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16. Abstract

The purpose of this investigation was to determine the variability of the Virginia Department of Transportation's (VDOT) indirect tensile stripping test. Five contractor labs and eight VDOT labs participated in the study. Each lab performed three replicate tests on each of two mixes, one containing hydrated lime and one containing chemical antistripping additive.

The standard deviation was 3.5 percent for within-lab results and 6.1 percent for between-lab results. Lack of significant correlations between strength and voids total mix indicated that a strength correction procedure for voids is not necessary. Examination of the VDOT specification indicates that contractors need to maintain the average TSR of the alternative mix containing chemical additive at least two standard deviations above the minimum value to ensure that single tests do not fail.

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Stripping, indirect tensile test, variability, chemical additive, hydrated lime, specifications

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FINAL REPORT

# THE VARIABILITY OF THE INDIRECT TENSILE STRIPPING TEST

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(A Cooperative Organization Sponsored Jointly by the
Virginia Department of Transportation and
the University of Virginia)

In Cooperation with the U. S. Department of Transportation
Federal Highway Administration

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BITUMINOUS RESEARCH ADVISORY COMMITTEE

**ABSTRACT**

The purpose of this investigation was to determine the variability of the Virginia Department of Transportation's (VDOT) indirect tensile stripping test. Five contractor labs and eight VDOT labs participated in the study. Each lab performed three replicate tests on each of two mixes, one containing hydrated lime and one containing chemical antistripping additive.

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FINAL REPORT

# THE VARIABILITY OF THE INDIRECT TENSILE STRIPPING TEST

G. W. Maupin, Jr.

## INTRODUCTION

Virginia's indirect tensile stripping test (VTM-62) (*1*) is used to accept antistripping additives during both the mix design and production phases. When any test method is used to accept materials, it is important that the variability of the method be known accurately in order that a proper specification can be prepared. There have been many changes in the stripping test procedure since the initial variability determinations were made; therefore, it was decided that a thorough evaluation of the testing variability should be made.

The purpose of this investigation was to determine the variability of Virginia's indirect tensile stripping test (VTM-62) and to examine the present additive specifications that relate to the stripping test.

Materials for two mixes were distributed to eight of the Virginia Department of Transportation's (VDOT) materials labs and seven contractor's labs; however, two of the contractor's labs did not participate.

## MATERIALS AND MIXES

Two mixes were tested. Both used the same aggregate and gradation (S-5) and the same asphalt cement and asphalt content. The only difference in the two mixes was the type and quantity of the two antistripping additives used. The ingredients of the two mixes are listed in Table 1.

The S-5 mixes were based on an S-5 mix that has been produced and used extensively. The contractor's design gradation and the gradation that was produced in the Research Council lab for this study are very similar and are listed in Table 2. The aggregates were separated into three sizes--minus 1/2 in - plus #4, minus #4 - plus #30, and minus #30--and combined into the appropriate batch sizes for testing. One percent of the minus #30 aggregate was removed from the mixes with hydrated lime to allow for the addition of one percent lime. The Research Council delivered approximately 50 kg of aggregate, a container of hydrated lime, a container of chemical additive, and eight containers of asphalt cement to each lab.

Table 1

MIX INGREDIENTS

| Type | Source |
|---|---|
| | Aggregates |
| 80% - 1/2" Crusher run granite | Luck Stone Corp. - Powhatan |
| 20% - Grade A natural sand | M. A. Smith Sand & Gravel - Ruther Glen |
| | Asphalt Cement |
| 5.7%* - AC-20 | Exxon - Richmond |
| | Additives |
| 1.0%** - Hydrated lime | Virginia Lime Co. - Kimballton, Va. |
| 0.5%*** - 101-25B chemical | Exxon Chemical America - Milton, WI |

*5.7% by weight of total mix
**1.0% by weight of dry aggregate
***0.5% by weight of asphalt cement

Table 2

WASHED MIX GRADATIONS

| | Percent Passing | |
|---|---|---|
| Sieve | Contractors' Design | Research Council's Design |
| 1/2" | 100.0 | 100.0 |
| No. 4 | 61.0 | 61.8 |
| No. 30 | 25.0 | 23.2 |
| No. 200 | 5.5 | 5.7 |

## TESTING

The labs performed three replicate tests on a mix containing 1 percent hydrated lime and a mix containing 0.5 percent of chemical additive (see Table 3). Each replicate test used two sets of samples, three samples tested dry and three samples tested wet (see Figure 1).

Table 3

SUMMARY OF TESTS

| Mixes | Replicate | Tests/Lab | Labs | Total Tests |
|---|---|---|---|---|
| 2 | 3 | 6 | 13 | 78* |

*Total no. of samples = 78 x 6 = 468

Each lab was instructed to use stripping test method VTM-62 (Appendix A) as required in section 212 of the Virginia Department of Transportation specifications. The specimens were compacted and separated into the two sets (dry and wet) so that each set had approximately the same air void content with a target average of 7.5 ± 1 percent voids total mix (VTM). One set was subjected to vacuum under water until 55 to 80 percent of the air voids were filled and then soaked in a water bath at 140°F for 24 hours. Then both sets were tested in indirect tension at a temperature of 77°F and a vertical deformation rate of 2 in per minute. The test procedure is identical to ASTM D4867 (2) except that the air void contents are slightly different (7.5 ± 1 percent vs. 7.0 ± 1 percent) and compaction must be by the Marshall hammer for VTM-62 (whereas several compaction devices are allowed for ASTM D4867).

The stripping test produces a ratio of the strength of a conditioned (wet) set of specimens to the strength of a set of unconditioned (dry) specimens (equation 1). Since the test is an indirect tensile test, the ratio is called a tensile strength ratio (TSR), and for the purposes of this study it is expressed as a percentage.

$$TSR = S_W/S_D \times 100 \qquad (1)$$

where: TSR = tensile strength ratio (percent)
$S_W$ = wet tensile strength (psi)
$S_D$ = dry tensile strength (psi)

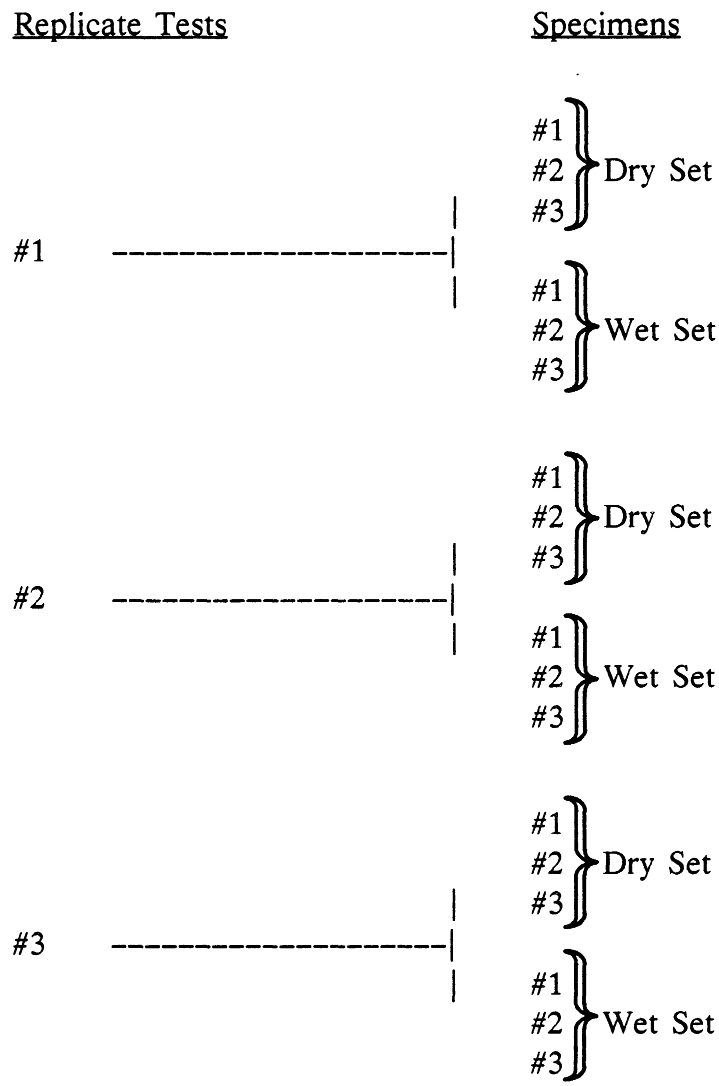


Figure 1. Tests per lab per mix.

## RESULTS

The test results for each replicate TSR test are listed in Tables 4 and 5. The individual results for each specimen are listed in Appendix B. A summary of the average TSR and related data for each lab is tabulated in Tables 6 and 7.

Table 4

TSR TEST RESULTS FOR MIXES WITH CHEMICAL ADDITIVE

| | | Dry | | Wet | | |
|---|---|---|---|---|---|---|
| Lab | Replicate | VTM % | Strength psi | VTM % | Strength psi | TSR % |
| A | 1 | 6.61 | 85.4 | 6.58 | 69.4 | 81.3 |
| | 2 | 6.86 | 80.6 | 6.89 | 72.0 | 89.3 |
| | 3 | 7.25 | 79.7 | 7.24 | 67.0 | 84.1 |
| B | 1 | 7.39 | 70.5 | 7.50 | 63.8 | 90.5 |
| | 2 | 7.17 | 82.6 | 7.33 | 69.8 | 84.5 |
| | 3 | 7.47 | 98.7 | 7.38 | 83.6 | 84.7 |
| C | 1 | 7.23 | 92.8 | 7.20 | 82.9 | 89.3 |
| | 2 | 7.51 | 91.2 | 7.46 | 81.9 | 89.8 |
| | 3 | 7.52 | 117.8 | 7.57 | 104.5 | 88.7 |
| D | 1 | 7.69 | 94.5 | 7.70 | 92.2 | 97.6* |
| | 2 | 7.49 | 99.4 | 7.47 | 71.6 | 72.0 |
| | 3 | 7.19 | 98.6 | 7.00 | 78.3 | 79.4 |
| E | 1 | 7.51 | 112.6 | 7.51 | 99.9 | 88.7 |
| | 2 | 7.84 | 112.9 | 7.81 | 99.1 | 87.8 |
| | 3 | 7.80 | 110.0 | 7.79 | 88.1 | 80.1 |
| F | 1 | 6.99 | 95.4 | 7.02 | 88.0 | 92.2 |
| | 2 | 7.48 | 98.1 | 7.46 | 83.1 | 84.7 |
| | 3 | 8.02 | 87.3 | 7.99 | 80.4 | 92.1 |
| G | 1 | 7.78 | 105.6 | 7.67 | 91.9 | 87.0 |
| | 2 | 7.91 | 90.4 | 7.98 | 80.3 | 88.8 |
| | 3 | 7.80 | 103.6 | 7.78 | 90.9 | 87.7 |
| H | 1 | 7.18 | 91.8 | 7.17 | 79.2 | 86.3 |
| | 2 | 7.30 | 94.7 | 7.29 | 78.5 | 82.9 |
| | 3 | 7.45 | 98.7 | 7.41 | 83.3 | 84.4 |

*continues*

Table 4 (continued)
TSR TEST RESULTS FOR MIXES WITH CHEMICAL ADDITIVE

| | | Dry | | Wet | | |
|---|---|---|---|---|---|---|
| Lab | Replicate | VTM % | Strength psi | VTM % | Strength psi | TSR % |
| I | 1 | 8.15 | 91.2 | 8.24 | 74.5 | 81.7 |
| | 2 | 7.93 | 91.6 | 8.09 | 77.5 | 84.6 |
| | 3 | 7.95 | 89.9 | 7.94 | 78.0 | 86.8 |
| J | 1 | 7.52 | 103.2 | 7.60 | 75.0 | 72.7 |
| | 2 | 7.01 | 114.9 | 6.93 | 93.6 | 81.5 |
| | 3 | 7.12 | 128.7 | 6.98 | 105.9 | 82.3 |
| K | 1 | 7.50 | 97.8 | 7.49 | 79.7 | 81.5 |
| | 2 | 7.69 | 100.3 | 7.62 | 81.2 | 81.0 |
| | 3 | 7.83 | 105.0 | 7.83 | 76.0 | 72.4 |
| L | 1 | 7.59 | 87.6 | 7.82 | 73.4 | 83.8 |
| | 2 | 7.83 | 85.1 | 7.97 | 73.1 | 85.9 |
| | 3 | 7.72 | 89.3 | 7.81 | 76.2 | 85.3 |
| M | 1 | 7.70 | 155.3 | 7.81 | 128.6 | 82.8 |
| | 2 | 7.70 | 133.3 | 7.72 | 105.0 | 78.8 |
| | 3 | 8.22 | 155.9 | 8.30 | 124.3 | 79.7 |
| | | | | | Avg. = | 83.8 |

*Outlier removed before calculations were performed

Table 5
TSR TEST RESULTS FOR MIXES WITH HYDRATED LIME

| | | Dry | | Wet | | |
|---|---|---|---|---|---|---|
| Lab | Replicate | VTM % | Strength psi | VTM % | Strength psi | TSR % |
| A | 1 | 7.00 | 68.9 | 7.05 | 67.3 | 97.7 |
| | 2 | 7.07 | 69.5 | 7.01 | 70.1 | 100.9 |
| | 3 | 7.47 | 69.0 | 7.49 | 67.8 | 98.3 |
| B | 1 | 6.87 | 79.1 | 7.04 | 65.2 | 82.4 |
| | 2 | 7.51 | 99.5 | 7.63 | 85.2 | 85.6 |
| | 3 | 7.01 | 93.0 | 6.90 | 72.1 | 77.5 |
| C | 1 | 7.13 | 85.0 | 7.13 | 79.6 | 93.6 |
| | 2 | 7.84 | 82.5 | 7.84 | 76.7 | 93.0 |

*continues*

Table 5 (continued)
TSR TEST RESULTS FOR MIXES WITH HYDRATED LIME

| | | Dry | | Wet | | |
|---|---|---|---|---|---|---|
| Lab | Replicate | VTM % | Strength psi | VTM % | Strength psi | TSR % |
| | 3 | 7.18 | 86.7 | 7.09 | 89.9 | 96.4 |
| D | 1 | 7.12 | 96.2 | 7.10 | 95.2 | 99.0 |
| | 2 | 7.68 | 87.0 | 7.61 | 89.5 | 102.9 |
| | 3 | 7.20 | 92.7 | 7.06 | 84.1 | 90.7 |
| E | 1 | 7.48 | 119.9 | 7.44 | 107.2 | 89.4 |
| | 2 | 7.57 | 115.4 | 7.47 | 104.7 | 90.7 |
| | 3 | 7.44 | 118.0 | 7.51 | 111.3 | 94.3 |
| F | 1 | 7.19 | 93.0 | 7.17 | 88.6 | 95.3 |
| | 2 | 6.82 | 98.9 | 6.90 | 93.2 | 94.2 |
| | 3 | 7.67 | 87.3 | 7.60 | 82.5 | 94.5 |
| G | 1 | 7.14 | 119.2 | 6.93 | 113.2 | 95.0 |
| | 2 | 7.23 | 89.7 | 7.22 | 81.4 | 90.7 |
| | 3 | 7.65 | 88.3 | 7.65 | 80.9 | 91.6 |
| H | 1 | 7.90 | 86.6 | 7.88 | 79.7 | 92.0 |
| | 2 | 8.15 | 88.3 | 8.14 | 81.9 | 92.8 |
| | 3 | 8.27 | 87.5 | 8.26 | 84.7 | 96.8 |
| I | 1 | 7.74 | 87.8 | 7.49 | 81.4 | 92.7 |
| | 2 | 8.03 | 91.9 | 7.98 | 89.0 | 96.8 |
| | 3 | 7.37 | 91.6 | 7.37 | 86.9 | 94.9 |
| J | 1 | 7.40 | 99.8 | 7.45 | 91.5 | 91.7 |
| | 2 | 6.93 | 103.0 | 6.76 | 93.4 | 90.7 |
| | 3 | 7.08 | 113.8 | 7.18 | 90.2 | 79.3 |
| K | 1 | 7.55 | 98.0 | 7.58 | 83.4 | 85.1 |
| | 2 | 7.34 | 108.3 | 7.29 | 92.1 | 85.0 |
| | 3 | 7.61 | 104.8 | 7.59 | 81.5 | 77.8 |
| L | 1 | 8.04 | 74.8 | 7.96 | 71.5 | 95.6 |
| | 2 | 8.67 | 67.2 | 8.76 | 67.6 | 100.6 |
| | 3 | 7.57 | 81.8 | 7.81 | 80.3 | 98.2 |
| M | 1 | 7.41 | 122.6 | 7.50 | 99.6 | 81.2 |
| | 2 | 8.32 | 128.3 | 8.42 | 106.8 | 83.2 |
| | 3 | 7.55 | 143.4 | 7.39 | 113.7 | 79.3 |
| | | | | | Avg. = | 91.5 |

Table 6
AVERAGE TSR RESULTS FOR CHEMICAL ADDITIVE

| Lab | Dry VTM % | Dry Strength psi | Wet VTM % | Wet Strength psi | TSR % |
|---|---|---|---|---|---|
| A | 6.91 | 81.9 | 6.90 | 69.5 | 84.9 |
| B | 7.34 | 83.9 | 7.40 | 72.4 | 86.6 |
| C | 7.42 | 100.6 | 7.41 | 89.8 | 89.3 |
| D | 7.46 | 97.5 | 7.39 | 80.7 | 75.7 |
| E | 7.72 | 111.8 | 7.70 | 95.7 | 85.5 |
| F | 7.50 | 93.6 | 7.49 | 83.8 | 89.7 |
| G | 7.83 | 99.9 | 7.81 | 87.7 | 87.8 |
| H | 7.31 | 95.1 | 7.29 | 80.3 | 84.5 |
| I | 8.01 | 90.9 | 8.09 | 76.7 | 84.4 |
| J | 7.22 | 115.6 | 7.17 | 91.5 | 78.8 |
| K | 7.67 | 101.0 | 7.65 | 79.0 | 78.3 |
| L | 7.71 | 87.3 | 7.87 | 74.2 | 85.0 |
| M | 7.87 | 148.2 | 7.94 | 119.3 | 80.4 |
| | | | | Avg. = | 83.8 |

Table 7
AVERAGE TSR RESULTS FOR HYDRATED LIME

| Lab | Dry VTM % | Dry Strength psi | Wet VTM % | Wet Strength psi | TSR % |
|---|---|---|---|---|---|
| A | 7.18 | 69.1 | 7.18 | 68.4 | 99.0 |
| B | 7.13 | 90.5 | 7.19 | 74.2 | 81.8 |
| C | 7.38 | 84.7 | 7.35 | 82.1 | 94.3 |
| D | 7.33 | 92.0 | 7.26 | 89.6 | 97.5 |
| E | 7.50 | 117.8 | 7.47 | 107.7 | 91.5 |
| F | 7.23 | 93.1 | 7.22 | 88.1 | 94.7 |
| G | 7.34 | 99.1 | 7.27 | 91.8 | 92.4 |
| H | 8.11 | 87.5 | 8.09 | 82.1 | 93.9 |
| I | 7.71 | 90.4 | 7.61 | 85.8 | 94.8 |
| J | 7.14 | 105.5 | 7.13 | 91.7 | 87.2 |
| K | 7.50 | 103.7 | 7.49 | 85.7 | 82.6 |
| L | 8.09 | 74.6 | 8.18 | 73.1 | 98.1 |
| M | 7.76 | 131.4 | 7.77 | 106.7 | 81.2 |
| | | | | Avg. = | 91.5 |

## ANALYSIS AND DISCUSSION OF RESULTS

### Estimates of Precision

The ASTM practices for conducting interlaboratory precision of test methods—ASTM C802-80, ASTM E691-79, and ASTM E178-80 (*3*)—were used for guidance in carrying out the study and the analysis of the results.

It was recommended in ASTM C802-80 that at least 10 labs should test a minimum of 3 mixes using at least 3 replicate tests per mix. The large number of tests for each voluntary participant necessitated that the number of mixes be limited to 2.

An examination of the ratios of individual laboratory cell variances to the sum of cell variances indicated that lab D had a high variance for the chemical mix. The TSR values for that cell were 0.97, 0.72, and 0.79 (0.97 is questionable). Examination of the dry and wet strength values of all of the tests used to compute the 3 ratios indicated that the high wet strengths of the test samples in one case resulted in the high TSR. Although an investigation of the data revealed no obvious reasons for the questionable result, it was felt that it should be considered an outlier, and it was not included in the computations.

The variability results in terms of within-lab and between-lab standard deviation are tabulated in Table 8. The standard deviations of the chemical and lime mixes were pooled because the variances were not significantly different at a 90 percent confidence level when the F test was applied.

The coefficient of variation (COV) of the within-lab and between-lab test results is less than 10 percent, which is an indication that the test method is acceptable. The COV for this test is comparable to the most precise tests used in asphalt mix testing.

Table 8

WITHIN-LAB AND BETWEEN-LAB STANDARD DEVIATION OF TSR

| Mix | Within Lab, % | Between Lab, % |
|---|---|---|
| Chemical | 3.6 | 5.3 |
| Lime | 3.5 | 6.8 |
| Pooled | 3.5 | 6.1 |

## Correlation of Tensile Strength and Voids

It has been surmised by some users of the test that voids may have a significant influence on the strength of specimens, even over the narrow range of values that is allowed by the test method. In order to check this hypothesis, linear regressions were performed between dry and wet strengths and total voids for each of the 13 labs resulting in 52 correlations (see Table 9). Most of the correlations were very poor as evidenced by the low correlation coefficients. The correlations were significant at a

Table 9

CORRELATION COEFFICIENTS OF STRENGTH VS. VTM

| | Chemical Additive | | Hydrated Lime | |
|---|---|---|---|---|
| Lab | Dry | Wet | Dry | Wet |
| A | 0.47 | 0.44 | 0.26 | 0.30 |
| B | 0.20 | 0.32 | 0.17 | 0.61 |
| C | 0.32 | 0.54 | 0.86* | 0.66* |
| D | 0.69* | 0.10 | 0.92* | 0.26 |
| E | 0.62 | 0.45 | 0.78* | 0.61 |
| F | 0.56 | 0.74* | 0.59 | 0.92* |
| G | 0.37 | 0.63 | 0.48 | 0.44 |
| H | 0.28 | 0.10 | 0.10 | 0.60 |
| I | 0.10 | 0.33 | 0.43 | 0.00 |
| J | 0.59 | 0.84* | 0.44 | 0.26 |
| K | 0.30 | 0.81* | 0.10 | 0.36 |
| L | 0.78* | 0.55 | 0.96* | 0.79* |
| M | 0.20 | 0.30 | 0.10 | 0.00 |

*Significant correlations at 95 percent confidence level

95 percent confidence level in only 12 of 52 cases, and there were no labs that had significant correlations in all instances (*4*). Also the t test was used to determine that there was no significant difference at a 95 percent confidence level between the average correlation coefficient of each dry and wet series and zero. In other words, the average correlation coefficients are equivalent to zero, and a significant correlation does not exist. Therefore, the use of regressions to correct strength values to the strength at the specified target voids (VTM) of 7.5 percent is neither desirable or warranted.

## Influence of Degree of Saturation

It could be surmised that the degree of saturation of the wet specimens within the relatively wide limits of 55 to 80 percent might affect the strength. An examination of correlations between the degree of saturation and the tensile strength for several labs revealed no correlation, and a cursory review of all of the data reveals no significant effect of saturation on strength.

## EXAMINATION OF SPECIFICATION

The TSR test (VTM–62) is used to determine the acceptability of an antistripping additive in both the design and production stages of asphalt concrete. The specification [Section 212.02 (g)] states that:

1. A minimum TSR of 0.75 (75 percent) must be obtained during the design and production of asphalt concrete.
2. All mixes must contain hydrated lime or an equivalent chemical additive (i.e., the TSR of a mix with chemical additive must be equal to or greater than the TSR of the mix with lime).
3. During production, the TSR of the mix with chemical additive must not be more than 6 percent below the design TSR of the mix with lime.

An example of how the specification functions is illustrated in Figures 2 and 3. A minimum TSR value is established in the design phase by performing a single test on the mix containing lime. If the contractor desires to use a chemical additive in lieu of lime he must perform a test using a chemical additive, and the test value of the mix must equal or exceed the test value of the mix containing lime. If the contractor desires to reduce the risk that his product will not fail in production, he should perform several tests on the mix with chemical additive to ensure that the average value for the mix with chemical additive is *at least* two standard deviations above the minimum value (Figure 2). During production, the minimum value is adjusted by lowering it 6 percent; however, in this case, the larger between–lab standard deviation applies. The average of the production tests must still be two standard deviations above the adjusted minimum value (Figure 3). In this example, the average TSR of the mix with chemical additive should be at least 7 percentage points above the initial design minimum value to ensure that the product passes.

The probable intent of the specification is to use the mix containing lime as a standard that produces satisfactory results; therefore, the average TSR of an alternative mix containing a chemical additive should be equal to or greater than the TSR of the mix containing lime. Since single tests are used to establish an average, there are substantial risks involved. There is a 50 percent chance that the minimum target value that is established by a single test on the lime mix will be less than the average TSR of the lime mix (see Figure 4); therefore, the average TSR of the chemical mix that is produced, may be less than the average TSR of the lime mix. One way to lessen that risk is to use more tests to more accurately define the average value.

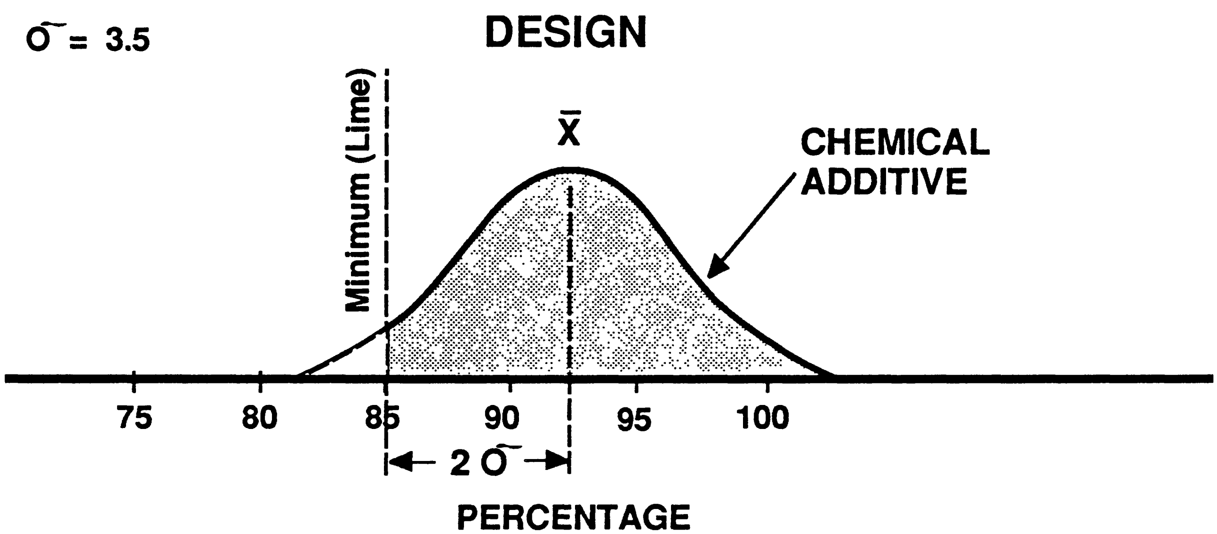


Figure 2. Example of design tests.

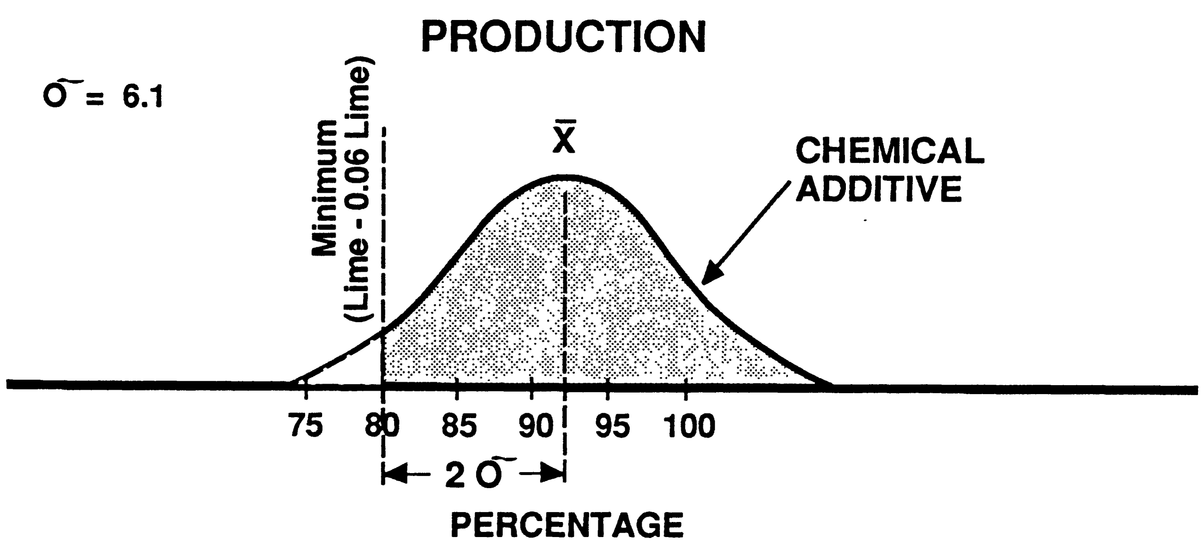


Figure 3. Example of production tests.

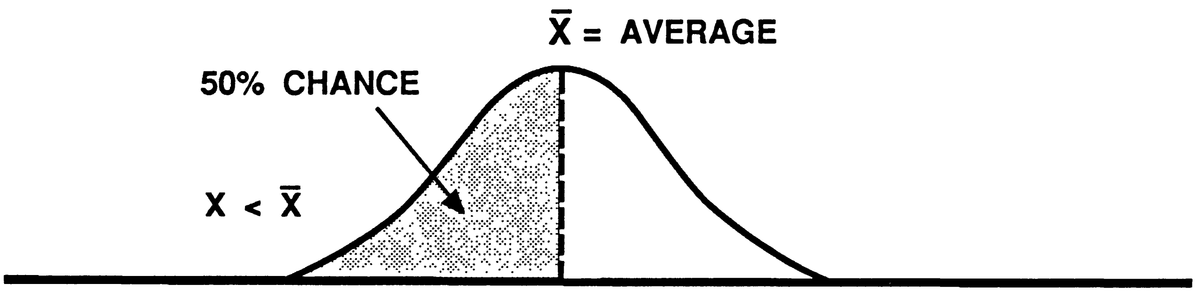


Figure 4. Distribution of individual test results as related to the average.

## CONCLUSIONS

1. The pooled standard deviations of TSR for within-lab and between-labs was 3.5 percent and 6.1 percent, respectively.
2. The COV of the test is less than 10 percent, which is considered to be an indication of an acceptable test method.
3. The use of regressions to adjust strength values to the strength at 7.5 percent voids is not warranted.
4. Since single test values can be at least two standard deviations below the average value, it is important for the contractor to produce the alternative mix containing chemical additive with an average TSR at least two standard deviations above the minimum allowable TSR.

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Superior Paving Corporation

Tri–County Asphalt Company

### Virginia Department of Transportation

Bristol District Materials Laboratory

Central Materials Laboratory

Culpeper District Materials Laboratory

Lynchburg District Materials Laboratory

Research Council Asphalt Laboratory

Salem District Materials Laboratory

Staunton District Materials Laboratory

Suffolk District Materials Laboratory

## REFERENCES


1. *Virginia Test Method Manual.* 1984. Richmond, VA: Materials Division, Virginia Department of Transportation.

2. American Society for Testing and Materials. 1989. *Road and Paving Materials; Traveled Surface Characteristics* (vol. 04.03). Philadelphia, PA.

3. American Society for Testing and Materials. 1988. *ASTM Standards on Precision and Bias for Various Applications* (3rd ed). Philadelphia, PA.

4. Volk, William. 1958. *Applied Statistics for Engineers.* New York, Toronto, London: McGraw-Hill Book Company, Inc.

APPENDIX A

Virginia Test Method

Rev. 5-1-89

# Virginia Test Method

# For

# Stripping Test for Asphalt Concrete

# Designation: VTM-62

## 1. Scope

1.1 This test method measures the strength loss resulting from damage caused by "stripping" under laboratory controlled accelerated water conditioning. The results may be used to predict long-term susceptibility to stripping of an asphalt concrete.

1.2 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

## 2. Apparatus

2.1 As listed in AASHTO T-245, with the exception of Sec. 2.6. Additional equipment required.

2.2 77 ± 1°F water bath thermostatically controlled.

2.3 6" Caliper

2.4 Polycarbonate plastic or equal vacuum container with vacuum gage. (with pref. bottom)

2.5 Automatic Marshall compactor.

2.6 Test breaking head with curved loading strips (0.5 in. wide and 2 in. radius and minimum of 3" long).

2.7 Aluminum pans having a surface area of 75-100 $in.^2$ in the bottom and a depth of approximately 1 in.

## 3. Preparation of Laboratory Test Specimens

3.1 Make at least six specimens for each test, three to be tested dry and three to be tested after partial saturation and moisture conditioning.

3.2 When a liquid antistripping additive is used, heat a sufficient quantity of asphalt cement for one batch to 275 ± 5°F in a loosely covered one-quart can in an oven. Add the required quantity of additive. Immediately stir contents until thoroughly mixed. Maintain the treated asphalt cement at 275 ± 5°F in the can until it is used. If the treated asphalt cement is not used on the same day it is prepared or is allowed to cool so that it would require reheating, discard it.

3.3 When hydrated lime is used as the antistripping additive, simulate the application procedure expected in the field. Compose a batch of damp mineral aggregate, and adjust its moisture content to the minimum specified level. Add the required quantity of hydrated lime (type specified) to the damp aggregate, and thoroughly mix the entire mass until a uniform distribution has been achieved. Take care to minimize loss of the hydrated lime to the atmosphere in the form of dust.

NOTE 1: When using RAP on lab test, lime will be figured on the total aggregate for the mix design, but will only be added to the virgin aggregate containing 3% moisture. The RAP material will be heated to 275 ± 5°F, same as the virgin aggregate and the two blended together with the required asphalt.

3.4 After mixing, heat the treated aggregate in a 275°F oven until the temperature of the aggregate is 275 ± 5°F and maintain it at that temperature until it is used (within 2 hours). The asphalt cement should be heated on a hot plate (with continuous stirring) or in an oven to 275 ± 5°F. Combine the aggregate and asphalt and mix until the aggregate is thoroughly coated. The aggregate and asphalt may be mixed as a single specimen or as multiple specimens and then separated.

After mixing, spread the mixture for each specimen uniformly in an aluminum pan and place in a 275°F oven for not less than one hour and not more than two hours prior to compaction at a temperature of 275 ± 5°F. (Samples from the hot mix plant should be reheated to 275 ± 5°F. and thoroughly remixed. The mix should not remain in the oven for more than 30 minutes after reaching 275 ± 5°F and it should only be reheated once).

NOTE 2: Remove the plus 3/4 in. material when testing asphalt concrete mixtures containing plus 1 in. aggregate.

NOTE 3: Tests for comparing for lime versus a chemical additive shall be run simultaneously.

3.5 Compact the mixture into Marshall specimens (4 in. dia. x 2.5 in. thick) with a Marshall hammer. Use a compactive effort yielding an average 7.5% ± 1% (Voids, Total Mixture), and use no individual specimen beyond 7.5 ± 2%. After extraction from the molds, cool the specimens to room temperature before proceeding. The average voids in the liquid additive cores, and the average voids in the lime cores must be within 0.5%.

4. Measurement of Physical Properties

4.1 Determine the theoretical maximum specific gravity of an aliquot portion of mixture that has been subjected to the entire preparation procedure prior to compaction or by using the "dry" specimens after the tensile test is performed by AASHTO T 209.

4.2 Determine the specimen height by ASTM Test Method D3549.

4.3 Determine the bulk specific gravity by AASHTO T 166, Method "A" approximately 1 hr. prior to vacuum saturation and express the volume of the specimen in cubic centimeters. The term B - C in AASHTO T 166, Method "A", is the volume of the specimen in cubic centimeters.

4.4 Calculate the percent of air voids by AASHTO T 269, and multiply it by the volume of the specimen to obtain the volume of air.

4.5 Divide the specimens into a dry group of three specimens and a preconditioned group of three specimens so that the average bulk specific gravity of each group is approximately equal. The specimens with specific gravities that differ from the average specific gravity the most should be assigned to the dry group. Store the group to be tested dry at room temperature until needed in Section 5.7.

5. Vacuum Saturation and Moisture Conditioning

5.1 After 20 to 30 hrs., partially saturate the group to be moisture conditioned by vacuum so that the volume of water is between 55% and 80% of the volume of the air in the specimen. The magnitude of vacuum and time of duration may be varied for each mix to achieve the specified degree of saturation.

5.2 Determine the bulk specific gravity of the partially saturated specimens using AASHTO T 166, Method "A". Determine the volume of absorbed water by subtracting the air dry weight of the specimen found in Section 4.3 from the saturated surface dry weight of the partially saturated specimen. (Note: 1 gram of water = 1 cc).

5.3 Determine the degree of saturation by dividing the volume of absorbed water found in Section 5.2 by the volume of air voids found in Section 4.4 and express the result as a percentage. If the volume of water is between 55% and 80% of the volume of air, proceed to Section 5.4. If the volume of water is less than 55%, repeat the procedure beginning with Section 5.1 using a slightly higher partial vacuum. If the volume of water is more than 80%, discard the specimen.

5.4 Moisture condition the partially saturated specimens by soaking in distilled or demineralized water at 140°F for 24 hours.

5.5 Place the moisture conditioned specimens into a 77 ± 1°F water bath for 1 hour. At the end of 1 hour, proceed with Sections 5.6 and 6.1 for each moisture conditioned specimen. It is important that each specimen be tested as soon as possible after removal from the water bath so that the temperature of the specimen does not change excessively.

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5.6 Determine the bulk specific gravity by using AASHTO T 166, Method "A", of each moisture conditioned specimen. Determine water absorption and the degree of saturation in accordance with Section 5.2 and Section 5.3. A degree of saturation exceeding 80% is acceptable in this step.

5.7 Place the dry specimens into a 77 ± 1°F water bath for 20 minutes before performing the indirect tensile test.

6. Indirect Tensile Test

6.1 Position each specimen into the the test breaking head and place the completed assembly in position on the testing machine. Care must be taken in placing the specimen in the breaking head so that the load will be applied along the diameter of the specimen. Apply the load to the specimen by moving the testing machine head at a constant rate of 2 in. per minute. Record the maximum compressive load. Continue loading until the specimen fractures; break it open and estimate the degree of stripping on a scale of 0 to 5. Assign 0 for no stripping and 5 for very severe stripping. If substantial stripping is visible, the sample fails requardless of the T.S.R. value.

NOTE 4: When running comparison tests using chemical additive versus lime, if the chemical additive specimens visually shows sugstantially more stripping than the lime specimens the chemical additive will be rejected reguardless of the T.S.R. value.

7. Calculations

7.1 Tensile Strength

$$S_t = 2P/ tD (\pi)$$

Where $S_t$ = tensile strength, psi

$P$ = maximum load, pounds

$t$ = specimen height, inches

$D$ = specimen diameter, inches

$\pi$ = 3.14

7.2 Tensile Strength Ratio

$$TSR = (S_{tm}/S_{td})$$

Where TSR = tensile strength ratio, percent

$S_{tm}$ = average tensile strength of moisture conditioned group, psi

$S_{td}$ = average tensile strength of dry group, psi

LAB /BM# ________

5-1-89

# LABORATORY DATA SHEET, TENSILE STRENGTH RATIO

Mix ______________________ Additive ______________________

Paving Contractor ______________________ Testing Lab ______________________

Room Temp. ____________ Date Tested ____________ By ____________

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sample I.D. | | | | | | | | | |
| Diameter, in. | D | | | | | | | | |
| Thickness, in. | t | | | | | | | | |
| Dry Weight in Air, gm | A | | | | | | | | |
| SSD Weight, gm | B | | | | | | | | |
| Weight in Water, gm | C | | | | | | | | |
| Volume, B–C, cc | E | | | | | | | | |
| Bulk Sp. Gr., A/E | F | | | | | | | | |
| Max. Sp. Gr. | G | | | | | | | | |
| % Air Void, 100(G–F)/G | H | | | | | | | | |
| Volume Air Void, HE/100, cc | I | | | | | | | | |
| Load, pounds | P | | | | | | | | |

Saturated ____________ min. @ ____________ "Hg or ____________ psi

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SSD Weight, gm | B' | | | | | | | | |
| Weight in Water, gm | C' | | | | | | | | |
| Volume, B'–C', cc | E' | | | | | | | | |
| Vol. Abs. Water, B'–A, cc | J' | | | | | | | | |
| % Saturation, 100J'/I | | | | | | | | | |

Conditioned 24 hrs. in 140°F Water

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SSD Weight, gm | B" | | | | | | | | |
| Weight in Water, gm | C" | | | | | | | | |
| Volume, B"–C", cc | E" | | | | | | | | |
| Vol. Abs. Water, B"–A, cc | J" | | | | | | | | |
| % Saturation, 100J"/I | | | | | | | | | |
| Load, pounds | P" | | | | | | | | |
| Dry Strength, 2P/tDπ | $S_{td}$ | | | | | | | | |
| Wet Strength, 2P"/tDπ | $S_{tm}$ | | | | | | | | |
| TSR, $S_{tm}/S_{td}$ | | | | | | | | | |
| Visual Stripping, 0–5 | | | | | | | | | |

# LABORATORY DATA SHEET, TENSILE STRENGTH RATIO 5-1-89

Mix S-5 Additive 1% Hydrated Lime

Paving Contractor Smith Construction Co. Testing Lab Same

Room Temp. 72°F Date Tested 10-20-86 By John Doe

| Sample I.D. | | 1 | 2 | 3 | 4 | 5 | 6 | | |
|---|---|---|---|---|---|---|---|---|---|
| Diameter, in. | D | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | 3.96 | | |
| Thickness, in. | t | 2.48 | 2.49 | 2.52 | 2.50 | 2.52 | 2.48 | | |
| Dry Weight in Air, gm | A | 1192.0 | 1190.4 | 1193.6 | 1189.3 | 1197.0 | 1189.3 | | |
| SSD Weight, gm | B | 1194.2 | 1192.1 | 1197.0 | 1192.4 | 1200.7 | 1192.0 | | |
| Weight in Water, gm | C | 694.0 | 692.4 | 689.4 | 689.4 | 692.0 | 691.8 | | |
| Volume, B–C, cc | E | 500.2 | 499.7 | 507.6 | 503.0 | 508.7 | 500.2 | | |
| Bulk Sp. Gr., A/E | F | 2.383 | 2.382 | 2.351 | 2.364 | 2.353 | 2.378 | | |
| Max. Sp. Gr. | G | 2.533 | 2.533 | 2.533 | 2.533 | 2.533 | 2.533 | | |
| % Air Void, 100(G–F)/G | H | 5.92 | 5.96 | 7.19 | 6.67 | 7.11 | 6.12 | | |
| Volume Air Void, HE/100, cc | I | 29.5 | 30.0 | 36.5 | 33.7 | 36.1 | 30.5 | | |
| Load, pounds | P | | 2480 | 2790 | | | 2740 | | |

Saturated 1 min. @ ______ "Hg or 10 psi

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SSD Weight, gm | B' | 1209.2 | | | 1209.6 | 1218.2 | | | |
| Weight in Water, gm | C' | 710.4 | | | 707.6 | 710.6 | | | |
| Volume, B'–C', cc | E' | 498.8 | | | 502.0 | 507.6 | | | |
| Vol. Abs. Water, B'–A, cc | J' | 17.2 | | | 20.3 | 21.2 | | | |
| % Saturation, 100J'/I | | 58.3 | | | 60.2 | 58.7 | | | |

Conditioned 24 hrs. in 140°F Water

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SSD Weight, gm | B" | 1212.7 | | | 1213.8 | 1222.9 | | | |
| Weight in Water, gm | C" | 712.5 | | | 710.3 | 713.4 | | | |
| Volume, B"–C", cc | E" | 500.2 | | | 503.5 | 509.5 | | | |
| Vol. Abs. Water, B"–A, cc | J" | 20.7 | | | 24.5 | 25.9 | | | |
| % Saturation, 100J"/I | | 70.2 | | | 72.7 | 71.7 | | | |
| Load, pounds | P" | 2460 | | | 2650 | 2330 | | Average | |
| Dry Strength, 2P/tDπ | $S_{td}$ | | 160 | 178 | | | 178 | 172 | |
| Wet Strength, 2P"/tDπ | $S_{tm}$ | 160 | | | 170 | 149 | | 160 | |
| TSR, $S_{tm}/S_{td}$ | | | | | | | | 0.93 | |
| Visual Stripping, 0-5 | | 0 | 0 | 0 | 0 | 1 | 0 | | |

# APPENDIX B

# INDIVIDUAL TEST VALUES

Chemical Additive

| Lab | Test | Maximum Specific Gravity | Dry VTM | Dry Strength | Wet VTM | Wet Strength | % Saturation Initial | % Saturation Final |
|---|---|---|---|---|---|---|---|---|
| A | 1 | 2.528 | 6.92 | 88.3 | 6.61 | 64.8 | 58.9 | 74.0 |
| | 2 | | 6.25 | 84.0 | 6.45 | 72.5 | 56.6 | 75.0 |
| | 3 | | 6.65 | 83.9 | 6.69 | 70.8 | 60.3 | 76.1 |
| | 1 | | 7.59 | 79.2 | 6.69 | 70.6 | 59.0 | 74.6 |
| | 2 | | 6.53 | 80.0 | 6.69 | 76.9 | 61.3 | 77.8 |
| | 3 | | 6.45 | 82.6 | 7.28 | 68.5 | 73.2 | 82.8 |
| | 1 | | 7.04 | 79.7 | 7.16 | 64.1 | 60.9 | 79.1 |
| | 2 | | 7.56 | 79.7 | 7.28 | 66.7 | 63.7 | 82.4 |
| | 3 | | 7.16 | 79.8 | 7.28 | 70.1 | 64.6 | 82.7 |
| B | 1 | 2.543 | 7.20 | 68.7 | 7.59 | 64.4 | 61.2 | 73.8 |
| | 2 | | 7.78 | 70.1 | 7.51 | 59.8 | 61.1 | 78.1 |
| | 3 | | 7.19 | 72.6 | 7.41 | 67.1 | 56.2 | 67.6 |
| | 1 | | 6.92 | 82.5 | 7.47 | 71.6 | 62.8 | 74.3 |
| | 2 | | 7.59 | 78.9 | 7.31 | 67.5 | 67.3 | 79.6 |
| | 3 | | 7.00 | 86.5 | 7.20 | 70.2 | 76.1 | 88.6 |
| | 1 | | 7.90 | 83.7 | 7.31 | 82.1 | 74.5 | 83.8 |
| | 2 | | 7.27 | 107.6 | 7.35 | 84.1 | 60.9 | 70.7 |
| | 3 | | 7.24 | 104.8 | 7.47 | 84.7 | 65.6 | 75.0 |
| C | 1 | 2.538 | 6.86 | 83.2 | 7.25 | 74.7 | 68.0 | 74.7 |
| | 2 | | 7.45 | 95.6 | 7.13 | 87.9 | 61.2 | 87.9 |
| | 3 | | 7.37 | 99.5 | 7.21 | 86.2 | 58.2 | 86.2 |
| | 1 | | 7.29 | 82.7 | 7.41 | 73.5 | 70.9 | 76.8 |
| | 2 | | 7.92 | 99.7 | 7.37 | 85.4 | 64.2 | 72.6 |
| | 3 | | 7.33 | 91.3 | 7.60 | 86.8 | 55.1 | 64.8 |
| | 1 | | 7.05 | 124.9 | 7.53 | 102.1 | 62.3 | 68.7 |
| | 2 | | 7.60 | 112.2 | 7.37 | 104.0 | 66.4 | 73.7 |
| | 3 | | 7.92 | 116.4 | 7.80 | 107.3 | 64.3 | 74.2 |
| D | 1 | 2.545 | 8.13 | 87.9 | 8.09 | 84.9 | 69.1 | 84.2 |
| | 2 | | 7.27 | 101.7 | 7.82 | 89.7 | 71.9 | 93.9 |
| | 3 | | 7.66 | 94.0 | 7.19 | 101.9 | 56.0 | 70.1 |

Chemical Additive (cont.)

| Lab | Test | Maximum Specific Gravity | Dry VTM | Dry Strength | Wet VTM | Wet Strength | % Saturation Initial | % Saturation Final |
|---|---|---|---|---|---|---|---|---|
| | 1 | | 7.78 | 91.6 | 7.35 | 69.8 | 69.6 | 69.8 |
| | 2 | | 6.64 | 105.0 | 7.07 | 73.0 | 66.6 | 73.0 |
| | 3 | | 8.06 | 101.5 | 7.98 | 72.1 | 71.3 | 72.1 |
| | 1 | | 7.19 | 97.9 | 7.31 | 77.3 | 64.3 | 77.3 |
| | 2 | | 7.19 | 99.2 | 6.76 | 71.9 | 64.5 | 71.9 |
| | 3 | | | | 6.92 | 85.6 | 63.1 | 85.6 |
| E | 1 | 2.531 | 7.59 | 109.9 | 7.31 | 102.2 | 72.7 | 84.7 |
| | 2 | | 7.35 | 114.8 | 7.70 | 94.0 | 71.5 | 82.0 |
| | 3 | | 7.59 | 113.1 | 7.51 | 103.5 | 66.4 | 79.6 |
| | 1 | | 8.18 | 108.4 | 7.70 | 100.8 | 68.2 | 79.5 |
| | 2 | | 8.22 | 106.1 | 7.98 | 99.5 | 67.5 | 76.8 |
| | 3 | | 7.11 | 124.3 | 7.74 | 97.0 | 71.9 | 80.9 |
| | 1 | | 7.82 | 98.4 | 7.90 | 87.5 | 71.1 | 82.0 |
| | 2 | | 7.63 | 114.2 | 7.66 | 85.8 | 72.7 | 87.1 |
| | 3 | | 7.94 | 117.4 | 7.82 | 91.0 | 71.0 | 80.4 |
| F | 1 | 2.536 | 7.29 | 94.7 | 7.06 | 86.3 | 67.4 | 76.7 |
| | 2 | | 7.10 | 99.1 | 6.98 | 89.3 | 66.2 | 79.9 |
| | 3 | | 6.59 | 92.4 | 7.02 | 88.4 | 64.4 | 74.0 |
| | 1 | | 7.33 | 103.9 | 7.37 | 79.6 | 73.4 | 87.1 |
| | 2 | | 7.45 | 94.5 | 7.53 | 81.0 | 72.3 | 87.6 |
| | 3 | | 7.65 | 96.0 | 7.49 | 88.7 | 70.9 | 84.9 |
| | 1 | | 7.85 | 93.4 | 8.08 | 77.7 | 74.7 | 89.8 |
| | 2 | | 8.12 | 85.4 | 8.00 | 81.9 | 72.7 | 86.5 |
| | 3 | | 8.08 | 83.2 | 7.89 | 81.7 | 74.8 | 89.6 |
| G | 1 | 2.567 | 7.56 | 104.0 | 7.79 | 85.6 | 72.7 | 84.3 |
| | 2 | | 7.95 | 104.4 | 7.75 | 98.7 | 71.8 | 83.3 |
| | 3 | | 7.83 | 108.3 | 7.48 | 91.4 | 74.3 | 83.5 |
| | 1 | | 8.06 | 87.0 | 8.00 | 82.2 | 72.6 | 80.4 |
| | 2 | | 7.56 | 95.2 | 7.95 | 78.6 | 72.5 | 79.7 |
| | 3 | | 8.10 | 88.9 | 8.00 | 80.1 | 73.6 | 80.1 |

Chemical Additive (cont.)

| Lab | Test | Maximum Specific Gravity | Dry VTM | Dry Strength | Wet VTM | Wet Strength | % Saturation Initial | % Saturation Final |
|---|---|---|---|---|---|---|---|---|
| | 1 | | 7.64 | 98.8 | 7.99 | 82.9 | 72.6 | 80.4 |
| | 2 | | 8.06 | 103.7 | 7.56 | 91.0 | 61.9 | 65.3 |
| | 3 | | 7.71 | 108.4 | 7.79 | 98.7 | 75.8 | 85.9 |
| H | 1 | 2.525 | 7.17 | 90.4 | 7.13 | 75.1 | 57.7 | 77.9 |
| | 2 | | 7.17 | 91.6 | 7.56 | 84.2 | 62.2 | 79.9 |
| | 3 | | 7.21 | 93.4 | 6.81 | 78.3 | 59.5 | 75.1 |
| | 1 | | 7.01 | 99.5 | 7.01 | 80.5 | 59.1 | 72.7 |
| | 2 | | 7.29 | 86.8 | 7.09 | 79.6 | 55.2 | 72.0 |
| | 3 | | 7.60 | 97.8 | 7.76 | 75.4 | 60.5 | 72.7 |
| | 1 | | 7.56 | 97.4 | 7.29 | 87.4 | 64.9 | 78.8 |
| | 2 | | 7.41 | 97.0 | 7.33 | 81.1 | 60.3 | 76.6 |
| | 3 | | 7.37 | 101.8 | 7.60 | 81.4 | 63.3 | 77.6 |
| I | 1 | 2.547 | 7.97 | 90.6 | 8.24 | 72.1 | 61.4 | 72.1 |
| | 2 | | 8.01 | 91.6 | 8.17 | 76.4 | 61.2 | 76.4 |
| | 3 | | 8.48 | 91.5 | 8.32 | 74.9 | 61.8 | 74.9 |
| | 1 | | 7.66 | 94.4 | 7.93 | 80.8 | 61.6 | 77.9 |
| | 2 | | 7.66 | 88.4 | 8.28 | 75.2 | 59.9 | 75.2 |
| | 3 | | 8.48 | 91.9 | 8.05 | 76.5 | 63.4 | 76.5 |
| | 1 | | 7.70 | 91.7 | 7.85 | 75.5 | 64.0 | 80.8 |
| | 2 | | 7.58 | 89.7 | 8.52 | 79.3 | 62.3 | 77.2 |
| | 3 | | 8.56 | 88.4 | 7.46 | 79.3 | 57.8 | 71.0 |
| J | 1 | 2.540 | 7.71 | 99.7 | 7.68 | 73.2 | 71.0 | 84.0 |
| | 2 | | 7.48 | 106.5 | 7.44 | 75.2 | 69.8 | 84.0 |
| | 3 | | 7.37 | 103.5 | 7.67 | 76.6 | 67.3 | 80.4 |
| | 1 | | 7.05 | 112.1 | 6.91 | 92.2 | 67.1 | 80.9 |
| | 2 | | 6.83 | 113.5 | 6.92 | 88.6 | 70.1 | 84.5 |
| | 3 | | 7.16 | 119.1 | 6.96 | 99.9 | 65.9 | 75.4 |
| | 1 | | 6.92 | 129.2 | 7.01 | 107.6 | 61.8 | 73.4 |
| | 2 | | 7.24 | 129.3 | 6.93 | 109.8 | 65.8 | 78.1 |
| | 3 | | 7.20 | 127.7 | 7.01 | 100.3 | 66.6 | 79.0 |

Chemical Additive (cont.)

| Lab | Test | Maximum Specific Gravity | Dry VTM | Dry Strength | Wet VTM | Wet Strength | % Saturation Initial | % Saturation Final |
|---|---|---|---|---|---|---|---|---|
| K | 1 | 2.550 | 7.53 | 99.7 | 6.75 | 85.1 | 60.8 | 69.5 |
| | 2 | | 7.57 | 96.4 | 7.65 | 79.0 | 71.1 | 79.5 |
| | 3 | | 7.41 | 97.3 | 8.08 | 74.9 | 76.2 | 82.5 |
| | 1 | | 7.80 | 101.1 | 8.20 | 77.5 | 68.2 | 73.0 |
| | 2 | | 8.08 | 98.9 | 7.22 | 82.5 | 68.3 | 74.7 |
| | 3 | | 7.18 | 100.8 | 7.45 | 83.5 | 63.3 | 69.7 |
| | 1 | | 7.69 | 105.8 | 7.84 | 73.8 | 65.2 | 75.9 |
| | 2 | | 8.04 | 103.5 | 7.88 | 73.8 | 67.7 | 78.4 |
| | 3 | | 7.76 | 105.8 | 7.76 | 80.3 | 68.4 | 77.4 |
| L | | 2.544 | | | | | | |
| | 1 | | 8.18 | 81.2 | 7.82 | 70.9 | 69.1 | 81.5 |
| | 2 | | 7.15 | 93.9 | 7.86 | 75.5 | 69.5 | 79.0 |
| | 3 | | 7.43 | 87.8 | 7.78 | 73.7 | 70.1 | 80.6 |
| | 1 | | 7.74 | 87.8 | 7.94 | 73.0 | 58.1 | 73.1 |
| | 2 | | 7.43 | 86.3 | 8.10 | 74.1 | 63.0 | 74.0 |
| | 3 | | 8.33 | 81.2 | 7.86 | 72.3 | 63.3 | 78.9 |
| | 1 | | 7.51 | 86.7 | 7.94 | 69.0 | 61.8 | 81.7 |
| | 2 | | 8.14 | 86.2 | 7.63 | 81.8 | 62.5 | 73.5 |
| | 3 | | 7.51 | 94.9 | 7.86 | 77.7 | 61.6 | 74.1 |
| M | 1 | 2.549 | 7.30 | 154.9 | 7.53 | 131.7 | 59.8 | 73.4 |
| | 2 | | 8.08 | 155.7 | 8.04 | 127.1 | 55.0 | 64.9 |
| | 3 | | 7.73 | 155.3 | 7.85 | 127.0 | 63.1 | 73.8 |
| | 1 | | 7.61 | 132.3 | 7.65 | 105.7 | 74.9 | 90.7 |
| | 2 | | 8.20 | 134.3 | 7.38 | 105.9 | 69.9 | 87.5 |
| | 3 | | 7.30 | 133.3 | 8.12 | 103.3 | 68.6 | 79.6 |
| | 1 | | 8.59 | 147.5 | 8.43 | 125.6 | 56.7 | 72.0 |
| | 2 | | 8.08 | 160.1 | 8.32 | 125.0 | 55.0 | 74.4 |
| | 3 | | 8.00 | 160.2 | 8.16 | 122.2 | 55.3 | 72.6 |

Hydrated Lime

| Lab | Test | Maximum Specific Gravity | Dry VTM | Dry Strength | Wet VTM | Wet Strength | % Saturation Initial | % Saturation Final |
|---|---|---|---|---|---|---|---|---|
| A | 1 | 2.515 | 6.60 | 70.6 | 7.08 | 65.1 | 60.7 | 72.6 |
| | 2 | | 7.20 | 66.7 | 7.16 | 66.6 | 59.4 | 72.0 |
| | 3 | | 7.20 | 69.4 | 6.92 | 70.3 | 56.2 | 69.9 |
| | 1 | | 6.88 | 74.6 | 7.08 | 65.8 | 63.9 | 65.8 |
| | 2 | | 7.44 | 67.0 | 7.00 | 69.5 | 65.8 | 69.5 |
| | 3 | | 6.88 | 67.0 | 6.96 | 75.0 | 61.7 | 75.0 |
| | 1 | | 7.63 | 70.9 | 7.44 | 67.0 | 58.5 | 71.2 |
| | 2 | | 7.55 | 68.8 | 7.40 | 67.0 | 59.6 | 72.9 |
| | 3 | | 7.24 | 67.2 | 7.63 | 69.3 | 59.8 | 74.0 |
| B | 1 | 2.534 | 8.05 | 67.0 | 7.06 | 61.6 | 71.4 | 80.8 |
| | 2 | | 6.39 | 84.6 | 7.30 | 61.3 | 59.0 | 70.2 |
| | 3 | | 6.16 | 85.6 | 6.75 | 72.6 | 65.0 | 76.5 |
| | 1 | | 7.85 | 104.6 | 7.38 | 79.9 | 59.7 | 73.2 |
| | 2 | | 7.14 | 97.5 | 7.62 | 86.0 | 58.9 | 71.1 |
| | 3 | | 7.54 | 96.5 | 7.89 | 89.8 | 69.6 | 84.1 |
| | 1 | | 6.63 | 100.2 | 6.87 | 80.9 | 58.0 | 65.6 |
| | 2 | | 6.79 | 96.6 | 6.99 | 69.8 | 65.9 | 73.1 |
| | 3 | | 7.62 | 82.1 | 6.83 | 65.7 | 69.7 | 81.1 |
| C | 1 | 2.534 | 6.55 | 89.0 | 7.30 | 70.1 | 62.6 | 68.3 |
| | 2 | | 7.22 | 84.8 | 7.14 | 82.9 | 66.9 | 69.7 |
| | 3 | | 7.62 | 81.2 | 6.95 | 85.8 | 60.5 | 66.5 |
| | 1 | | 7.46 | 86.4 | 8.56 | 69.6 | 56.6 | 63.0 |
| | 2 | | 8.92 | 74.6 | 7.42 | 78.7 | 66.0 | 71.4 |
| | 3 | | 7.14 | 86.4 | 7.54 | 81.8 | 61.5 | 68.7 |
| | 1 | | 7.38 | 82.3 | 7.02 | 85.7 | 58.1 | 66.1 |
| | 2 | | 7.46 | 81.2 | 6.79 | 92.4 | 60.2 | 69.4 |
| | 3 | | 6.71 | 96.6 | 7.46 | 91.6 | 56.8 | 66.9 |
| D | 1 | 2.522 | 6.78 | 96.9 | 6.94 | 97.6 | 76.0 | 97.6 |
| | 2 | | 7.73 | 89.1 | 7.10 | 89.2 | 75.0 | 89.2 |
| | 3 | | 6.86 | 102.7 | 7.26 | 98.8 | 71.7 | 98.8 |

Hydrated Lime (cont.)

| Lab | Test | Maximum Specific Gravity | Dry VTM | Dry Strength | Wet VTM | Wet Strength | % Saturation Initial | % Saturation Final |
|---|---|---|---|---|---|---|---|---|
| | 1 | | 7.45 | 89.2 | 7.81 | 88.9 | 74.0 | 83.0 |
| | 2 | | 7.30 | 91.7 | 8.01 | 83.9 | 71.1 | 77.4 |
| | 3 | | 8.29 | 80.2 | 7.02 | 95.7 | 70.7 | 81.9 |
| | 1 | | 7.10 | 91.4 | 6.38 | 83.0 | 75.3 | 96.3 |
| | 2 | | 7.06 | 95.8 | 8.13 | 81.9 | 72.3 | 81.9 |
| | 3 | | 7.45 | 90.9 | 6.66 | 87.3 | 71.1 | 84.3 |
| E | 1 | 2.526 | 7.60 | 115.1 | 6.97 | 114.4 | 73.9 | 86.4 |
| | 2 | | 7.17 | 122.9 | 7.60 | 100.1 | 78.0 | 92.5 |
| | 3 | | 7.68 | 121.9 | 7.76 | 107.2 | 77.1 | 85.4 |
| | 1 | | 6.33 | 126.4 | 7.48 | 105.7 | 68.1 | 77.3 |
| | 2 | | 7.44 | 122.8 | 8.47 | 93.8 | 70.0 | 79.7 |
| | 3 | | 8.95 | 97.0 | 6.45 | 114.6 | 71.3 | 86.1 |
| | 1 | | 7.36 | 109.2 | 7.72 | 105.4 | 66.4 | 75.9 |
| | 2 | | 7.68 | 124.1 | 7.40 | 100.9 | 66.8 | 75.9 |
| | 3 | | 7.28 | 120.7 | 7.40 | 127.6 | 71.1 | 80.2 |
| F | 1 | 2.542 | 7.20 | 92.3 | 7.16 | 90.3 | 66.6 | 76.6 |
| | 2 | | 7.08 | 95.2 | 7.12 | 89.5 | 69.2 | 79.0 |
| | 3 | | 7.28 | 91.6 | 7.24 | 85.9 | 71.3 | 80.1 |
| | 1 | | 6.53 | 99.4 | 6.85 | 96.0 | 63.2 | 72.6 |
| | 2 | | 7.00 | 92.1 | 6.96 | 93.3 | 67.1 | 76.3 |
| | 3 | | 6.92 | 105.3 | 6.88 | 90.4 | 63.2 | 73.7 |
| | 1 | | 7.40 | 81.5 | 7.51 | 81.2 | 66.3 | 78.2 |
| | 2 | | 7.71 | 87.8 | 7.71 | 82.4 | 65.8 | 75.8 |
| | 3 | | 7.91 | 92.6 | 7.59 | 83.9 | 66.7 | 75.9 |
| G | 1 | 2.563 | 6.75 | 121.0 | 5.74 | 115.1 | 60.1 | 64.1 |
| | 2 | | 7.22 | 115.1 | 7.57 | 110.6 | 48.5 | 52.7 |
| | 3 | | 7.45 | 121.6 | 7.49 | 113.9 | 50.8 | 52.5 |
| | 1 | | 7.22 | 83.8 | 7.65 | 78.6 | 60.0 | 74.6 |
| | 2 | | 6.75 | 94.4 | 6.98 | 78.6 | 63.1 | 70.3 |
| | 3 | | 7.73 | 90.9 | 7.02 | 87.1 | 61.9 | 68.0 |

Hydrated Lime (cont.)

| Lab | Test | Maximum Specific Gravity | Dry VTM | Dry Strength | Wet VTM | Wet Strength | % Saturation Initial | % Saturation Final |
|---|---|---|---|---|---|---|---|---|
| | 1 | | 8.04 | 79.4 | 7.88 | 80.1 | 58.7 | 69.6 |
| | 2 | | 7.76 | 90.4 | 7.61 | 86.0 | 67.3 | 75.6 |
| | 3 | | 7.14 | 95.0 | 7.45 | 76.6 | 57.3 | 61.7 |
| H | 1 | 2.528 | 7.75 | 86.0 | 7.63 | 77.5 | 63.3 | 80.7 |
| | 2 | | 7.91 | 86.8 | 7.99 | 80.8 | 57.4 | 71.4 |
| | 3 | | 8.03 | 86.9 | 8.03 | 80.8 | 63.5 | 76.8 |
| | 1 | | 8.03 | 88.8 | 7.99 | 82.0 | 58.4 | 70.7 |
| | 2 | | 8.27 | 86.3 | 8.27 | 79.0 | 57.4 | 71.6 |
| | 3 | | 8.15 | 89.7 | 8.15 | 84.6 | 55.1 | 69.7 |
| | 1 | | 8.11 | 91.0 | 7.95 | 80.6 | 64.0 | 79.3 |
| | 2 | | 8.35 | 83.5 | 8.39 | 91.7 | 57.8 | 70.7 |
| | 3 | | 8.35 | 88.1 | 8.43 | 81.8 | 63.4 | 72.3 |
| I | 1 | 2.541 | 7.08 | 90.9 | 7.52 | 78.0 | 63.0 | 78.9 |
| | 2 | | 8.15 | 87.4 | 7.83 | 78.3 | 64.2 | 75.6 |
| | 3 | | 7.99 | 85.2 | 7.12 | 87.8 | 60.0 | 70.9 |
| | 1 | | 7.63 | 94.5 | 7.99 | 85.3 | 59.9 | 71.4 |
| | 2 | | 8.15 | 89.1 | 8.03 | 87.8 | 63.6 | 77.4 |
| | 3 | | 8.30 | 92.2 | 7.91 | 93.8 | 64.7 | 81.2 |
| | 1 | | 7.44 | 86.9 | 7.32 | 81.8 | 62.4 | 73.5 |
| | 2 | | 7.08 | 96.5 | 7.56 | 88.8 | 60.1 | 73.5 |
| | 3 | | 7.60 | 91.3 | 7.24 | 90.1 | 61.3 | 76.9 |
| J | 1 | 2.537 | 7.30 | 101.2 | 7.43 | 88.9 | 65.2 | 75.8 |
| | 2 | | 7.30 | 102.9 | 7.38 | 91.9 | 65.4 | 76.1 |
| | 3 | | 7.61 | 95.2 | 7.54 | 93.6 | 67.6 | 76.8 |
| | 1 | | 7.14 | 103.4 | 6.68 | 97.5 | 58.4 | 68.9 |
| | 2 | | 7.07 | 102.7 | 6.88 | 94.8 | 61.7 | 72.2 |
| | 3 | | 6.58 | 103.0 | 6.73 | 88.0 | 64.3 | 74.9 |
| | 1 | | 6.91 | 113.3 | 7.20 | 89.6 | 63.4 | 73.3 |
| | 2 | | 7.39 | 109.0 | 7.10 | 89.4 | 65.6 | 74.0 |
| | 3 | | 6.95 | 119.1 | 7.23 | 91.5 | 65.8 | 77.5 |

Hydrated Lime (cont.)

| Lab | Test | Maximum Specific Gravity | Dry VTM | Dry Strength | Wet VTM | Wet Strength | % Saturation Initial | % Saturation Final |
|---|---|---|---|---|---|---|---|---|
| K | 1 | 2.547 | 7.42 | 100.6 | 7.62 | 78.4 | 66.7 | 72.9 |
| | 2 | | 7.42 | 98.6 | 7.54 | 84.6 | 61.5 | 69.9 |
| | 3 | | 7.81 | 94.8 | 7.58 | 87.2 | 62.8 | 69.3 |
| | 1 | | 6.67 | 100.7 | 7.62 | 88.7 | 64.1 | 68.5 |
| | 2 | | 7.62 | 112.6 | 6.71 | 92.2 | 68.7 | 71.0 |
| | 3 | | 7.73 | 111.6 | 7.54 | 95.3 | 62.8 | 66.5 |
| | 1 | | 7.54 | 103.1 | 7.50 | 77.9 | 64.9 | 73.1 |
| | 2 | | 8.17 | 100.4 | 7.26 | 83.2 | 63.2 | 72.2 |
| | 3 | | 7.11 | 111.0 | 8.01 | 83.3 | 62.6 | 70.0 |
| L | 1 | 2.522 | 6.86 | 87.4 | 8.29 | 69.1 | 62.9 | 77.9 |
| | 2 | | 8.37 | 70.1 | 7.81 | 71.8 | 63.5 | 80.3 |
| | 3 | | 8.88 | 66.8 | 7.77 | 73.6 | 65.1 | 75.8 |
| | 1 | | 8.60 | 70.0 | 8.68 | 67.2 | 61.9 | 74.8 |
| | 2 | | 8.37 | 66.8 | 8.88 | 68.7 | 69.1 | 79.5 |
| | 3 | | 9.04 | 64.7 | 8.72 | 67.0 | 68.6 | 78.4 |
| | 1 | | 7.45 | 85.6 | 7.73 | 79.1 | 66.7 | 82.2 |
| | 2 | | 8.09 | 74.9 | 7.89 | 80.9 | 67.0 | 74.5 |
| | 3 | | 7.18 | 84.9 | 7.81 | 81.0 | 68.5 | 79.7 |
| M | 1 | 2.535 | 7.81 | 119.8 | 7.42 | 102.7 | 67.5 | 81.2 |
| | 2 | | 7.57 | 123.3 | 7.50 | 94.9 | 66.0 | 79.0 |
| | 3 | | 6.86 | 124.7 | 7.57 | 101.3 | 62.6 | 76.2 |
| | 1 | | 8.24 | 126.6 | 8.05 | 105.5 | 66.6 | 83.7 |
| | 2 | | 8.01 | 125.8 | 8.44 | 107.0 | 65.7 | 77.9 |
| | 3 | | 8.72 | 132.4 | 8.76 | 107.8 | 60.7 | 75.4 |
| | 1 | | 7.22 | 142.8 | 7.34 | 113.2 | 65.4 | 79.3 |
| | 2 | | 7.73 | 139.7 | 7.22 | 112.3 | 64.3 | 80.9 |
| | 3 | | 7.69 | 147.6 | 7.61 | 115.5 | 62.9 | 73.6 |