Arizona Experience with Asphalt-Aggregate Mixture Analysis System Procedure

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An asphalt concrete mixture used by the Arizona Department of Transportation (ADOT) is evaluated on the basis of a asphalt-aggregate mixture analysis system (AAMAS) procedure. Two sets of ADOT asphalt concrete specimens were prepared using the California kneading compactor and the Marshall hammer. All tests recommended by the AAMAS procedure were performed. The test results were analyzed using the AAMAS guidelines. It was found that the diametral resilient moduli of the ADOT mixture are within the acceptable range. The ADOT structural layer coefficient is close to the value recommended by the AAMAS study. The rutting potential is low in some cases and moderate in other cases. The ADOT mixture has slightly higher fatigue resistance at low temperatures than the asphalt concrete placed at the AASHO Road Test. Recommendations for the evaluation of thermal cracking are provided. The potential for moisture damage is high, whereas the potential for disintegration is marginal. The AAMAS prediction generally matches the historical experience of the asphalt mixture. The current version of the AAMAS procedure is quite comprehensive and seems to provide good performance predictions.

The asphalt concrete mix design in Arizona is based on the Marshall procedure. The Marshall method of mix design is basically empirical, so it results in index-type values such as Marshall stability and flow. In general, empirical characterization parameters are useful for comparing materials under specific conditions. However, empirical correlations are valid only for conditions similar to those under which they were originally developed. Further, empirical methods of characterization do not provide material properties needed for fundamental or theory-based structural analysis of pavements. With the continuous increase in truck weight, tire pressure, and traffic volume, and with the fast deterioration of the nation's highway system, more rational philosophy for asphalt concrete characterization is needed so that the pavement design can be based on a more optimal manner.

NCHRP Project 9-6, *Asphalt-Aggregate Mixture Analysis System: AAMAS*, has been recently completed (*1*). One of the objectives of that project was to develop a more rational mixture characterization procedure based on performance-related criteria. The AAMAS method provides rational evaluation procedure that is directly related to the mixture performance in the field. Because the project was completed only recently, the AAMAS procedure has not been implemented by most states. However, various highway agencies are planning to implement it soon. The implementation of the AAMAS procedure by the Arizona Department of Transportation (ADOT) could be a major step forward toward rationalizing the asphalt concrete mix design process.

According to the AAMAS procedure, six test types should be performed. Some of these tests are nondestructive, so each specimen could be tested using different test types and at different test temperatures. Some specimens are to be tested without conditioning; others should be conditioned, by being subjected to some treatments before testing. The detailed test and analysis procedure are reported by Von Quintus et al. (*1*). A summary of the test procedure is presented in the next section for completeness.

The objectives of this study are to evaluate typical ADOT hot-mixed asphalt concretes using the AAMAS recommendations (*1*), to expand the ADOT data base by providing typical lab test values for ADOT asphalt concrete, and to evaluate the amount of effort and equipment cost required for the AAMAS procedure and discuss its potential use by ADOT engineers.

SUMMARY OF AAMAS PROCEDURE

Specific items addressed in the AAMAS report include compaction of laboratory mixtures to simulate the characteristics of mixtures placed in the field, preparation and mixing of materials in the laboratory to simulate the asphalt concrete plant production process, simulation of the long-term effects of traffic and the environment (this includes accelerated aging and densification of the mixes caused by traffic), and conditioning of laboratory samples to simulate the effects of moisture-induced damage and hardening of the asphalt. Specific laboratory tests are recommended as well as methods of evaluating the expected performance of dense-graded asphalt concrete mixtures. Suggested recommendations for incorporating results of the AAMAS program into a final mixture design procedure are also provided.

Laboratory Tests

The NCHRP report (*1*) includes a detailed laboratory program to simulate the characteristics of mixtures placed in the

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field. The complete AAMAS procedure requires six types of test, as shown in Table 1. The diametral resilient modulus test is performed according to ASTM D4123. The indirect tensile strength test is summarized in applying a compressive load with a constant rate of deformation along a diametrical plane of a Marshall-size specimen until failure. The load at failure is recorded, from which the indirect tensile strength is computed. The horizontal deformation at failure can be used to compute the indirect tensile strain at failure. The AAMAS procedure requires that the diametral resilient modulus test be performed before the indirect tensile strength test. It is also required to use a deformation rate of 0.05 in./min at 41°F and 2 in./min at 77 and 104°F.

In the indirect tensile creep test, a constant-magnitude compression load is continuously applied along the vertical diametral plane of a Marshall-size specimen. The horizontal deformation is then used to calculate the tensile creep modulus at a particular duration. After the load is released, the rebound vertical and horizontal deformations are recorded over a fixed duration, and the recovery efficiency is determined. A loading time of 60 min and an unloading time of 60 min are required.

The concept of the uniaxial compression resilient modulus test is similar to the diametral indirect tensile resilient modulus test except that an axial load is applied. Unlike the diametral resilient modulus test, the uniaxial test results in a uniform axial compressive stress in the specimen. In this test, a pulsating uniaxial load is applied on a cylindrical specimen every 1 sec with a 0.1-sec duration, and the corresponding axial deformation is recorded. The total resilient modulus is determined by dividing the repeated axial compressive stress by the total recoverable axial strain. A specimen 4 in. in diameter and 4 in. high is recommended by the AAMAS study.

The unconfined compressive strength test is performed on a specimen 4 in. in diameter and 4 in. high, according to ASTM D1074. In the AAMAS report, however, a rate of strain of 0.15 in./in./min and a test temperature of 104°F are required. At failure, the compressive strength is calculated by dividing the load at failure by the cross-sectional area.

In the uniaxial creep test, a constant-magnitude uniaxial compression load is applied on a 4- × 4-in. cylindrical specimen, and the axial deformation is continuously recorded. The compressive creep modulus can be computed at any loading time by dividing the axial compressive stress by the axial compressive creep strain. The AAMAS procedure requires a test temperature of 104°F. A loading time of 60 min and an unloading time of 60 min are required. The slope and intercept of the creep curve as well as the recovery efficiency are computed.

TABLE 1 Laboratory Tests Recommended by AAMAS Study

Test No.	Test Name	Loading Pattern	Specimen Loading
1	Diametral resilient modulus	Pulses with 0.1 sec duration and 0.9 sec rest period (ASTM D 4123)	Diametral
2	Indirect tensile strength	Loading at a rate of deformation of 0.05 or 2 in/min until failure	Diametral
3	Indirect tensile creep	Static load with a specified magnitude for 60 min and unloading for 60 min	Diametral
4	Uniaxial compression resilient modulus	Pulses with 0.1 sec duration and 0.9 sec rest period	Axial
5	Unconfined compressive strength	Loading at a rate of deformation of 0.6 in/min until failure	Axial
6	Uniaxial creep	Static load with a specified magnitude for 60 min and unloading for 60 min	Axial

Specimen Conditioning

The AAMAS study recommends three types of specimen conditioning in the lab to simulate field conditions. A summary of the procedure is as follows:

1. Moisture conditioning—Specimens are vacuum-saturated until the water absorption is greater than 55 percent. Specimens are then frozen for 16 hr and thawed at 140°F for 24 hr and at 77°F for 2 hr.
2. Environmental aging (temperature conditioning)—Specimens are heated at 140°F for 2 days and at 225°F for 5 days. Specimens are then cooled at 41°F for 12 hr.
3. Traffic densification—Specimens are heated and further compacted to simulate traffic densification until refusal or until the final air void level is reached.

Table 2 shows a summary of specimen-conditioning types and procedures.

Grouping and Test Sequence

The complete AAMAS procedure requires 24 specimens: eighteen 4- by 2.5 in. specimens and six 4- by 4-in. specimens. Specimens are grouped into eight sets of three specimens each. The first six sets have 4- by 2.5-in. specimens; the last two sets have 4- by 4-in. specimens. The specimens are grouped so that the average unit weight (and air voids) of the different sets are approximately equal. Table 3 shows the conditioning as well as test type, sequence, temperature, and measurements for each specimen set.

EVALUATION OF ADOT MIXTURE PROPERTIES

Specimen Preparation and Testing

The AAMAS study recommends the use of the gyratory compactor (ASTM D3387 or D4013) because it closely simulates the mix compaction in the field. The report further concludes that the California kneading compactor (ASTM D1561) is the next preferred device, and the Marshall hammer (ASTM D1559) is the least desirable compactor. Because the Marshall hammer is the most commonly used compactor and it is the compactor currently used by ADOT, there is a need to compare the responses of Marshall-compacted specimens and of specimens compacted by other devices. Also, because the

TABLE 2 Specimen Conditioning

Conditioning No.	Name	Procedure
a	Moisture conditioning	Vacuum saturation + freeze and thaw
b	Environmental aging	Heating for 7 days + cooling for 12 hours
c	Traffic densification	Heating and further compaction

TABLE 3 Conditioning, Test Sequence, and Measurements

Set No.	No. of Speci-mens	Size (in.)	Condi-tioning*	Test No.,** Sequence & Temperature	Measurement
1	3	4 x 2.5	None	1, 2 (41°F)	Diametral resilient modulus, indirect tensile strength, tensile strain at failure
2	3	4 x 2.5	None	1, 2 (77°F)	Same as set 1
3	3	4 x 2.5	None	1, 2 (104°F)	Same as set 1
4	3	4 x 2.5	a	1, 2 (77°F)	Same as set 1
5	3	4 x 2.5	b	1, 2 (41°F)	Same as set 1
6	3	4 x 2.5	b	3 (41°F)	Tensile creep modulus, recovery efficiency
7	3	4 x 4	c	4, 5 (104°F)	Axial resilient modulus, unconfined compressive strength, compressive strain at failure
8	3	4 x 4	c	6 (104°F)	Slope and intercept of creep curve, compressive creep modulus, recovery efficiency

* See Table 2
** See Table 1

gyratory compactor was not available to the authors at that time, it was decided to evaluate two sets of 24 specimens: one set compacted by the kneading compactor, and the other set compacted by the Marshall hammer. It was also decided that the bulk specific gravities and air voids of all specimens should be similar to those of typical ADOT mixes. The aggregate was prepared following the midpoint of the typical ADOT dense gradation with a maximum size of ¾ in. An AC-30 asphalt cement was used in the mix preparation with a penetration of 40 and a kinematic viscosity of 320 cSt at 275°F.

The mix was designed according to the ARIZ 815c procedure (*2*), which is a modified version of ASTM D1559. The design asphalt content was 4.7 percent by total weight of mix. The bulk density was 145.2 pcf. The maximum theoretical density of the loose mixture was 152.4 pcf, and the air void of the compacted specimens was 4.7 percent. This mix is typically used in areas with desert climate and low to moderate traffic volume.

The first set of specimens was compacted using the California kneading compactor according to ASTM D1561. The compacting effort was adjusted on a trial-and-error basis to achieve a bulk specific gravity and air voids similar to those of typical ADOT mixtures. After several trials it was found that 20 blows at 250 psi followed by 100 blows at 500 psi provided the required density for the 4- by 2.5-in. specimens. The 4- by 4-in. specimens were compacted using the same procedure except for 20 blows at 250 psi and 120 blows at 500 psi. The second set of specimens was compacted using the manual Marshall hammer according to ASTM D1559. Seventy-five blows on each side of the specimen were applied on the 4- by 2.5-in. specimens; 100 blows on each side were applied on the 4- by 4-in. specimens.

All of the kneading-compacted and Marshall-compacted specimens were grouped into eight sets so that the average unit weights of all sets were similar, as recommended by the AAMAS study (*1*).

Both kneading-compacted and Marshall-compacted specimens were conditioned according to the AAMAS procedure. Three types of conditioning were used: moisture conditioning, environmental aging, and traffic densification. The California kneading compactor was used for the traffic densification of the kneading-compacted and the Marshall-compacted specimens. Five hundred kneading blows were applied to each specimen to ensure that refusal was reached. Table 4 shows the bulk unit weights and air voids before and after traffic densification. The results show that traffic densification of kneading-compacted specimens resulted in slightly larger unit weights and slightly less air voids than those of Marshall-compacted specimens.

Test Results

Testing was performed as specified in the AAMAS report. An electrohydraulic testing machine was used for all tests. Table 5 shows the average test results of unconditioned, moisture-conditioned, environmental-conditioned, and traffic-densified specimens. Comparison of the kneading- and the Marshall-compacted specimens indicates that the test results are close in most cases.

TABLE 4 Average Unit Weights and Air Voids Before and After Traffic Densification

Property	Set No.	Kneading Compacted	Marshall Compacted	Average
Unit weight before (pcf)	7	145.3	145.2	145.3
Unit weight after (pcf)	7	148.4	147.1	147.8
Unit weight before (pcf)	8	145.3	145.2	145.3
Unit weight after (pcf)	8	148.8	147.4	148.1
Air voids before (%)	7	4.7	4.8	4.8
Air void after (%)	7	2.6	3.4	3.0
Air voids before (%)	8	4.7	4.8	4.8
Air void after (%)	8	2.4	3.3	2.9

TABLE 5 Average Test Results of Unconditioned and Conditioned Specimens

Property	Set No.	Temp. (F)	Kneading Compacted	Marshall Compacted	Average
Diametral E_r (ksi)	1	41	2,414	2,371	2,393
Tensile strength (psi)	1	41	374	357	366
Tensile strain at failure (mils/in)	1	41	3.0	4.0	3.5
Diametral E_r (ksi)	2	77	785	943	864
Tensile strength (psi)	2	77	283	322	303
Tensile strain at failure (mils/in)	2	77	6.7	6.5	6.6
Diametral E_r (ksi)	3	104	192	179	186
Tensile strength (psi	3	104	93	107	100
Tensile strain at failure (mils/in)	3	104	8.2	6.0	7.1
Diametral E_r (ksi)	4	77	399	296	348
Tensile strength (psi)	4	77	87	81	84
Tensile strain at failure (mils/in)	4	77	6.4	4.0	5.2
Diametral E_r (ksi)	5	41	3,086	3,912	3,499
Tensile strength (psi)	5	41	392	443	418
Tensile strain at failure (mils/in)	5	41	2.6	2.7	2.7
Tensile creep modulus at 3,600 sec.(ksi)	6	41	92	475	284
Recovery efficiency	6	41	0.17	0.37	0.27
Axial E_r (ksi)	7	104	30	31	31
Compressive strength (psi)	7	104	715	705	710
Compressive strain at failure (mils/in)	7	104	24.0	18.5	21.3
Slope of creep curve	8	104	.051	.050	.050
Intercept of creep curve (10^{-3})	8	104	3.26	3.62	3.44
Compressive creep modulus (ksi)					
at 10 sec	8	104	15.5	15.2	15.4
100 sec	8	104	11.1	10.4	10.8
1,000 sec	8	104	9.8	8.0	8.9
3,600 sec	8	104	9.2	8.1	8.7
Recovery efficiency	8	104	0.55	0.45	0.50

PREDICTION OF ADOT MIXTURE PERFORMANCE

The concept of relating the mixture properties to the pavement performance is logical and appropriate in order to optimize mixture and structural designs. Many models have been developed for this purpose. However, these models are limited in use to some degree, mainly because they are not comprehensive enough to cover all variables involved in pavement performance. The AAMAS study presents some guidelines to provide a recommended practice for evaluating asphalt concrete mixtures on the basis of performance-related criteria.

The AAMAS procedure consists of a series of steps using results from the test program, discussed earlier, as well as interactions with various models predicting the types of distress more common with asphalt concrete pavements. The final products of the AAMAS are the structural and material combinations needed to meet the design requirements or assumptions used by the pavement design engineer. In this section, the properties of typical ADOT mixtures presented earlier are compared with the performance-related criteria reported in the AAMAS study.

AASHTO Structural Layer Coefficient

The 1986 AASHTO guide (*3*) recommends the estimation of the structural layer coefficient from the resilient modulus measured at 68°F in accordance with ASTM D4123. The AAMAS study, however, recommends the consideration of the environmental effects on the structural design by considering the seasonal fatigue damage. In other words, use seasonal resilient moduli to calculate seasonal fatigue damage and add the seasonal damages to determine an annual damage. From the annual damage, an effective asphalt concrete resilient modulus can be calculated, which can be used to estimate the structural layer coefficient.

The following is a step-by-step procedure that can be used to ensure that the asphalt concrete mixture meets or exceeds the layer coefficient assumed during structural design (*1*).

1. Obtain the seasonal average pavement temperature for each season.
2. Determine the total resilient modulus at each seasonal temperature. Figure 1 shows the acceptable range of moduli (unconditioned) at various temperatures. Figure 1 also shows that the ADOT moduli (average of results using the two compaction methods) are within the acceptable range at all three test temperatures; 41, 77, and 104°F for unconditioned specimens.
3. Obtain the fatigue factor for each seasonal resilient modulus from Figure 2 (*1*).
4. Calculate the effective resilient modulus using Equation 1.

$$E_{\mathrm{RE}} = \frac{\sum[E_{\mathrm{RT}}^{(i)} \times \mathrm{FF}^{(i)}]}{\sum \mathrm{FF}} \tag{1}$$

where

E_{RE} = effective resilient modulus based on a fatigue damage approach,

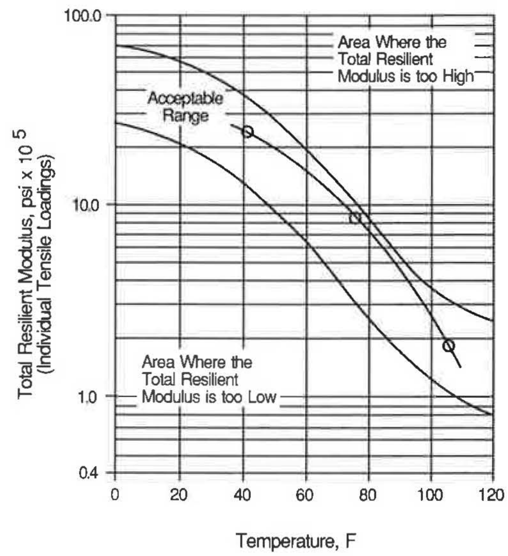

FIGURE 1 Acceptable range of diametral total resilient moduli at various temperatures and typical ADOT moduli.

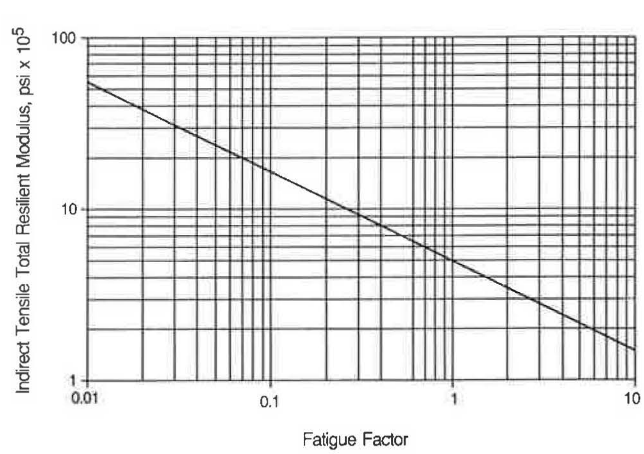

FIGURE 2 Estimation of fatigue factor to determine equivalent annual modulus (*1*).

$E_{\mathrm{RT}}^{(i)}$ = total resilient modulus as measured by ASTM D4123 at the average pavement temperature for season *i*, and

FF = fatigue factors obtained from Figure 2.

This effective resilient modulus should equal or exceed the modulus value used to estimate the AASHTO structural layer coefficient used for design [Figure 3 (*3*)].

As an example for determining the structural layer coefficient, use AC-30 for asphalt concrete, an aggregate type and gradation as used in this study, and an asphalt content of 4.7 percent by total weight of mix. The seasonal average pavement temperatures are 80°F for fall, 70°F for winter, 85°F for spring, and 100°F for summer.

From Figure 1 the moduli at 80, 70, 85, and 100°F are 700, 1050, 560, and 260 ksi. From Figure 2 the corresponding fatigue factors are 0.50, 0.22, 0.80, and 3.6. Using Equation 1, the effective resilient modulus is 384 ksi. Figure 3 shows that the structural coefficient (a_1) for this material should be

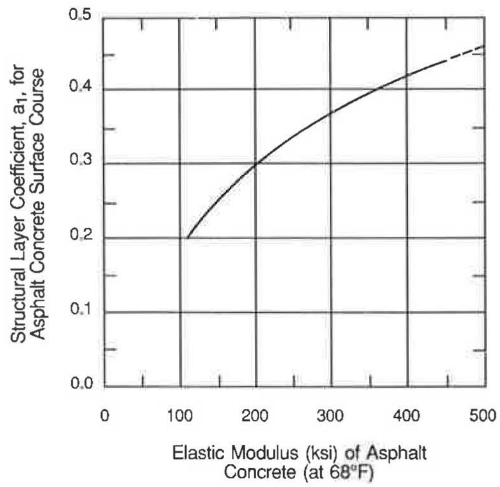

FIGURE 3 Chart for estimating structural layer coefficient of dense-graded asphalt concrete based on elastic (resilient) moduli (3).

0.42. The ADOT design manual (2) recommends a value of 0.44 for this mixture. This indicates that the structural layer coefficient used by ADOT is close to the value recommended by the AAMAS study. Note, however, that the seasonal average pavement temperatures used in this sample are approximate.

Rutting

Two types of rutting are considered: (a) densification or one-dimensional consolidation, and (b) the lateral movement or plastic flow of asphalt from wheel loads. The more severe premature rutting failures and distortion of asphalt concrete materials are related to lateral flow or loss of shear strength of the mix, rather than to densification. Currently, there is no mechanistic or empirical model that adequately considers the lateral flow problem (1).

Rutting from one-dimensional consolidation can be estimated using the traffic densification procedure recommended in the AAMAS report (1). Limiting the air voids at mixture refusal limits the amount of additional densification caused by traffic, assuming that the mixture is properly compacted on the roadway to an air void level between 5 to 7 percent. The air voids at mixture refusal should be greater than 2 percent when compacted with the gyratory devices (1). Table 4 indicates that the air voids after densification of specimens tested in this study are greater than 2 percent. Therefore, the possibility of rutting due to one-dimensional consolidation is small.

A few mathematical models are reported in the AAMAS report to estimate the rutting rate of asphalt concrete layers in the field. Figures 4 through 7 illustrate graphical solutions of the range of data that can be generated for different pavements, climates, and loading conditions. The figures can be used as gross guidelines for mixture evaluation on high-volume roadways.

The compressive creep moduli (average of results using the two compaction methods) reported in Table 5 (Set 8) for

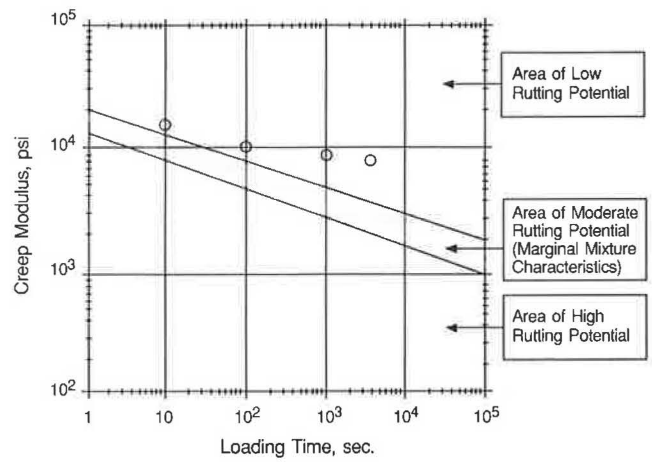

FIGURE 4 ADOT mixture rutting potential for lower layers of full-depth asphalt pavements.

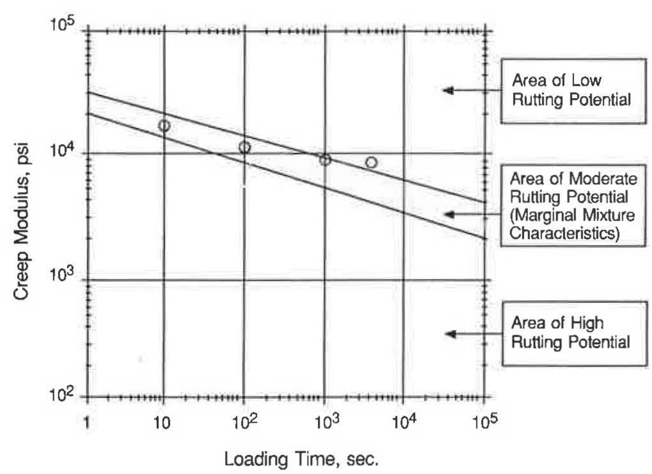

FIGURE 5 ADOT mixture rutting potential for intermediate layers in thick or full-depth asphalt pavements.

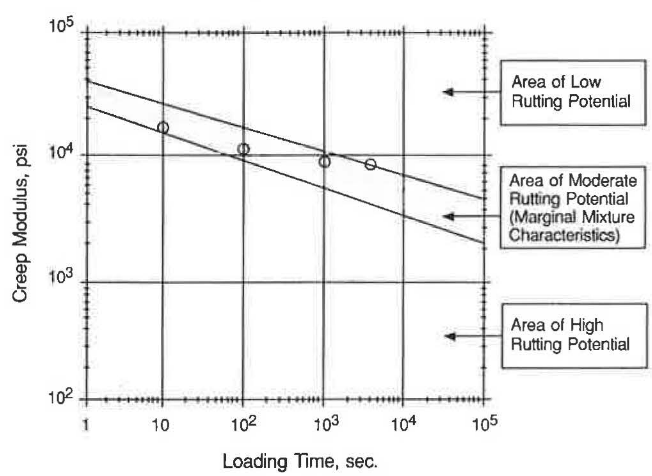

FIGURE 6 ADOT mixture rutting potential for surface layers of asphalt pavements.

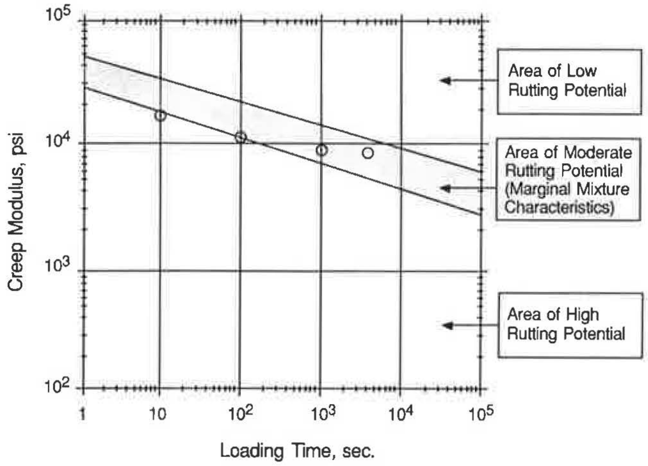

FIGURE 7 ADOT mixture rutting potential for layers placed over rigid pavements or rigid base materials.

typical ADOT mixtures are plotted in Figures 4 through 7. It can be concluded that the ADOT mixture has a low rutting potential for the lower layers of full-depth asphalt pavements (Figure 4). On the other hand, it has a moderate rutting potential (marginal) for the intermediate layers in thick or full-depth asphalt pavements (Figure 5), for surface layers (Figure 6), and for layers placed over rigid pavements or rigid base materials (Figure 7).

Fatigue Cracking

According to the AAMAS procedure, two methods can be used for evaluating asphaltic concrete mixtures for fatigue cracking. The first is to ensure that the mixture meets or exceeds the fatigue resistance of a "standard" material (which is assumed in structural design), and the second is to ensure that the mixture has the required fatigue resistance for the specific environment and pavement cross section. The first method is recommended because it is simpler.

For purposes of AAMAS, the standard mixture will be the dense-graded asphaltic concrete placed at the AASHO Road Test. The fatigue curves from NCHRP 1-10B (*4*) were developed from these data, which have been used in other research and design studies (*5,6*). Figure 8 shows two relationships between the total resilient modulus and indirect tensile strain at failure for the standard mixture.

If the total resilient modulus and indirect tensile strains at failure for a particular mixture plot above the standard mixture (FHWA fatigue curve is recommended), it is assumed that the mixture has better fatigue resistance than the standard mixture.

The test results of unconditioned ADOT specimens (average between the two compaction methods) (Table 5, Sets 1, 2, and 3) are plotted in Figure 8. It can be seen that two of the points are above the FHWA fatigue curve and one point is below the curve. Thus, the ADOT mixture has higher fatigue resistance at low temperatures and lower fatigue resistance at high temperatures when compared with the "standard" mix.

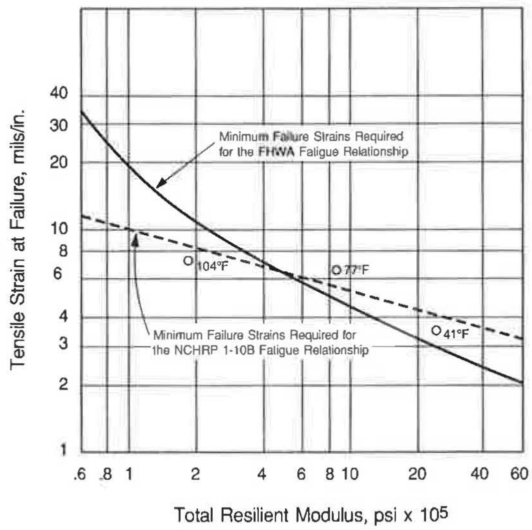

FIGURE 8 Fatigue cracking potential of ADOT mixture.

Thermal Cracking

To evaluate thermal cracking, certain critical mixture properties as well as project-specific environmental conditions must be determined. The mixture properties include indirect tensile strength, low-temperature creep modulus, failure strains, and the thermal coefficient of contraction. These parameters can be used to calculate the occurrence of thermal cracking with time.

The critical temperature change (°F) at which cracking is expected to occur can be calculated as follows (*1*):

$$\Delta T = \left[\frac{E_{ct}(T_i)}{E_o}\right]^{1/n_t} \frac{t_r^{n_c}}{\alpha A^{E_o(T_i)}}$$

where

$E_{ct}(T_i)$ = indirect tensile creep modulus measured at temperature T_i;
E_o = regression constant developed from laboratory test data;
n_t = slope of relationship between indirect tensile strength and total resilient modulus of the mixture measured at temperatures of 41, 77, and 104°F (unconditioned);
$E_o(T_i)$ = intercept of indirect tensile creep curve at temperature T_i (psi);
t_r = relaxation time (3,600 sec);
n_c = slope of the indirect tensile creep curve at temperature T_i; and
αA = thermal coefficient of contraction of the asphalt concrete (typical values range from 1.0×10^{-5} to 1.8×10^{-5} in./in./°F).

From these criteria, the cracking potential of ADOT mixture can be evaluated. The available data, however, are not enough to provide complete evaluation.

Moisture Damage

Currently, the moisture damage evaluation—tensile strength ratio (TSR) and resilient modulus ratio (MRR) after and before moisture conditioning—of AAMAS is simply used as a means of accepting or rejecting a mixture. Both of these ratios should exceed a value of 0.80 for dense-graded asphalt concrete. If values less than 0.80 are measured, an asphalt additive or antistripping agent may be required or the aggregate blend may need modification. If these ratios are less than 0.70, an antistripping agent will be required for the aggregate blend (*1*).

For the ADOT mixture, the tensile strength ratio and the resilient modulus ratio at 77°F can be obtained from Table 5 by dividing the results of moisture-conditioned specimens (Set 4) by the results of the unconditioned specimens (Set 2) as follows:

$$\text{TSR} = \frac{84}{303} = 0.28$$

$$\text{MRR} = \frac{348}{864} 0.40$$

It can be seen that both ratios are less than 0.70, which indicates high potential for moisture damage. Therefore, an antistripping agent is required for the aggregate blend, according to the AAMAS recommendations. It should be noted, however, that this mixture is typically used in the Phoenix area where the amount of rainfall is very limited. In other areas within the state where the rainfall is higher, the aggregate would require treatment with either lime or portland cement to increase the stripping resistance. The applicability of the 0.70 ratio recommended by the AAMAS study to desert climate is questioned.

Disintegration

The following summarizes the AAMAS criteria that can be used as guidelines to evaluate the acceptability of surface mixtures as related to disintegration:

- Air voids at refusal > 3 percent;
- Indirect tensile strength ratio, TSR > 0.80;
- Bonding loss < 50;
- Tensile strain at failure (77°F) > 10 mils/in.;
- Tensile strain at failure (41°F after accelerated aging) > 2.0 mils/in.; and
- Bonding loss = $(1 - \varepsilon_{ht}/\varepsilon_{ho}) \times 100$, where ε_{ht} is the indirect tensile strain at failure measured on specimens that have been temperature-conditioned (accelerated aging), and ε_{ho} is the indirect tensile strain at failure measured on unconditioned specimens

The following information is obtained from the ADOT mixture:

- Air voids at refusal (Table 4) = 3 percent (OK);
- Indirect tensile strength ratio, TSR (from Table 5, Sets 4 and 2) = 0.28;
- Bonding loss at 41°F (from Table 5, Sets 5 and 1) = 23 (OK);
- Tensile strain at failure (77°F) (Table 5, Set 2) = 6.6 mils/in.; and
- Tensile strain at failure (41°F) (Table 5, Set 5) = 2.7 mils/in. (OK).

It can be seen that three of the conditions are satisfied and the other two are not. This indicates that the potential for disintegration is marginal.

COMPARING AAMAS PREDICTION WITH HISTORICAL EXPERIENCE

The AASHTO structural layer coefficient predicted by the AAMAS procedure for the typical ADOT mixture conditions is similar to that recommended by the AASHTO procedure. It should be noted, however, that the AAMAS procedure considers the seasonal average pavement temperatures, whereas the AASHTO procedure does not explicitly consider the pavement temperature.

The AAMAS procedure indicates that the ADOT mixture has a moderate rutting potential for surface layers. The ADOT experience, however, shows that rutting is very limited despite the hot climate of the Phoenix area. On the other hand, the AAMAS procedure shows low to moderate resistance to fatigue cracking. The historical experience with the mixture is similar to the AAMAS prediction in that respect.

The potential for thermal cracking of the ADOT mixture was not completely evaluated in this study. Moreover, the AAMAS procedure indicates that the ADOT mixture has a high potential for moisture damage. This condition, however, is not applicable to the asphalt mixture evaluated in this study, because the amount of rainfall is very limited in the Phoenix area, where the mixture is used. Finally, the AAMAS procedure shows that the disintegration potential of the ADOT mixture is marginal. The ADOT experience shows that raveling sometimes occurs when the mixture is placed during cold weather. However, raveling usually heals during the hot weather. Also, the routine maintenance used by ADOT usually solves disintegration problems when they arise.

SUMMARY AND CONCLUSIONS

In this study an ADOT asphalt concrete mixture typically used in areas with desert climate was evaluated on the basis of the AAMAS procedure (*1*). Two sets of ADOT asphalt concrete specimens were prepared using the California kneading compactor and the manual Marshall hammer. All tests recommended by the AAMAS study were performed. The test results were analyzed using the AAMAS guidelines.

It was found that the diametral resilient moduli of the ADOT mixture are within the acceptable range. The ADOT structural layer coefficient is close to the value recommended by the AAMAS study. The rutting potential is low in some cases and moderate in others. The ADOT mixture has higher fatigue resistance at low temperatures than the asphalt concrete placed at the AASHO Road Test. Recommendations for the evaluation of thermal cracking are provided. The potential for moisture damage is high, but the potential for disintegration is marginal. The AAMAS prediction generally matches the historical experience of the asphalt mixture, although the moisture-damage evaluation may not apply to the mixture used in desert climates.

The current version of the AAMAS procedure is quite comprehensive and seems to provide good performance prediction. Further research is currently being conducted by the Strategic Highway Research Program. Thus, the results obtained in this study should not be considered final. More studies are needed for comprehensive evaluations of ADOT asphalt concrete performance.

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