PERFORMANCE EVALUATION OF ARIZONA ASPHALT RUBBER MIXTURES USING ADVANCED DYNAMIC MATERIAL CHARACTERIZATION TESTS

Final Report

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July 2002

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EXECUTIVE SUMMARY

The Arizona Department of Transportation (ADOT) has used Asphalt Rubber (AR) as a modified binder since the early 1970's. The primary purpose for using AR is to reduce reflective cracking in hot mix asphalt (HMA) rehabilitation overlays. In addition to this AR has been used to reduce maintenance, provide a smooth riding surface, with good skid resistance. The AR mix has also performed well in snow and ice conditions providing a tough surface that stands up well to snow plows.

The AR as tested in this study and used in Arizona is a mixture of approximately 20 percent ground tire rubber (crumb rubber) made from the recycling of used or defective tires. The ground tire rubber is added to hot paving grade asphalt at a high temperature and mixed with a high shear mixer. The mixing time and subsequent time of material interaction is generally 45 to 60 minutes. After the interaction, the hot AR product has acquired unique elastomeric properties. The hot AR is then pumped into a conventional hot plant and mixed with aggregate and placed like a conventional HMA, except for a few significant differences.

These significant differences relate to the gradation of the mineral aggregate and the percent binder. The AR hot mix is generally either a gap graded or open graded mix. The gap graded mix contains about 7.5 percent AR binder and is placed generally as the final structural course 1.5 to 2 inches in thickness. The open graded contains generally 9 percent binder and is placed as the final wearing course from 0.5 to 1.0 inch thick. The

mix designs for these two mixes are typically of a volumetric type and little has been published or researched about the binder or mix engineering properties in terms of the inputs needed for the new AASHTO 2002 Pavement Design Guide.

In the spring of 2001, ADOT in cooperation with FNF Construction Inc. entered into a research and testing plan with Arizona State University (ASU). The plan involves characterizing AR mixes and binders in order to determine their properties for future use in the AASHTO 2002 Pavement Design Guide. An additional part of the long-term plan is to begin building a database to support the new 2002 Pavement Design Guide. This research report represents the findings from this first project. The plan is to characterize AR mixes from several projects in order to represent different grades of AR binder, different aggregates and different climates representative of Arizona.

This first project, named Buffalo Range TI-Canyon Diablo (IM-040-D(1)P, Tracs # H4883) is located on Interstate 40 at Mile Posts 224.7 to 229.9, close to Winslow Arizona. The project elevation is approximately 5,000 feet and the region is considered a dry freeze zone according to SHRP. Air temperatures of over 100^{o}F occur in the summer and temperatures below –20 degrees F occur in the winter. The Interstate truck traffic is quite heavy and averages 2.2 million ESAL's per year. The pavement was overlaid in 1988 with 4.5 inches of conventional HMA. By 2001 the pavement had 3 percent cracking and a 0.20 inches of rutting. However, these values are somewhat misleading since extensive patching maintenance averaging $4,000 per mile were applied in 1998. This maintenance activity masked the high degree of fatigue cracking and rutting. The AR overlay project was constructed by FNF Construction Inc. The project consisted of removing by milling off 2.5 inches of the old cracked pavement full width and replacing it with 2 inches of the AR gap graded mix followed by 0.5 inch of AR open graded mix. This is a relatively routine type of rehabilitation of older cracked pavements in Arizona. The construction took place in June of 2000. Materials for the ARAC – Gap Graded mixture and AR-ACFC – Open Graded mixture were collected during construction.

The focus of the laboratory experimental program was on conducting tests that were recommended by the NCHRP 9-19 Project. These tests dealt with recommending Simple Performance Tests (SPT) for the evaluation of asphalt mixtures. The goal was to also compare the performance of these AR mixtures to other conventional asphalt mixtures that are also being tested at ASU.

<u>Conventional asphalt binder tests</u> were conducted to develop information that will complement other mixture material properties such as fatigue cracking and permanent deformation. The conventional consistency tests (penetration, softening point and viscosity) were conducted on the Crumb Rubber Modified (CRM) binder to determine whether there were any unique characteristics or difficulties in handling the material. Consistency tests across a wide range of temperatures were conducted according to the accepted American Society for Testing and Materials (ASTM) practices. Based on the test results and analysis conducted in this study, the conventional asphalt cement tests were

shown to be adequate in describing the viscosity-temperature susceptibility of crumb rubber modified asphalt cement. This favorable viscosity-temperature susceptibility relationship also appeared to relate to the observed field performance behavior. Such behavior is characterized as less low temperature cracking and good resistance to permanent deformation at high temperatures.

Triaxial Shear Strength tests were conducted at unconfined and confined conditions (three different levels) at 100^{o}F. These tests provided the standard cohesion and the angle of internal friction parameters of the mixtures. The Mohr-Coulomb failure envelope was developed for each tested mixture. In addition results from previously tested standard ADOT Salt River Base (SRB) mixture with binder PG64-22 were included in the analysis in order to compare its properties to those obtained for the AR. The results of the cohesion parameter showed that the asphalt rubber open graded mix (AR-ACFC) had much lower resistance to shearing stresses than the other two mixes. This observation must be supported by information that the AR-ACFC is utilized as a mixture for non-structural layer. For this Buffalo Range project, the AR-ACFC mix was placed as 0.5 in lift, and for that type of application, the shearing stress is not so critical. At the same time, the AR-ACFC mix had the highest value of angle of internal friction, which indicates that this material has the largest capacity to develop strength from the applied loads, and hence having smaller potential for permanent deformation. Similar results were observed for the ARAC mixtures as it had smaller cohesion than the SRB PG64-22, but also had larger angle of internal friction, and smaller potential for permanent deformation.

Repeated Load and Static Creep Permanent Deformation tests were conducted at two temperatures using unconfined and confined SPT protocols. Many test parameters were evaluated including tertiary flow (flow time and flow number of repetitions) as one of the SPT candidates. The test results obtained were compared to results available at ASU for conventional ADOT dense graded mixtures. For both tests, the ARAC mixture indicated superior performance, much higher resistance to permanent deformation compared to the standard ADOT SRB PG64-22 mixture. The AR-ACFC mix generally showed lower resistance to permanent deformation compared to the other tested mixtures. The poor performance was attributed to the lack of adequate laboratory confinement level applied, which does not represent the level of confinement that the material experiences in the field. In addition, few test specimens for the ARAC gap graded mix were prepared at lower air void content (7%) than that reported in the field (11%). The air voids variation test results showed that the ARAC mix compacted to 7% air voids would have much better performance and less potential for permanent deformation than the same mixture compacted to 11% air voids. Therefore, field compaction considerations should be carefully evaluated for this mixture. Overall, the permanent deformation test results were promising, in that utilizing the SPT candidate tests were able to verify the known field performance of the asphalt rubber mixtures.

Dynamic Complex Modulus (E*) tests were also conducted at unconfined and confined conditions (three different levels), and the E* master curves were developed for each mixture. The E* test results for the AR mixes were compared with conventional dense graded mixtures test results available from previous studies at Arizona State University. A modular (E*) ratio was calculated for all mixtures using a conventional PG 64-22 mixture as a reference. A comparison of the modular ratios was done at 14°F and 100°F, for a selected test frequency of 10 Hz. For the unconfined tests, at 14°F, the AR exhibited the lowest modular ratio (lowest stiffness), and therefore the best desirable performance against cracking. At 100°F, the AR mixtures had comparatively the lowest stiffness values. However, when the comparison of the ratios was made using the confined test results, the AR mixtures showed higher ratios (modulus values), and therefore, the best performance against permanent deformation. Since the performance of the AR mixtures have been remarkable in the field, these results showed the importance of using confined laboratory tests when comparing the performance of open graded to dense graded mixtures.

The AR mixes were also subjected to <u>fatigue and indirect tensile cracking tests</u>. The results were compared to data and test results available at ASU for ADOT conventional dense graded mixtures. The goal was to start developing a database of typical ADOT AR mixture cracking (fatigue and thermal) properties and parameters for their use in the implementation of the new AASHTO 2002 Design Guide.

<u>Constant Strain Fatigue tests</u> were conducted at different test temperatures using the beam fatigue apparatus proposed by the Strategic Highway Research Program (SHRP). The fatigue models developed for the AR mixtures in this study had excellent measures of

accuracy and were rational in that lower fatigue life was obtained as the test temperature decreased. Furthermore, a comparison was made of the fatigue life obtained for the AR mixes with an ADOT PG 76-16 conventional dense graded mix. The fatigue life was found to be higher for asphalt rubber mixes compared to the conventional PG 76-16. The comparison was done at 70^{o}F and at 50% reduction of initial stiffness for all mixtures. The ARAC mix resulted in approximately 3 times greater fatigue life than the conventional mix. On the other hand, the AR-ACFC mix resulted in 15 times greater fatigue life than the conventional mix. These order of magnitudes of fatigue life for the three mixtures were rational considering that the PG 76-16 mix had 4.20% binder content whereas the ARAC and AR-ACFC mixtures had 6.8% and 8.8%, respectively.

Both <u>indirect tensile cracking tests</u> (Strength and Creep) were carried out according to the procedure described in the draft indirect tensile tests protocol for the AASHTO 2002 Design Guide. The tests were carried out at three temperatures: 32, 14 and 5^{o}F. The results of strain at failure showed that the AR-ACFC and ARAC mixes had higher values than the SRB PG64-22 mix. Mixtures with higher strain at failure have higher resistance to thermal cracking. The results of energy until failure and fracture energy from the indirect tensile strength test, as well as the results of the creep compliance from the indirect tensile creep test indicated that AR mixtures, and especially the AR-ACFC mix, are not sensitive to decrease in temperature compared to the SRB PG64-22 mixture. Both AR mixtures had higher energy values, which were indicative of more resistant to thermal cracking.