Effects of Residual Aggregate Moisture on Stripping Potential of Asphalt Concrete Mixtures

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For some asphalt concrete mixes in Alabama, correlations between field stripping performance and stripping test predictions have been poor. One of the possible causes of this inconsistency appears to be the inability of the laboratory stripping tests to simulate field conditions, particularly the drying of aggregates before mixing with asphalt cement. In the field, highly absorptive, saturated aggregates may not be effectively dried by rapid heating in drum dryers. Laboratory preparation of test samples, however, begins with well-dried aggregates. Moisture content measurements of hot bin aggregates and freshly mixed hot asphalt concrete occasionally confirm the presence of residual moisture at levels that are likely to have an effect on the moisture damage susceptibility of the mix. The amount of moisture retained in plant-produced mix is highly dependent on ambient temperature and the moisture content of aggregate stockpiles. Wet-dry indirect tensile stripping tests indicate that the effect that residual moisture has on tensile strength depends on aggregate type. On the basis of tensile strength ratios of conditioned specimens to unconditioned specimens, residual moisture can be detrimental to mixes containing primarily siliceous aggregate. However, mixes containing limestone as the dominant aggregate did not appear to be adversely affected by residual aggregate moisture.

Considerable effort has been devoted to developing tests and procedures for characterizing the stripping potential of asphalt concrete mixtures and methods for evaluating the effectiveness of antistripping additives. Yet it is recognized that even the best procedures do not always accurately predict stripping performance because of the many internal and external factors that are known or believed to affect stripping of asphalt pavements. Most internal (mix) factors such as aggregate and asphalt characteristics, mix design, and component variations have been investigated, and their effects are generally well understood. However, most external (construction and environmental) factors are difficult to accurately model with accelerated laboratory tests.

Probably the most common stripping test is the basic wet-dry indirect tensile test procedure with some variation of specimen conditioning. Two of the most popular methods are the Tunnicliff-Root procedure (*1*) and the Lottman procedure (*2*). The success of these procedures is largely due to their ability to simulate factors in the field that are most influential in the stripping performance of asphalt pavements.

The Alabama Highway Department currently uses a method for evaluating stripping susceptibility of mixes much like the Tunnicliff-Root method as part of the mix design process. During the initial development of this procedure, Parker and Gharaybeh (*3*) tested black base/binder mixes from different regions of the state that were representative of the range of stripping performance in Alabama. Of five mixes tested, results for two did not match with their respective performance histories. Part of these inconsistent results were attributed to the inability of the procedure to simulate some field conditions. It was postulated that some of the error was due to the differences between laboratory and field drying of aggregates, mixing conditions, and compaction.

The original purpose of the research from which this paper is derived was to determine whether laboratory sample preparation and conditioning procedures were adequately simulating field construction and environmental conditions. To do this, plant mix samples were obtained from typical production operations, tested, and compared with laboratory-prepared specimens. Moisture contents of the aggregates and mix were measured as it progressed through the manufacturing and placing sequences. These measurements indicated that some mixes retained significant levels of residual moisture through production. At this point the investigation became focused on the difference between laboratory and field drying/heating of aggregates and how residual moisture affects the results of the stripping test.

MOISTURE CONTENT MEASUREMENTS

Moisture content measurements of asphalt concrete mixes taken in the field and in the laboratory were made using a microwave oven for drying the samples. Microwave oven drying was rapid and much more convenient than the distillation method, ASTM D 1461. More information regarding the use of the microwave oven for moisture content determination of asphalt concrete mixes is reported elsewhere.

Moisture Contents of Hot Bin Aggregates

Moisture contents of hot bin aggregates from five mixes are shown in Figure 1. A wide range of residual moisture between the five mixes is evident, especially for the coarsest aggregates. This variation is directly related to the weather conditions preceding and during mix production. Mixes F, H, and I, which retained higher levels of moisture in the coarser aggregates, were sampled during periods of cool and rainy

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weather. Mixes A and G were sampled during very hot and dry periods.

The distribution of moisture within the mixes is also significant. Nearly all mixes contained the highest levels of moisture in the coarsest aggregates and lesser amounts of moisture for the successive finer aggregates. The moisture differential between aggregate sizes is a result of the rapid heating and screening in the batch plants.

Drying Wet Aggregates

It has often been said that the purpose of heating aggregates in hot mix production is to produce surface dry conditions for promoting asphalt coating and adhesion and to provide enough heat to the mixture to sustain workability of the asphalt through paving operations. However, drying of aggregates only to a surface dry condition may not be enough.

Lottman described the heating of wet aggregates (*5*). According to Lottman, for a given blend of wet aggregates entering the dryer, the fine aggregate particles will heat up and dry out faster because of their larger surface to mass ratio. Larger aggregate particles, which contain more moisture, give off large amounts of water vapor and are slower to reach a uniform temperature. As the aggregates exit the dryer and are separated over the screen deck, the temperature differences are compounded by the separate bins. The lower temperature of the incompletely dried coarse aggregates in the hot bin may not be sufficient to continue the drying of large particles. When the aggregates are batched into the pugmill and coated with asphalt, the transfer of heat from the asphalt and fine aggregates elevates the temperature of the coarse aggregate particles enough to drive out some of the moisture remaining in the deeper pores of the large particles.

A similar scenario can develop in drum plants. The parallel flow process rapidly heats aggregates entering the drum dryer, and, as before, the fine aggregates heat and dry quickly and the coarse aggregates more slowly. The water vapor liberated from the wet aggregates consumes heat energy and prevents aggregates from reaching optimum drying temperature. When the aggregate meets the asphalt spray in the drum, the moisture remaining on the aggregate may cause the asphalt to foam. The foaming is considered to aid in coating. However, as heating is continued in the drum and as the mix is held in storage silos, the remaining moisture may be driven off. This may disrupt the asphalt-aggregate bond and contribute to stripping susceptibility.

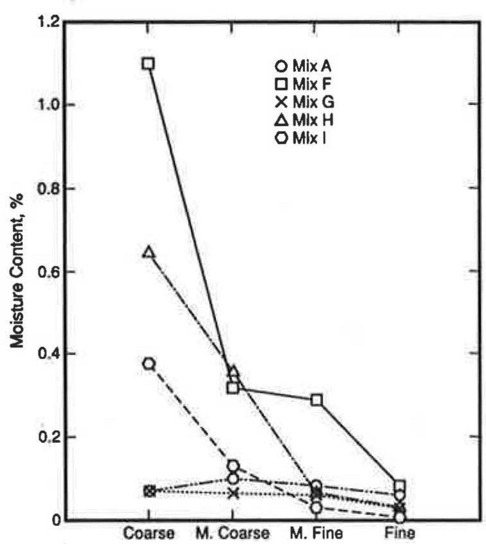

FIGURE 1 Hot bin moisture content.

Moisture Contents of Mixes

Moisture contents of mixes sampled after discharge from the pugmill and at the spreader are given in Table 1. Again there is a positive correlation between weather conditions and moisture content. These measurements clearly indicate that the plants that were producing mix during cool wet weather were not effectively removing some moisture from the aggregates during the drying process. For Mixes D and F there is evidence that this residual moisture continued to escape from the mix during hauling and spreading. For Mix F there is also evidence that moisture contents of the mix decreased during the day as ambient temperature increased and the plant conditions stabilized.

Residual Moisture Damage

The fact that some field-produced mixtures are not moisture-free is not surprising. Yet, residual moisture has received little attention in stripping research, even though some connection between residual moisture and bond strength and, thus, potential for moisture damage is logical.

Attitudes regarding the importance of residual moisture change. Information from a Highway Research Board conference held in January 1974 on moisture restrictions in hot-mix plant operations is contained elsewhere (*6*). This was during the time when drum mix plants were being introduced

TABLE 1 MOISTURE CONTENTS OF FIELD MIXES

Mix	Pug Mill	Spreader	Comments	
A	0.08%	--	Summer, Hot & Dry	
D	0.20%	0.07%	Fall, Cool	
F	0.57% 0.41% 0.39%	-- -- --	Spring, Cool & Rainy, " "	8:30 a.m. 2:00 p.m. 4:00 p.m.
F	0.58% 0.26% 0.30%	-- -- --	" " "	8:30 a.m. 11:20 a.m. 1:30 p.m.
F	0.35% 0.48%	0.21% 0.23%	" "	9:00 a.m. 10:25 a.m.
G	0.03% 0.05%	0.03% --	Summer, Hot & Dry "	
H	0.39%	--	Fall, Cool & Rainy	
I	0.25% 0.30%	-- --	Fall, Cool & Rainy "	

into the hot-mix paving industry, and higher residual moisture contents and lower temperatures were the focus of the conference. In response to increased use of drum mix plants, some states, including Alabama, changed specifications limiting residual moisture. Higher residual moisture contents were permitted for mix from drum mix plants than for mix from batch plants. There appears to have been a reversal in this trend with consistent moisture content requirements that are independent of plant type. Current FHWA recommendations (*7*) are a maximum of 0.5 percent moisture measured behind the paver.

The most damaging aspect of incomplete aggregate drying is probably the release of steam or water vapor after mixing to the completion of rolling. There are three consequences of the escaping vapor, and each has the potential for adversely affecting bond and causing moisture damage.

1. Energy expended liberating the residual moisture will result in heat loss and a lower mixing temperature. At a lower mixing temperature the asphalt viscosity increases and reduces its wetting power or ability to coat and penetrate into the aggregate.
2. Escaping steam also impedes the asphalt from bonding with the aggregate particles. Some aggregates have a greater affinity for water than for asphalt. Moisture emerging from the internal pores displaces the asphalt film at the aggregate surface, forming a water layer around the particle and preventing the asphalt from achieving intimate contact with the particle surface. This leaves the asphalt coating unbound to the aggregate and vulnerable to stripping.
3. As the mix cools, steam continuing to emerge from the internal pores of the aggregates will cause ruptures or blisters in the asphalt coating. A rupture in the asphalt film then provides an avenue for external water to enter between the asphalt film and aggregate surface.

Healing will probably partially mitigate the detrimental consequences of residual moisture. It has been shown that strength and stiffness of compacted specimens recover as introduced moisture is removed (*8,9*). Conditions in hot uncompacted mix where residual moisture is present are certainly different from conditions in compacted mix where external moisture is introduced. However, data presented later indicate that some healing may take place as residual moisture is removed during mix storage and transport. The data indicate that, in all but one case, field samples had higher strengths and retained strength ratios than laboratory samples that were compacted and cooling initiated immediately after mixing.

STRIPPING TESTING

To measure the effect of residual moisture on stripping, six mixes were evaluated by the wet-dry indirect tensile strength stripping test. Two mixes (A and J) contain 90 percent dolomitic limestone and are generally considered nonstripping mixes. The remaining four mixes (F, G, H, and I) contain siliceous sand and gravel as the dominant aggregate type and are rated from moderate to severe strippers on the basis of past field performance. Mixes H and I are surface course mixes; all other mixes are base or base/binder mixes. The aggregates for Mixes F, H, and I are from the northwestern part of Alabama and have a history of stripping problems. The aggregates for Mix G are from the southwestern part of Alabama and have a reputation for only moderate stripping problems.

Three methods were used to prepare specimens for indirect tensile testing: (*a*) field compacted plant mix, (*b*) laboratory compacted–laboratory fabricated mix (standard method), and (*c*) laboratory compacted–laboratory fabricated mix using an alternative method of aggregate heating (modified method). These preparation procedures are described in more detail in the following paragraphs.

The Tunnicliff-Root (*1*) procedure for conditioning and testing of specimens was used. Specimens were compacted to 6 to 8 percent voids, saturated to 60 to 80 percent, soaked 24 hr at 140° and 3 hr at 77°F, and tested at 77°F with 2 in./min loading.

Field Compacted Plant Mix

Hot mix was sampled from loaded trucks. Approximately 50 lb of hot mix was obtained and placed in a closed insulated box to minimize heat and moisture loss. The initial temperature of the sample varied from plant to plant between 275°F and 325°F. The hot mix was immediately taken into the field laboratory where samples were quickly measured into heated molds and compacted to 6 to 8 percent voids by an automatic Marshall hammer. The number of blows required to achieve the proper void content was determined by trial and error for each mix. Typically, 6 to 12 specimens could be compacted before the mix cooled below an acceptable level (a drop of 30°F from initial temperature was considered unacceptable). A sample of hot mix was also dried in a microwave oven for moisture content determination. When the molds could be handled, specimens were extracted and sealed individually in plastic wrap to prevent loss of moisture. At least two sets of six specimens were compacted for each mix, except Mix J, which was not sampled during construction. All specimens were transported to the laboratory, where conditioning and testing were completed within 2 days.

Laboratory Fabricated Mix (Standard Method)

Component aggregates were sampled from stockpiles and asphalt cement was secured at each plant during field sampling trips to produce corresponding laboratory specimens. The method for specimen preparation generally followed the procedure in ASTM D 1559. Stockpile samples of aggregates were combined in specified percentages and sieved to produce eight uniform size fractions (+¾ in. to #200 sieve). The fractions were recombined into individual samples to meet the job mix gradation. Aggregate samples were preheated to 325°F for 16 hr, then mechanically mixed with asphalt cement at 300°F for 3 min. The mix was then placed into heated molds, tamped with a spatula, and compacted with an automatic Marshall hammer to produce 6 to 8 percent voids in the compacted specimen. At least six compacted specimens were made for each mix.

Laboratory Fabricated Mix (Modified Method)

The following method was used to prepare specimens with aggregates containing residual moisture to simulate field mixes with incompletely dried aggregates. This general method was first used by Western Laboratories in their efforts to study instability of "wet" mixes (*10*).

For each set of specimens, sampled stockpile aggregates were combined according to job mix proportions. Aggregates were graded by size over eight sieves to the specified percentages. The aggregates for the entire set were then split at the No. 4 sieve into a coarse portion and a fine portion. The coarse aggregate portion (+#4 sieve) was placed in a can filled with tap water and set in a water bath at 140°F overnight. This soaking period allowed the coarse aggregate to achieve saturation and served as a warm-up phase in the heating process. The fine aggregates were combined in another can and placed in a convection oven at 425°F overnight.

At the end of the soaking period, the saturated coarse aggregate and water were emptied into a 6-quart pressure cooker. Hot water was added, as required, to cover all aggregates. The pressure cooker and contents were heated on a hot plate at 15 psi until the rocker valve began to release pressure. Typically, this phase took 30 min. Meanwhile, asphalt cement, standard 4-in. compaction molds, and a large mixing bowl were heated to 300°F. When the coarse aggregate had reached pressure, the fine aggregate and asphalt cement were combined in the mixing bowl. Pressure on the cooker was released, and the coarse aggregate was drained. Once the water had drained, the aggregate surfaces dried quickly, and the coarse aggregate was added to the mixing bowl. Mixing was accomplished by a large mixer until all particles were coated.

The mixture was then divided into four molds and a moisture content dish. The moisture content sample was immediately weighed and placed in the microwave oven. Two molds were covered while the other two specimens were compacted simultaneously with a twin hammer automatic Marshall compactor. The covered samples were compacted immediately after the first pair was completed. The moisture content of the mix achieved by this procedure depended on the absorption of the coarse aggregate and the length of time the aggregate was allowed to drain. It was difficult to achieve a specific moisture content, but variations were obtained by adjusting the time between draining and mixing.

TABLE 2 SUMMARY OF INDIRECT TENSILE AND BOIL TEST DATA

Mix	M.C. (%)	Voids (%)	Sat. (%)	U.C. Str. (psi)	C. Str. (psi)	TSR (%)
A-Lab	0	7.3	75	109.4	34.2	31.3
	0.18	7.8	68	68.5	32.8	47.9
	0.44	7.4	78	83.5	42.5	50.9
	0.54	7.6	68	74.6	47.9	64.9
	0.46	8.3*	70	78.1	36.9	47.2
A-Field	0.08	7.4	78	134.5	84.1	62.5
F-Lab	0	7.6	68	125.7	88.4	70.3
	0.21	7.1	69	110.1	35.7	32.4
	0.66	7.1	70	101.6	43.0	42.3
	0.90	10.7*	79	78.8	25.6	22.8
	1.50	8.6*	79	86.6	34.3	39.6
F-Field	0.58	7.8	69	117.6	74.5	63.4
	0.30	9.7*	79	120.1	68.5	57.1
	0.30	8.8*	73	134.0	79.1	59.0
G-Lab	0	6.2	71	137.1	77.7	56.7
	0.20	8.1*	66	124.4	72.7	54.1
	0.40	8.4*	78	88.4	47.2	53.4
	0.45	7.2	76	124.7	49.6	40.0
	0.75	8.5*	67	110.3	46.7	42.3
G-Field	0.05	6.6	78	121.3	65.2	53.8
	0.03	5.9*	75	108.3	59.4	54.8
H-Lab	0	7.7	76	77.8	43.8	56.3
	0.42	7.7	70	91.6	37.2	40.6
	0.43	6.7	70	106.9	42.8	40.0
	0.48	7.5	80	88.4	27.6	31.3
H-Field	0.39	7.0	72	104.5	85.8	81.8
I-Lab	0	6.2	73	205.8	129.6	63.0
	0.27	7.9	77	137.4	77.2	56.2
	0.54	8.2*	67	120.2	78.5	65.3
	0.70	7.4	76	158.1	63.6	40.2
I-Field	0.25	5.3*	82	268.2	169.2	63.1
J-Lab	0	7.2	79	--	0	0
(Set 1)•	0.19	7.1	74	80.9	14.9	18.4
	0.32	6.3	68	72.3	27.0	37.3
	0.40	6.6	76	72.1	23.5	32.7
J-Lab	0	6.3	75	127.9	13.0	10.2
(Set 2)•	0.17	6.9	76	115.9	16.6	14.3
	0.24	6.8	71	121.6	17.3	14.3
	0.38	6.8	70	112.0	33.1	29.5

*Voids ≠ 6-8%

•Set 1 & Set 2 with different sources of AC20

WET-DRY INDIRECT TENSILE STRENGTH RESULTS

Indirect tensile test results for all six mixes are given in Table 2. Included are results from field mixes and laboratory mixes prepared with the standard method and the modified method. Each row contains average moisture content, voids, and percent saturation for sets of six samples. Unconditioned and conditioned strengths are averages for sets of three samples each, and the tensile strength ratios (TSRs) are ratios of the tensile strengths.

Dolomitic Limestone Mixes (A and J)

The data in Table 2 indicate that the TSRs are low for the limestone mixes prepared by the standard method (A = 31.3 and 55.4 percent, J = 0 and 10.2 percent), which is contrary to the reported field performance. These values are, however, consistent with results from tests by Parker and Gharaybeh (*3*). Others have also reported low strength and TSR values with limestone mixes (*11*).

For Mix A, field samples had higher strengths and retained strength ratios than standard laboratory prepared samples. Samples that contained reclaimed asphalt pavement also had higher strengths and TSRs than the mix with 100 percent virgin aggregate and asphalt.

To study the effects of residual moisture, the data from Table 2 were plotted in Figures 2 through 4. These figures

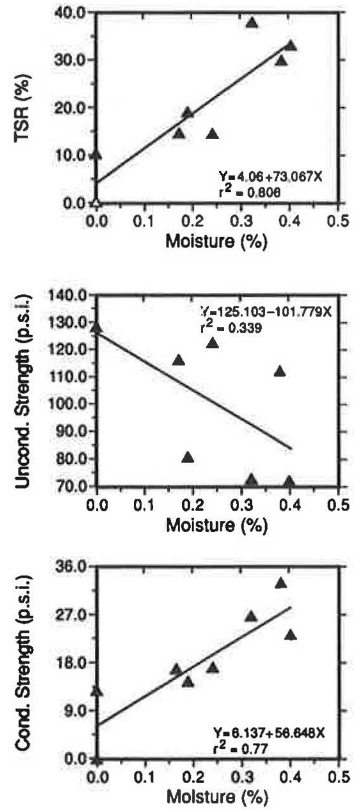

FIGURE 3 Mix J, Sets 1 and 2, laboratory data.

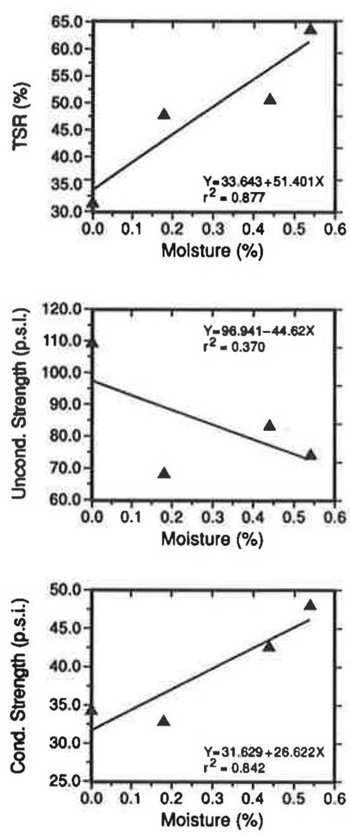

FIGURE 2 Mix A, laboratory data.

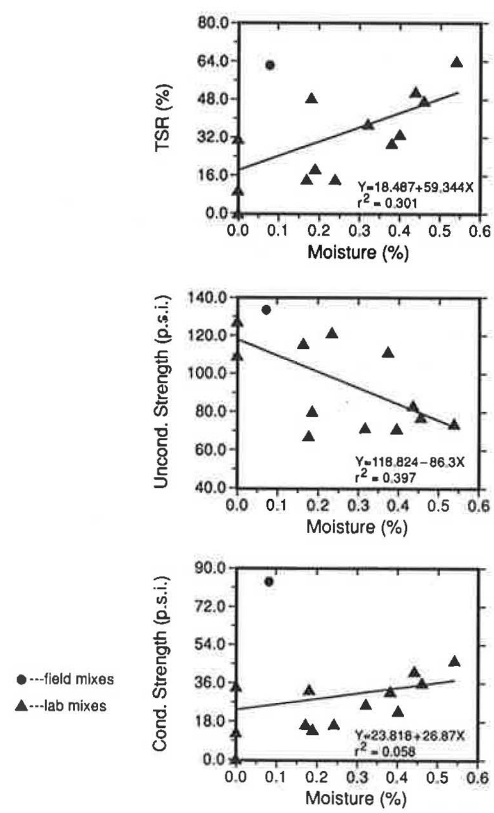

FIGURE 4 Mixes A and J, all data.

show unconditioned strength, conditioned strength, and TSR versus mix moisture content. Straight lines were fit to the data using least squares criteria.

Figure 2, which is a plot of laboratory data for Mix A, shows, unexpectedly, that TSR increases with increasing moisture content. Similar data for Mix J, shown in Figure 3, indicate the same trend. In both cases, the strength of the unconditioned samples dropped as moisture content increased, whereas the conditioned samples increased in strength with higher moisture contents. The coefficients of determination (r^2) indicate good correlations between TSR and moisture content, with values ranging from 0.88 for Mix A to 0.81 for Mix J.

Two sources of asphalt cement were used to prepare Mix J. Considered independently the same trends were demonstrated as shown in Figure 3 for the combined data. The following relationships were obtained for Sets 1 and 2, respectively.

$$\text{TSR}(\%) = 1.2 + 9.18\ (\%\ \text{moisture})$$

$$r^2 = 0.91 \tag{1}$$

$$\text{TSR}(\%) = 7.6 + 47.9\ (\%\ \text{moisture})$$

$$r^2 = 0.79 \tag{2}$$

When laboratory data for Mixes A and J are combined and field data included in Figure 4, the strength of the correlations, as expected, is reduced. However, the nature of the trends for all three variables remains the same (i.e., conditioned strength increases, unconditioned strength decreases, and TSR increases as residual moisture increases).

The reasons why residual aggregate moisture in the dolomitic limestones produces asphalt-aggregate bonds that are more resistant to the detrimental effects of water are not known. However, the evidence, increasing TSR and conditioned strength for two aggregate and three asphalt cement sources, strongly suggests that the observed trends are real. The explanation is likely a surface chemistry phenomenon resulting from unusual chemical composition or crystal structure, or both. Both limestones are quite dense (apparent specific gravities greater than 2.8) and have relatively low absorptions. Complete drying, as in standard laboratory mix preparation, produces bonds that are somewhat stronger if kept dry, but that lose strength dramatically when exposed to water. Conversely, small amounts of residual aggregate moisture produce bonds that are not as strong if kept dry, but that are more effective in resisting the detrimental effects of moisture.

The observed influence of moisture may explain the inconsistency in observed good field performance and poor performance predicted by low TSR. The small amounts of residual moisture in field mixes may produce moisture-resistant bonds that are not properly modeled with standard laboratory mix preparation procedures.

However, residual moisture does not provide a complete explanation of differences between observed and predicted performance. Even with residual moisture, TSR values for Mixes A and J are well below widely used criteria of 70 to 80 percent. In addition, conditioned strengths for Mixes A and J are not dramatically different from conditioned strengths of the four siliceous gravel mixes that will be considered in the next section. Other factors, including field mixing and possibly storage, may also affect field performance. As shown in Figure 4, TSR and conditional strengths of the field mix are higher than comparable laboratory mixes.

Siliceous Gravel Mixes (F, G, H, and I)

TSRs for standard laboratory samples of the gravel mixes are slightly higher than expected for moderate to severe strippers. TSRs for standard Mixes G, H, and I (56.7, 56.3, and 63.0 percent) correlate reasonably well with field performance; however, the standard sample for Mix F, which had a TSR right on the limiting criterion (70.3 percent), is reported to be a severe stripper.

Data for siliceous gravel mixes from standard, modified, and field samples are combined in Figures 5 through 8 to study the effects of residual moisture on tensile strength results. Although the correlations are not as strong as those for limestone mixes, Figures 5 through 8 consistently illustrate the destructive effects of moisture on the tensile strength of individual gravel mixes. With the exception of Mix H, increasing moisture contents result in lower conditioned and unconditioned strengths and a decline in TSRs. Conversely, conditioned strength and TSR increased as residual moisture increased for the limestone mixes.

Figure 5 is a plot with all data for Mix F. The $r^2 = 0.28$ indicates a weak correlation of TSR with residual moisture content. Field values plot above the regression equation. With

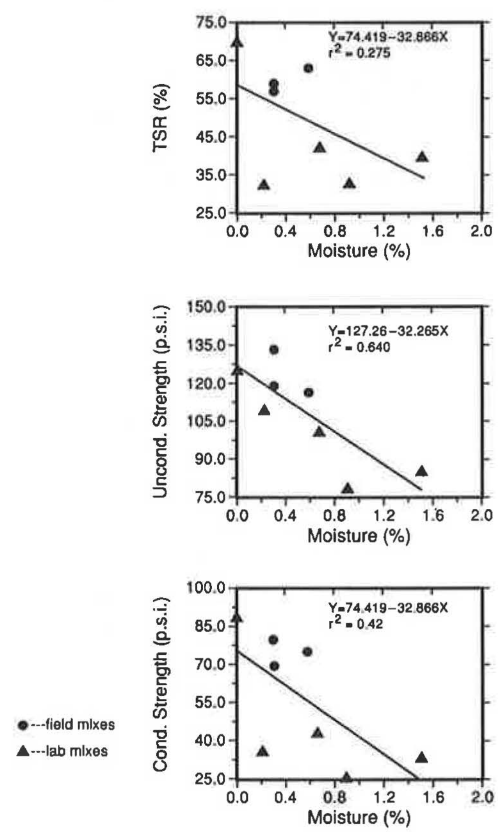

FIGURE 5 Mix F, all data.

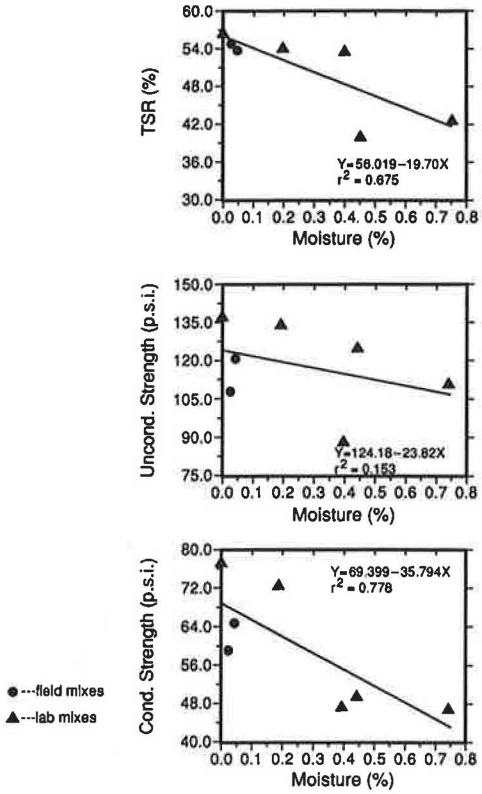

FIGURE 6 Mix G, all data.

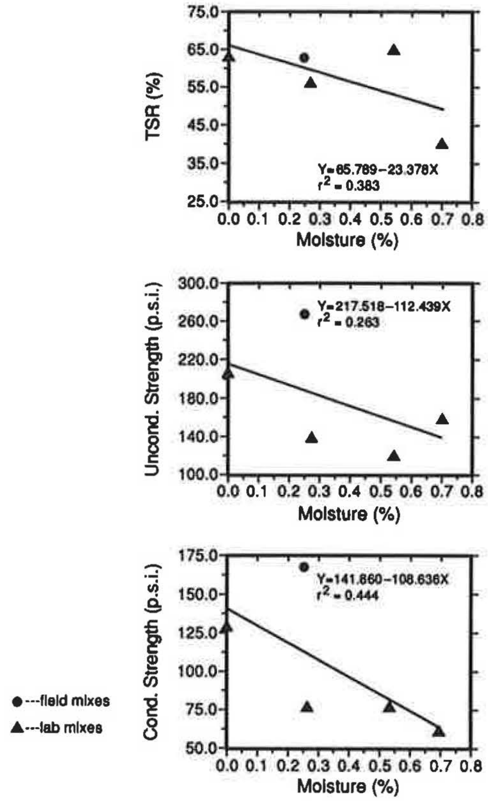

FIGURE 8 Mix I, all data.

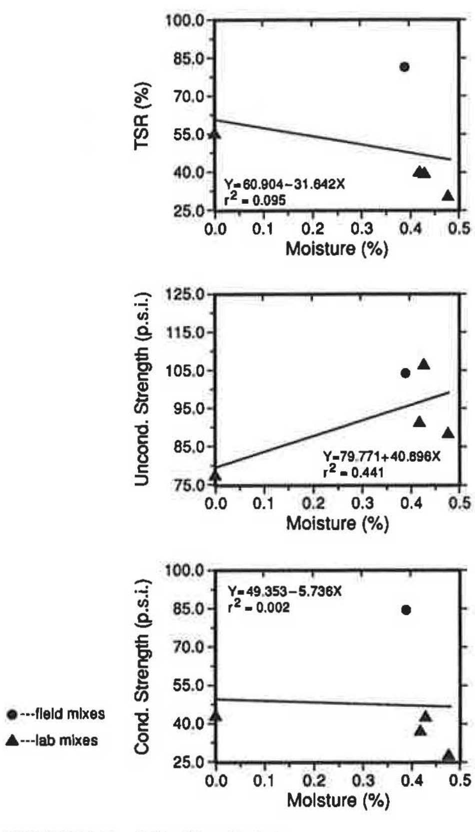

FIGURE 7 Mix H, all data.

only laboratory data the following equation was obtained, again indicating a weak correlation:

$$TSR(\%) = 53.0 - 11.5(\% \text{ moisture})$$

$$r^2 = 0.21 \qquad (3)$$

Figure 6 is a plot with all data for Mix G. The $r^2 = 0.68$ indicates a fair correlation of TSR with residual moisture content. Field values plot slightly below the regression equation. With only laboratory data the following equation was obtained, again indicating a fair correlation:

$$TSR(\%) = 57.1 - 21.6 (\% \text{ moisture})$$

$$r^2 = 0.64 \qquad (4)$$

Figure 7 is a plot with all data for Mix H. The $r^2 = 0.10$ indicates no correlation of TSR with residual moisture. However, the field value plots well above the regression equation. With only laboratory data the following equation was obtained:

$$TSR(\%) = 56.8 - 44.4 (\% \text{ moisture})$$

$$r^2 = 0.91 \qquad (5)$$

This coefficient of determination indicates a strong correlation of TSR with residual moisture. However, the sparse, poorly

distributed data diminish confidence in the correlation. Numerous attempts were made to get a wider distribution of residual moisture contents. It was finally concluded that the pore structure of the coarse aggregate (absorption = 2.63 percent) was such that drying and cooling did not occur at rates that would permit adequate mixing temperatures for a range of moisture contents.

Figure 8 is a plot with all data for Mix I. The $r^2 = 0.38$ indicates only a weak correlation of TSR with residual moisture. Again, field values plot above the regression equation. With only laboratory data the following equation was obtained, again indicating only a weak correlation:

$$\text{TSR}(\%) = 64.5 - 22.0\ (\%\ \text{moisture})$$

$$r^2 = 0.36 \qquad (6)$$

When data from Mixes F, G, H, and I were combined, the following equation was obtained:

$$\text{TSR}(\%) = 56.8 - 15.1\ (\%\ \text{moisture})$$

$$r^2 = 0.36 \qquad (7)$$

Because of differences in materials the correlation is very weak, but as was the case for individual mixes, the combined data indicate a consistently detrimental effect of residual moisture on unconditioned strength, conditioned strength, and TSR.

The strength of the correlations between tensile strength and residual moisture, as indicated by the r^2 values, are certainly lower than desirable for the siliceous gravel mixes. However, the consistency of the trends for all four mixes individually and collectively enhances the credibility of the conclusion that residual moisture has a detrimental effect on moisture susceptibility.

The causes or reasons why residual aggregate moisture in siliceous gravel is detrimental to the development of strong moisture resistant asphalt-aggregate bonds are well established. It is generally accepted that the mineralogy produces acidic surfaces that are hydrophilic in nature and are, thus, susceptible to interference of bond development during mixing (decreasing unconditioned strength with increasing moisture content) and to loss of bond during subsequent exposure to moisture (decreasing conditioned strength with increasing moisture content). When these aggregates are completely dry, relatively strong bonds develop. Absorption of asphalt into pores in the aggregate may also provide mechanical interlock and enhance bonding. However, when aggregates are wet, absorbed moisture will slow the drying process, and the escaping steam can be detrimental to bond formation and stripping resistance.

SUMMARY

The effect of residual moisture on stripping propensity appears to be a function of the mineralogy of the aggregates in the mix. Wet-dry indirect tensile test results indicate that dolomitic limestone mixes that contain some residual moisture have greater resistance to stripping. On the other hand, test results indicate that siliceous gravel mixes are less resistant to stripping when they contain residual moisture.

These responses partly explain why some laboratory stripping predictors using well-dried aggregate are not consistent with field performance. The effects of residual moisture may explain why stripping occurs erratically in asphalt pavements. Residual moisture may only be a problem for selected periods during construction, which leads to only portions of the roadway susceptible to stripping. Including tests for moisture susceptibility as a routine part of constructon quality control procedures will provide a method for identifying such conditions.

CONCLUSIONS AND RECOMMENDATIONS

Residual moisture in hot mix asphalt is a fact of life when aggregate stockpiles are wet. Absorptive coarse aggregates are especially difficult to dry by rapid heating as in typical production conditions. Standard laboratory preparation of test mix samples, however, begins with moisture-free aggregates. This difference can be significant when evaluating the moisture damage susceptibility of asphalt concrete mixes in the laboratory.

Currently available wet-dry tensile test procedures performed during mix design to assess the need for antistripping treatment may be conservative for dense dolomitic limestone mixes. However, their unusual and unexplained response warrants a conservative approach until refinements in sample preparation methodology permit better simulation of construction conditions.

Current procedures may be unconservative for some siliceous gravel mixes. For mix design purposes additional research is needed to more clearly differentiate the effects of residual moisture and modifications of laboratory sample preparation procedures to better simulate construction conditions. The potential effects of residual moisture reinforce the need for inclusion of moisture susceptibility testing during construction as part of the quality control process.

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