique performance attributes, materials or methods heretofore overlooked might prove useful. In addition, performance specifying should simplify the process of description in asphalt-rubber specifications and should potentially eliminate misunderstandings regarding materials and procedures.

The use of asphalt-rubber membranes offers much to the pavement maintenance engineer and manager. However, construction of these systems has proved that diligence is required by the inspector. With conventional surface treatments, specified methods may be relaxed or modified when necessary and adequate results may be obtained. Asphalt-rubber membranes allow no such deviation from outlined practice. Procedures identified in specifications must be followed if successful results are to be achieved. Many dramatic successes have been documented for such a new paving material; however, when practices in variance to specifications are adopted, equally dramatic failures may also be documented.

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Laboratory Measurements of Asphalt-Rubber Concrete Mixtures

R.A. JIMENEZ

The objective of this study was to develop procedures for making and testing specimens made with asphalt-rubber and aggregates. The investigation was aimed at finding a method or methods for (a) mixing the high-viscosity asphalt-rubber with aggregates, (b) forming test specimens made with this resilient material, and (c) testing the compacted specimens for characterization by using some common procedures. The above factors are discussed along with results obtained for Hveem stability, cohesiometer value, axial tension, double-punch tension and dynamic modulus of elasticity, and resistance to debonding under a dynamic repeated pore-water pressure exposure. In general, it was found that good aggregate coating can be obtained with a common laboratory mixer at the usual mixing temperatures, that California-tamping-foot compaction was not possible and that vibratory compaction yielded higher densities than static compaction, that compacted specimens required a storage period of three days in the mold at room temperature, that testing for strength had to be performed at room temperature or lower, and that expected low strength and durability are attributed to high air-void content.

Asphalt-rubber (A-R) is a blend of asphalt and fine grindings from rubber tires. The amount of rubber in the blend has been a relatively high value, about 25 percent by weight, and the rubber has been either vulcanized or devulcanized. An A-R with vulcanized rubber was investigated by C.H. McDonald and a specific formulation was patented by him in the 1960s. A review of the development and use of A-R has been given both by Jimenez, Morris, and DaDeppo (1) and by Morris and McDonald (2).

In Arizona, the main use of A-R blends has been as a binder in chip-seal construction. The chip seal has been placed as a surface course or as a strain-attenuating interlayer to minimize reflection cracking of a bituminous overlay.

Of particular concern to this study was the use of a strain-attenuating layer (SAL) constructed by using a mixture of A-R and aggregate. With chip-seal construction, there are difficulties with uniformity of application and with provision of a consistently good performance. The use of kerosene in the vulcanized rubber and asphalt blends would seem to present additional problems in the A-R SAL construction. The solution to the construction problems of chip seals would appear to be its replacement with a hot-mix A-R concrete. This would control the proportioning of materials and construction.

The objective of this study was to develop procedures for making and testing A-R concrete specimens; these mixtures were then characterized by using common asphaltic concrete (AC) measurements.

MATERIALS

Asphalts

The majority of spray applications of vulcanized rubber and asphalt has used a soft asphalt of the AR-1000 grade that meets the specifications described by the Arizona Department of Transportation (3). The A-R blends containing devulcanized rubber generally use an AR-4000 asphalt and an extender oil. Both these asphalt grades were used in the work presented.

Rubbers

The two types of rubber granules that have been used in the construction of A-R were mixed with the above asphalts to make the A-R blends. The two types are vulcanized and devulcanized rubber. The vulcanized rubber granules came from the grinding of passenger tire treads. These are a styrene-butadiene rubber that is of one size passing a No. 16 sieve and being retained on the No. 25 sieve. The second type of rubber granules was a mixture of natural and devulcanized rubber. The particle sizes were graded from the No. 8 sieve to the No. 200 sieve.

Aggregates

Two aggregate gradations of 9.5-mm (3/8-in) maximum size were used for making the AC. Their gradations and other physical properties are listed in Table 1. The open gradation was chosen because of its possible use as a hot plant seal for replacing a chip seal. Also, it was anticipated that coating difficulties might be overcome by using an aggregate of low surface area. The maximum size of aggregate was limited to 9.5 mm since in its use as an SAL the thickness of the layer would not be greater than 12.7 mm (0.5 in).

A-R Blends

The A-R blends were made according to procedures described in a report by Jimenez (4). A brief description follows.