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EVALUATION OF MOISTURE DAMAGE IN ASPHALT MIXTURES BY TUNNICLIFF AND ROOT PROCEDURE (NCHRP 274)

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16. Abstract

Six bituminous mixtures were evaluated in this study. They were tested by the Immersion-Compression test, AASHTO T-165, Group 2, Alternate Procedure, and the Tunnicliff-Root procedure (NCHRP 274). Field samples were then obtained. Comparisons were made between the laboratory tests and the field samples. It is then concluded, considering the difficulty and time required for sample preparation and the lack of reliability of the test results in predicting field performance, the Tunnicliff-Root procedure has no advantages over the Immersion-Compression test.

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EVALUATION OF MOISTURE DAMAGE IN ASPHALT MIXTURES BY TUNNICLIFF AND ROOT PROCEDURE (NCHRP 274)

FINAL REPORT

STUDY NO. 88-3

Prepared By

MISSOURI HIGHWAY AND TRANSPORTATION DEPARTMENT

DIVISION OF MATERIALS AND RESEARCH

MATERIALS FIELD OFFICE

OCTOBER, 1990

In Cooperation With

U. S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

The opinions, findings, and conclusions expressed in this publication are not necessarily those of the Federal Highway Administration.

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INTRODUCTION

The ability to accurately predict the susceptibility of a bituminous mixture to water damage has been a problem for some time. In recent years a variety of test methods have been developed to try to solve this problem. These test methods submit specimens to various adverse conditions such as freeze-thaw cycles, vacuum saturation, boiling water and warm water. The goal of these tests is to rapidly deteriorate the conditioned specimens. The conditioned specimen strength is then compared to the strength of unconditioned specimens in the form of a ratio of retained strength. The ratio of retained strength is then used to predict the field performance of the bituminous mixture.

The Missouri Highway and Transportation Department (MHTD) currently uses the Immersion-Compression Test, AASHTO T-165, Group 2, Alternate Procedure, to predict the susceptibility of bituminous mixtures to water damage. The reliability of the Immersion-Compression test has recently been questioned. It is believed that the test is not severe enough to accurately predict field performance. The Tunnicliff-Root procedure as described in the NCHRP Report Number 274 is seen as a possible promising alternative to the Immersion Compression Test.

This study was initiated to evaluate the Tunnicliff-Root procedure. The purpose of the study was to compare the Tunnicliff-Root procedure to the Immersion-Compression test and also to evaluate the Tunnicliff-Root procedure in its ability to accurately predict field performance. Six mixes

were chosen for study. Two Type B mixes, one using St. Louis limestone and one using Jefferson City dolomite. The Type B mix is used as a binder course. Two Type C mixes, one using St. Louis limestone and one using Jefferson City dolomite. The Type C mix is a surface course and is placed over Type B mixes. One Type A mix using Iron Mountain porphyry. The Type A mix is a surface course and is placed on bridge decks. One Type LP mix using Ozark Mountain porphyry and Potosi dolomite. The Type LP mix is a surface course and is normally used where traffic volume is greater. These mixes represent a good cross section of the types of aggregates and the types of mixtures placed on Missouri highways.

CONCLUSIONS

Based on the testing and visual observations done on the six bituminous mixtures included in this study, the following conclusions are made concerning the Tunnicliff-Root procedure and the Immersion-Compression test.

1. The Tunnicliff-Root procedure and the Immersion-Compression test both have high degrees of repeatability.

2. The Tunnicliff-Root procedure is a more severe test method than the Immersion-Compression test.

3. Determining the compactive effort necessary to provide specimens with the proper percent air voids for the Tunnicliff-Root procedure is both labor intensive and time consuming.

4. Difficulty can be expected in consistently molding specimens to the proper percent air voids for the Tunnicliff-Root procedure.

5. Neither the Immersion-Compression test nor the Tunnicliff-Root procedure provide reliable test results for accurately predicting the susceptibility of a bituminous mixture to water damage.

6. Considering the difficulty and time required for sample preparation and the reliability of the test results in predicting field performance; the Tunnicliff-Root procedure has no advantages over the Immersion Compression test.

IMPLEMENTATION

Due to the difficulty experienced in testing and since the Tunnicliff-Root procedure is not a good predictor of the field performance of bituminous mixtures, the Missouri Highway and Transportation Department will not implement the Tunnicliff-Root procedure. No further action is required.

DISCUSSION

General

The primary objective of this study was to compare the Immersion-Compression test, AASHTO T-165, Group 2, Alternate Procedure, to the Tunnicliff-Root procedure (NCHRP 274), and then to evaluate how well the Tunnicliff-Root Procedure predicts field performance of asphaltic concrete mixtures.

The laboratory phase of this study consisted of testing six bituminous mixtures. These mixes include a Type B mix and Type C mix using St. Louis limestone, a Type B mix and Type C mix using Jefferson City dolomite, a Type A mix using Iron Mountain porphyry and an LP mix using Potosi dolomite and Ozark Mountain porphyry.

Type B mixtures are used for binder courses. Type C and LP mixtures are surface courses. The Type LP mixtures are generally used where traffic volumes are greater. Type A mixtures are used on bridge decks. Appendix A shows the characteristics of each of the mixtures tested in this study and the physical characteristics of the aggregate used.

The Immersion-Compression test was run three times for each of the six mixes. The Tunnicliff-Root procedure was run three times for each mix using specimens molded by the Direct-Compression method (AASHTO T-167). The Tunnicliff-Root procedure was also run three times for each mix using specimens molded by the Marshall Method (AASHTO T-245). A summary of the Tunnicliff-Root Procedure Test Data is shown in

Appendix B. Each test was run three times in order to establish the repeatability of each test procedure. The 95% index of precision is shown in Table 1.

When preparing specimens for the Tunnicliff-Root procedure, every effort was made to obtain the proper percent air voids of 6± 1 percent. Trial specimens were molded for each mix in order to determine the compactive effort necessary to produce specimens containing 6 ± 1 percent air voids. All of the specimens for a particular mix were then molded using the compactive effort determined from the trial specimens. When the bulk specific gravity and percent air voids were determined, it was found that there was a wide variation in the percent air voids. Each mix contained specimens that did not have air voids within the proper range. It was decided to use these specimens in the study. This decision was reached for two reasons: (1) there was interest in how specimens with higher or lower air voids would react to the Tunnicliff-Root procedure, and (2) if the Tunnicliff-Root procedure is adopted, molding new specimens to replace those not having the proper percent air voids would present time and work load problems in the laboratory. The variation in air voids did not appreciably affect the degree of repeatability.

Saturation was achieved using a vacuum desiccator. The amount of vacuum could be controlled. The degree of saturation for each specimen is shown in Appendix B. Three specimens were saturated at a time to help maintain uniform degrees of saturation. The Type C mix using St. Louis

limestone presented problems with saturation. Four of the nine specimens that were molded by the Direct Compression method were slightly over saturated. These specimens were not discarded. The specimens were used for the same reasons pointed out in the discussion concerning the percent air voids in the previous paragraph. The variation in saturation did not appreciably affect the degree of repeatability.

The field phase of this study involved the testing of cores with the same aggregate types as were used in the laboratory phase of this study. A Type B and Type C mix with St. Louis limestone was sampled from Route I-55, Jefferson County. These mixes were laid in 1984. A Type B and Type C mix with Jefferson City dolomite was sampled from Route 63, Phelps County. These mixes were laid in 1987. A Type A mix using Iron Mountain porphyry was sampled from a bridge deck on Route 5, Morgan County. This mix was laid in 1985. An LP mix using Ozark Mountain porphyry and Potosi dolomite was sampled from Route I-44, Franklin County. This mix was laid in 1989.

The cores were taken in rows of three between the wheel paths at approximately 12 foot intervals. Twenty-four cores were taken for each type of mixture. The cores were kept in the "as sampled" field moisture content. The bulk specific gravity was run on the cores and the percent air voids determined. Six extra cores were taken. This would provide "spares" in the event that some of the cores were damaged. Eighteen cores from each mix were then divided into three sets of six specimens. Each set had essentially the same percent

air voids. Each set was then divided into two subsets of three specimens. The dry subsets were then broken. The other subsets were conditioned and then broken. Saturation of the cores presented problems. The maximum vacuum that could be obtained, 30 in. Hq., was used for twenty minutes. The specimens did not reach the minimum desired saturation of 55 percent. A summary of the test data for the field samples is in Appendix C.

To evaluate the Tunnicliff-Root procedure in its ability to predict the field performance of bituminous mixtures the unconditioned field samples were compared to the unconditioned laboratory samples. For each mixture the average of the nine unconditioned field samples was divided by the average of the nine unconditioned laboratory samples molded by both the Direct Compression method and the Marshall Method. This comparison is shown in Table 2. The unconditioned field samples were broken open and were visually rated. The visual rating of stripping, severe, moderate, or slight was a judgemental method of ranking the specimens relative to each other in order to then compare with test results. A comparison was made between the visual rating and the tensile strength ratio of the laboratory specimens. This comparison was made to evaluate how well the Tunnicliff-Root procedure and the Immersion-Compression test predicted field performance. This comparison can be found in Table 3.

Data containing physical characteristics of individual specimens and test results on each specimen is available upon request to the author.

Study Findings

The degree of repeatability of the Immersion-Compression test and the Tunnicliff-Root procedure is shown to be very high in this study. The 95% index of precision was run for each test method. The Type B mix using St. Louis limestone, when tested by the Tunnicliff-Root procedure using Marshall specimens, was the only exception. Good repeatability was maintained with the Tunnicliff-Root procedure even though problems were encountered in achieving the proper percent air voids and degrees of saturation. Therefore, slight deviations in these areas do not adversely affect test results. The high degree of repeatability achieved with the Immersion-Compression test was expected.

Numerical and visual comparisons were made for each mixture tested. In the Tunnicliff-Root procedure, the conditioned laboratory specimens showed severe stripping. The only exception was the Type A mix with Iron Mountain porphyry. This mixture experienced slight stripping. All of the specimens had only a few broken aggregates. In the Immersion-Compression test the conditioned specimens showed slight degrees of stripping. Each specimen contained several broken aggregates.

The Type B mix with St. Louis limestone had good retained strength by both the Tunnicliff-Root tests and the Immersion-

Compression test. The retained strength of the unconditioned field samples divided by the unconditioned laboratory specimens was low. The field samples were severely stripped. None of the test methods predicted the poor performance of this mix.

The Type C mix with St. Louis limestone had good retained strength with the Immersion-Compression test and the Tunnicliff-Root procedure using Marshall specimens. Poor retained strength was obtained in the Tunnicliff-Root procedure using Direct Compression specimens. The retained strength of the unconditioned field samples divided by the unconditioned laboratory specimens was low. The field samples were severely stripped. The Tunnicliff-Root procedure using Direct Compression specimens accurately predicted the poor performance of this mix. The other tests did not.

The Type B mix with Jefferson City dolomite had poor retained strength in all tests. The retained strength of the unconditioned field samples divided by the unconditioned laboratory samples was high. The field samples were slightly stripped. None of the test methods predicted the good performance of this mix.

The Type C mix with Jefferson City dolomite had high retained strength in the Immersion-Compression test and low retained strengths in the Tunnicliff-Root tests. The retained strength of the unconditioned field samples divided by the unconditioned laboratory specimens was high. The field samples were slightly stripped. the Immersion-Compression

test accurately predicted the good performance of this mix. The Tunnicliff-Root procedure did not.

The Type A mix with Iron Mountain porphyry had high retained strength in all tests. The retained strength of the unconditioned field samples divided by the unconditioned laboratory specimens was high. The field samples were slightly stripped. All tests predicted the good performance of this mix.

The Type LP mix with Ozark Mountain porphyry and Potosi dolomite had high retained strength in the Immersion-Compression test and low retained strength in the Tunnicliff-Root tests. The retained strength of the unconditioned field samples divided by the unconditioned laboratory specimens was low. The field samples were moderately stripped. The Tunnicliff-Root tests accurately predicted the poor performance of this mix. The Immersion-Compression test did not.

The Tunnicliff-Root procedure using Marshall specimens accurately predicted the field performance of two of the six mixes tested. The Tunnicliff-Root procedure using direct compression specimens accurately predicted three of the six, and the Immersion-Compression test accurately predicted the field performance of two of the six mixtures tested.

Neither the Immersion-Compression test nor the Tunnicliff-Root procedure consistently predicted the susceptibility of a bituminous mixture to water damage. The

Tunnicliff-Root procedure did not exhibit any appreciable advantages over the Immersion-Compression test in this study.

TABLE 1

95% INDEX OF PRECISION

	Ratio of Retained Strength Immersion-Compression	Tensile Strength Ratio Tunnicliff-Root Direct Compression Specimens	Tensile Strength Ratio Tunnicliff-Root Marshall Specimens
Type B Mix St. Louis Limestone	Test 1 = 87.3%	Test 1 = 86.0%	Test 1 = 100.2%
	Test 2 = 91.3%	Test 2 = 87.4%	Test 2 = 76.9%
	Test 3 = 86.2%	Test 3 = 87.6%	Test 3 = 87.5%
Type C Mix St. Louis Limestone	Test 1 = 88.6%	Test 1 = 77.7%	Test 1 = 96.6%
	Test 2 = 94.2%	Test 2 = 73.1%	Test 2 = 99.0%
	Test 3 = 96.5%	Test 3 = 74.9%	Test 3 = 101.6%
Type B Mix Jefferson City Dolomite	Test 1 = 65.4%	Test 1 = 60.3%	Test 1 = 75.4%
	Test 2 = 64.1%	Test 2 = 65.2%	Test 2 = 73.8%
	Test 3 = 60.5%	Test 3 = 69.0%	Test 3 = 72.9%
Type C Mix Jefferson City Dolomite	Test 1 = 79.4%	Test 1 = 54.1%	Test 1 = 69.5%
	Test 2 = 84.9%	Test 2 = 56.9%	Test 2 = 72.2%
	Test 3 = 86.7%	Test 3 = 47.6%	Test 3 = 73.1%
Type A Mix Iron Mountain Porphyry	Test 1 = 108.0%	Test 1 = 106.9%	Test 1 = 102.4%
	Test 2 = 106.3%	Test 2 = 102.5%	Test 2 = 107.6%
	Test 3 = 105.0%	Test 3 = 103.3%	Test 3 = 108.3%
Type LP Mix Ozark Mountain Porphyry Potosi Dolomite	Test 1 = 89.8%	Test 1 = 55.8%	Test 1 = 69.0%
	Test 2 = 88.9%	Test 2 = 59.9%	Test 2 = 69.3%
	Test 3 = 90.2%	Test 3 = 58.1%	Test 3 = 74.6%
*95% Index of Precision	5.6	6.2	10.6 (5.0)**

*95% of the time it is not expected that test results of a given aggregate would vary more than this amount.

**95% index of precision not including the Type B mix with St. Louis Limestone.

TABLE 2

NUMERICAL COMPARISON OF LABORATORY TESTS
TO TESTS ON FIELD SAMPLES

	Direct Compression		Marshall	
	Avg. Field Unconditioned Divided By Avg. Lab Unconditioned	Avg. Lab Conditioned Divided By Avg. Lab Unconditioned	Avg. Field Unconditioned Divided By Avg. Lab Unconditioned	Avg. Lab Conditioned Divided By Avg. Lab Unconditioned
Type B Mix St. Louis Limestone	58.1%	87.0%	55.1%	88.2%
Type C Mix St. Louis Limestone	76.9%	75.2%	77.3%	99.1%
Type B Mix Jefferson City Dolomite	183.2%	64.8%	161.1%	74.0%
Type C Mix Jefferson City Dolomite	220.4%	52.9%	203.0%	71.6%
Type A Mix Iron Mountain Porphyry	198.4%	104.2%	159.7%	106.1%
Type LP Mis Ozark Mountain Porphyry Potosi Dolomite	139.2%	57.9%	99.0%	71.0%

TABLE 3

COMPARISON OF LABORATORY TESTS TO
VISUAL PERFORMANCE OF FIELD SAMPLES

	Immersion-Compression Test Average Ratio of Retained Strength	Tunnicliff-Root Procedure Direct Compression Specimens Average Tensile Strength Ratio	Tunnicliff-Root Procedure Marshall Specimens Average Tensile Strength Ratio	Visual Rating
Type B Mix St. Louis Limestone	88.3%	87.0%	88.2%	Severe stripping
Type C Mix St. Louis Limestone	93.1%	75.2%	99.1%	Severe stripping
Type B Mix Jefferson City Dolomite	63.3%	64.8%	74.0%	Slight stripping
Type C Mix Jefferson City Dolomite	83.7%	52.9%	71.6%	Slight stripping
Type A Mix Iron Mountain Porphyry	106.4%	104.2%	106.1%	Slight stripping
Type LP Mix Ozark Mountain Porphyry Potosi Dolomite	89.6%	57.9%	71.0%	Moderate stripping

APPENDIX A

APPENDIX A

MIXTURE AND AGGREGATE CHARACTERISTICS

Laboratory Designed Mixtures

Mix No.	AASHTO T-167 Stability	% Air Voids	Bulk Sp. Gr.	Calculated Max. Sp. Gr.
B88-447	384	4.02	2.413	2.514
C88-450	471	3.82	2.416	2.512
B87-240	459	4.71	2.367	2.484
C87-241	501	4.60	2.363	2.473
A89-15	438	5.66	2.301	2.439
LP90-92	496	4.25	2.75	2.638

Field Sampled Mixtures

Mix No.	AASHTO T-167 Stability	% Air Voids	Bulk Sp. Gr.	Calculated Max. Sp. Gr.
B84-258	429	4.89	2.371	2.493
C84-259	465	4.90	2.370	2.492
B87-171	459	4.71	2.367	2.484
C87-166	501	4.60	2.363	2.477
A85-104	424	4.81	2.492	2.618
LP89-92	496	4.25	2.755	2.638

Aggregate Characteristics

	% L.A. Loss	Bulk Sp. Gr.	Absorption
St. Louis Limestone	30	2.688	0.8
Jefferson City Dolomite	33	2.697	4.2
Potosi Dolomite	27	2.764	0.8
Iron Mountain Porphyry	19	2.657	0.6
Ozark Mountain Porphyry	20	3.297	0.7

APPENDIX B

APPENDIX B

	Mix ID Number
Type B Mix St. Louis Limestone	XB88-447
Type C Mix St. Louis Limestone	XC88-450
Type B Mix Jefferson City Dolomite	XB87-240
Type C Mix Jefferson City Dolomite	XC87-241
Type A Mix Iron Mountain Porphyry	XA89-15
Type LP Mix Ozark Mountain Porphyry Potosi Dolomite	XLP89-92

SUMMARY OF TUNNICLIFF-ROOT PROCEDURE TEST DATA
FOR LABORATORY SPECIMENS

	Direct Compression Specimens				Marshall Specimens			
Mix #	Load	% Air Void Range	Vacuum	% Saturation Range	Load	% Air Void Range	Vacuum	% Saturatation Range
XB88-447	1000 psi/2 min.	5.7-6.8	24 in. Hg/2 min.	58.1-65.2	6 blows	6.0-8.1	28 in. Hg/2 min.	65.3-79.3
XC88-450	500 psi/2 min.	7.0-7.5	27 in. Hg/2 min.	76.6-83.6	3 blows	7.4-8.7	24 in. Hg/2 min.	61.2-68.9
XB87-240	300 psi/2 min.	5.9-7.0	25 in. Hg/2 min.	61.3-68.9	3 blows	3.9-7.6	26 in. Hg/2 min.	65.6-74.3
XC87-241	200 psi/2 min.	6.5-7.6	24 in. Hg/2 min.	68.5-75.9	3 blows	4.5-7.3	24 in. Hg/2 min.	69.8-76.6
XA89-15	1000 psi/2 min.	7.1-8.8	22 in. Hg/2 min.	62.2-69.6	14 blows	5.2-7.4	24 in. Hg/2 min.	56.6-77.7
XLP89-92	1250 psi/2 min.	7.6-8.9	23 in. Hg/2 min.	65.3-73.6	12 blows	6.1-8.3	24 in. Hg/2 min.	59.2-73.1

APPENDIX C

APPENDIX C

	Mix ID Number
Type B Mix St. Louis Limestone	B84-258
Type C Mix St. Louis Limestone	C84-259
Type B Mix Jefferson City Dolomite	B87-171
Type C Mix Jefferson City Dolomite	C87-166
Type A Mix Iron Mountain Porphyry	A85-104
Type LP Mix Ozark Mountain Porphyry Potosi Dolomite	LP89-92

APPENDIX C

SUMMARY OF TUNNICLIFF-ROOT PROCEDURE FOR FIELD SAMPLES

Mix #	% Air Void Range	Vacuum	% Saturation Range
B84-258	1.6-3.2	30 in. Hg/20 min.	2.8-54.7
C84-259	2.6-4.2	30 in. Hg/20 min.	10.9-54.9
B87-171	2.5-5.8	30 in. Hg/20 min.	1.9-42.4
C87-166	1.9-3.7	30 in. Hg/20 min.	13.0-30.9
A85-104	6.0-10.4	30 in. Hg/20 min.	38.6-57.4
LP89-92	6.5-9.5	30 in. Hg/20 min.	11.4-36.5

*Bulk specific gravities and % air voids were determined with the samples in their field moisture condition. (Ref. NCHRP 274 Pg. 46, Section 8.3).

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