EVALUATION OF ASPHALT STRIPPING TESTS

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March 1990

Technical Report Documentation Page

1. Report No. FHWA-TS-90-033	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle EVALUATION OF ASPHALT STRIPPING TESTS IN OREGON		5. Report Date MARCH 1990 6. Performing Organization Code
7. Author(s) Dickinson, L.L., Blachly, A.T., George, A.J.		8. Performing Organization Report No. FHWA-OR-RD-90-09
9. Performing Organization Name and Address Oregon State Highway Division State Transportation Building Salem, Oregon 97310		10. Work Unit No. (TRAIS) 3C9c0123 11. Contract or Grant No. DTFH 61-88-C-00083
12. Sponsoring Agency Name and Address Federal Highway Administration Office of Implementation 6300 Georgetown Pike McLean, Virginia 22101		13. Type of Report and Period Covered Final Report April 1988 - March 1990 14. Sponsoring Agency Code

15. Supplementary Notes

Contracting Officer's Technical Representative: Douglas Brown

16. Abstract

As part of the continuing effort to establish a standard for evaluating moisture susceptibility of asphalt concrete design mixes, this study evaluated and compared four tests methods by testing 15 diverse dense-graded mix designs during Oregon's 1988 construction season. The Index of Retained Strength (IRS), AASHTO T-165, and the Index of Retained Modulus of Resiliency (IRM_R). OSHD TM-315, were the existing ODOT tests compared with the Root-Tunnicliff, NCHRP 274, and the Modified Lottman, AASHTO T-283. None of the four tests predicted the same degree of asphalt stripping across the range of asphalt and aggregate tested.

The IRS test results showed the most stripping susceptible aggregates having a low test index when untreated, but when treated with lime or anti-strip additive there is a general improvement in the test indexes. The IRM_R tests results showed a greater inconsistency in the effectiveness of the lime-treated aggregate and anti-strip additive, but was the most severe test of the four evaluated. Neither the Root-Tunncliff nor Modified Lottman tests showed consistently higher stripping index for lime treated aggregate compared to anti-strip additive. Additionally, the Root-Tunncliff and Modified Lottman tests were the most difficult to perform and the least promising of the tests evaluated.

Based on the results of this study, the IRS Test Method continues to be considered a valid and useful stripping test. The IRM_R test appears to have the greatest potential for future improvement due to superior repeatability and apparent greater severity of the test.

As a result of the test findings, there still is a need for test equipment and procedure improvements to increase the accuracy and precision of the procedures and to improve the correlation between stripping tests.

17. Key Words Asphalt concrete, stripping, lime, antistripping additives, moisture susceptibility	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price

Form DOT F 1700.7 (8-72)

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

MASS

Symbol	When You Know	Multiply By	To Find	Symbol
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2

VOLUME

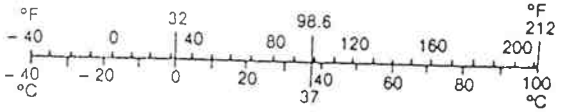
Symbol	When You Know	Multiply By	To Find	Symbol
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3

MASS

Symbol	When You Know	Multiply By	To Find	Symbol
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

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1.0 INTRODUCTION

1.1 Project Statement

There is a continuing concern about asphalt cement stripping from aggregate in asphalt concrete because some new pavement construction in the past has failed prematurely due to asphalt stripping. Therefore, a need exists to improve the ability to predict the stripping potential of bituminous mixtures in the mixture design stage, so that corrective actions (e.g. treatment of aggregate or use of asphalt additive) can be taken when necessary.

Numerous previous studies have reported on asphalt stripping,[1,2,3,4,5,6,7,8] including a recent joint study by Oregon State University and Oregon Department of Transportation (ODOT) (1989) entitled, "Effectiveness of Antistripping Additives Volume 1."[9] From a review of these studies, there is a need to continue to develop and refine test methods and data analysis procedures. This refinement is needed to eventually establish a standard for evaluating moisture susceptibility.

This study was intended to follow up on this need and to participate as one of four states in the Federal Highway Administration (FHWA) project titled "Evaluation of Asphalt Stripping Tests." The participation of ODOT in the study allowed a comparative evaluation of the Index of Retained Strength (IRS) with other more recently developed test methods (e.g. Root-Tunnicliff), and an upgrading of testing equipment and procedures. The study evaluated four tests procedures: 1) the Index of Retained Strength, AASHTO T 165-82; 2) the Root-Tunnicliff, NCHRP 274; 3) the Modified Lottman, AASHTO T 283-85; and 4) the IRM_R - Index of Retained Modulus of Resiliency, OSHD TM 315-89.

All four tests procedures were used on compacted bituminous specimens representing 15 dense-graded paving mixtures used by ODOT in 1988 for highway construction. Open-graded mixes were not included in the study because previous Oregon State

Highway Division (OSHD) experience indicates the IRM_R test is unreliable for these mixes. The open-graded specimens (briquets) tended to fall apart during water treatments due to thicker asphalt films and lower cohesion in the mix. Also, the voids between aggregates caused problems with accurate readings during modulus testing.

The tests measured changes in the specified mechanical properties of compressive strength, tensile strength or resilient modulus, "caused by exposure to moisture" or in some cases freeze-thaw and "then related these changes to the susceptibility of asphalt paving mixtures to moisture damage."[10] The effects of fine aggregate, filler, coarse aggregate, asphalt cement and additive (when present) were evaluated together as to the mixture's stripping sensitivity, but the tests were not "used to isolate one particular stripping mechanism or mechanisms of additive function. The mechanical properties of a compacted mixture, which are to be measured and related to stripping propensity of the mixture, depend on too many variables such as aggregate size and shape, asphalt viscosity and source, compaction method, and so on."[10]

1.2 Study Purpose

The three part purpose included 1) the evaluation of various bituminous mixture moisture susceptibility tests, 2) the determination of which test best predicts asphalt stripping by best fit to the study hypothesis, repeatability and correlation, and 3) the implementation of the study results in routine Oregon State Highway Division (OSHD) mixture testing.

1.3 Background and Significance

Oregon began using antistripping additives in the 1950's. Recently these additives have been augmented with lime treatment of aggregates. To determine moisture susceptible mixes which needed antistripping additives, ODOT has used two tests: the retained resilient modulus (IRM), an early name for the IRM_R - Index of Retained Modulus of Resiliency; and the index of retained strength (IRS), AASHTO T 165. In late 1979 and early 1980, a retained resilient modulus (IRM) test was established in ODOT's Bituminous Mixture Lab with a criteria of 70% minimum retained resilient modulus. Before 1983, the criteria of 70% was also used for the index of retained strength (IRS). After a study completed in 1983 by ODOT[1], the IRS criteria was increased to 75% to the tolerances used in construction specifications.

In achieving the purpose of evaluating the effects of material sources, void content, and additive type on the IRS or IRM after freeze-thaw conditioning, the ODOT study[1] concluded:

1) *Present mix design procedures may not always detect problems from asphalt-aggregate interaction.*
2) *Aggregate quality appears to relate to low values for Index of Retained Strength and Modulus Ratio.*
3) *Significant differences existed for Index of retained Strength and Modulus Ratio values for construction mix design, [field-sampled] mix and later laboratory batched specimens.*
4) *[Degree] of compaction greatly affected the compressive strength. However, Index of Retained Strength values show little change.*
5) *Conditioning greatly affected modulus and modulus ratio values.*
6) *The use of additives generally increases both the Modulus Ratio and Index of Retained Strength.*

In 1984 OSHD required lime treatment of aggregate on a mandatory or when-required basis. Current criteria developed in 1985 requires lime treatment of aggregate whenever the project meets one of the following criteria:

1) Elevations above 2,500 feet
2) Areas of known freeze-thaw conditions
3) Areas of known poor pavement performance
4) All freeways

In addition, current (1989) construction specifications require an index of retained strength (IRS) greater than 75% and a resilient modulus ratio (IRM_R) greater than 70%. If these criteria are not achieved, lime treatment of aggregate or addition of antistripping additives is required.

Of the four adhesion theories cited in the Shute Study[9], the Chemical Reaction and the Mechanical Theories for lime treatment and the Molecular Orientation and the Surface Energy Theories for the antistripping additives best explain what the moisture damage predictors are measuring in this study. The four theories are summarized in Shute's Study as follows:

> 1) *<u>Chemical Reaction Theory</u> The chemical composition of the aggregate plays an important role. Basic aggregates, such as limestone, are less likely to strip than "acidic" rocks, such as sandstone.*[11] *The chemical reaction is not complete between acidic aggregate and asphalt since there are less receptive sites for the carboxylic acids in the asphalt to bond. In other words, there are less electrically positive sites on the aggregate to receive the negative components of the asphalt.*
>
> 2) *<u>Molecular Orientation Theory</u> Contact between the aggregate and asphalt molecules can depend on their molecular orientation. Asphalt molecules orient themselves to satisfy energy demands of the aggregate.*[12] *However, the number of receptive sites on the aggregate influences the overall strength of the bond.*
>
> 3) *<u>Mechanical Theory</u> Adhesion is affected by surface texture, porosity, surface coating, surface area, and particle size. The rougher the surface texture, the greater the bond strength between the asphalt and aggregate. The greater the porosity (the pores being of sufficient size to allow the asphalt penetration), the greater the mechanical interlock.*[13] *Dust blocks pore openings by forming small dams across the pore openings preventing penetration of asphalt into the pores.*[14] *This reduces the contact surface area between the*

asphalt and aggregate. The more fines in the mixture, the greater the surface area, and therefore a greater amount of asphalt is required to coat all the aggregates sufficiently.

4) <u>Surface Energy Theory</u> The wetting ability of a liquid indicates the ability of a liquid [to] coat or migrate across a surface.[15] *Water has a greater wetting [power] than asphalt due to its low viscosity. Water also has greater adhesion to aggregate than asphalt. Therefore, it will tend to displace asphalt from an aggregate surface.*

Therefore, the use of lime changes the aggregate surface characteristics and antistripping additives in the asphalt effect the wettability of the asphalt itself. Both treatments improve asphalt adhesion to the aggregate.

2.0 DESCRIPTION OF THE TESTS

The four tests (see Tables 1 and 2) used in this study to predict asphalt cement stripping are:

2.1 IRS - Index of Retained Strength, OSHD TM-308C (modified AASHTO T-165).

For the IRS Test, 4-inch diameter by nominal 4-inch high specimens were fabricated by static loading at 3000 psi. The Oregon State Highway Division (OSHD) Test Method of Fabrication of Specimens is in Appendix A.

The OSHD modification (see Appendix B) of this AASHTO test method uses only one specimen for each condition instead of triplicates. In this test, 4-inch diameter by 4 inches nominal height specimens are fabricated in pairs using the static load. The control specimen is kept in 77°F air while the treated specimen is subjected to 24 hours of soaking in 140°F water. The treated specimen is cooled to 77°F in water, after which each specimen is compressed axially to failure. The maximum load achieved by the treated specimen is divided by the maximum load achieved by the unconditioned (control) specimen to compute the Index of Retained Strength. The Current OSHD minimum IRS is 75%.

2.2 Root-Tunnicliff, NCHRP 274 (see Appendix C for summary of method).

The test focuses on controlling the degree of saturation between 55% to 80% in the test specimens. The diametral tensile strength of two unconditioned and vacuum-saturated specimens of 4-inch diameter by 2.5-inch height, fabricated by kneading compaction to approximately 7 percent voids, were compared to each other to obtain a tensile strength ration (TSR). A TSR is used to evaluate the test results. The TSR is obtained by dividing the value for the tensile strength from the conditioned sample by the result for the unconditioned sample. The TSR was compared directly to the ratios of the other three test methods.

Vacuum saturation was repeated until the minimum of 55 percent void saturation was obtained as noted in Table 1.

2.3 Modified Lottman, AASHTO T-283 (see Appendix D for summary of method).

The treatment is similar to AASHTO T-283, except that only one specimen rather than triplicates were used for each condition. Loading strips of 3/4" were used instead of 1/2".

As in the Root-Tunnicliff procedure, the diametral tensile strength of two unconditioned and freeze-thaw specimens of 4-inch diameter by 2.5-inch height, fabricated by kneading compaction to approximately 7 percent voids, were compared to obtain a tensile strength ratio (TSR) of conditioned to unconditioned specimen.

Vacuum saturation was sufficient to obtain 55 to 80 percent void saturation with water. A TSR of 0.70 or greater is recommended by Lottman.[2]

2.4 IRM_R - Index of Retained Modulus of Resiliency, OSHD TM - 315(see Appendix E).

This OSHD test is similar to the resilient modulus option of the original Lottman procedure NCHRP 246, using modulus testing comparable to that described in ASTM D-4123, without duplicates or triplicates.

For each test, a single 4-inch diameter by 2.5-inch height specimen is fabricated with kneading compaction. On this specimen, the diametral resilient modulus was measured for three conditions:

1) unconditioned at 77°F,
2) at 77°F after vacuum saturation and water bath soak, and
3) at 77°F after a second vacuum saturation followed by a freeze and a quick thaw in 140°F water. The vacuum saturation is for 30 minutes at 1.2" Hg absolute.

The ratio of 2) to 1) gives intermediate vacuum saturated modulus, and the ratio of 3) to 1) is the OSHD IRM_R for a design mixture.

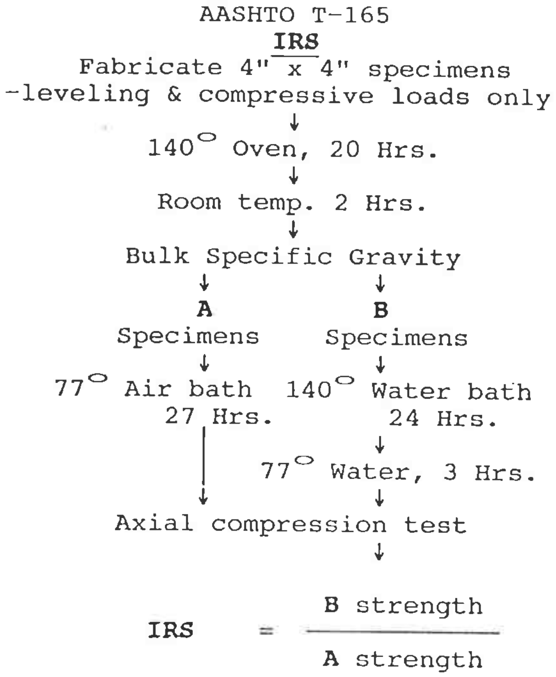
A Retsina Mark VI Resilient Modulus non-destructive testing apparatus was used for the M_R.

2.5 General Comments

AASHTO requires at least triplicate specimens of each condition for the IRS and the Modified Lottman Tests. Also, the Root-Tunnicliff, NCHRP 274 Report suggested triplicate specimens. However, only one specimen for each condition was fabricated in this study for the three tests mentioned above because of the amount of time, storage space and materials involved for the 15 different bituminous mixtures tested. The 15 mixtures were considered the minimum number needed to get a diverse but representative sample.

In three of the tests (see Table 3a at the end of Section 2.5 for a tests comparison), the 4-inch diameter by nominal 2.5-inch high specimens (briquets) of dense-graded asphalt concrete mixtures were molded and compacted with a Kneading Compactor to the specified size required by each test. The kneading foot of the compactor applied 20 blows at 250 psi followed by 150 blows at 500 psi. The specimens were then cooled to 140 . Then the specimens were leveled by compressive loads at 1000 psi.

TABLE 1



AASHTO T-165

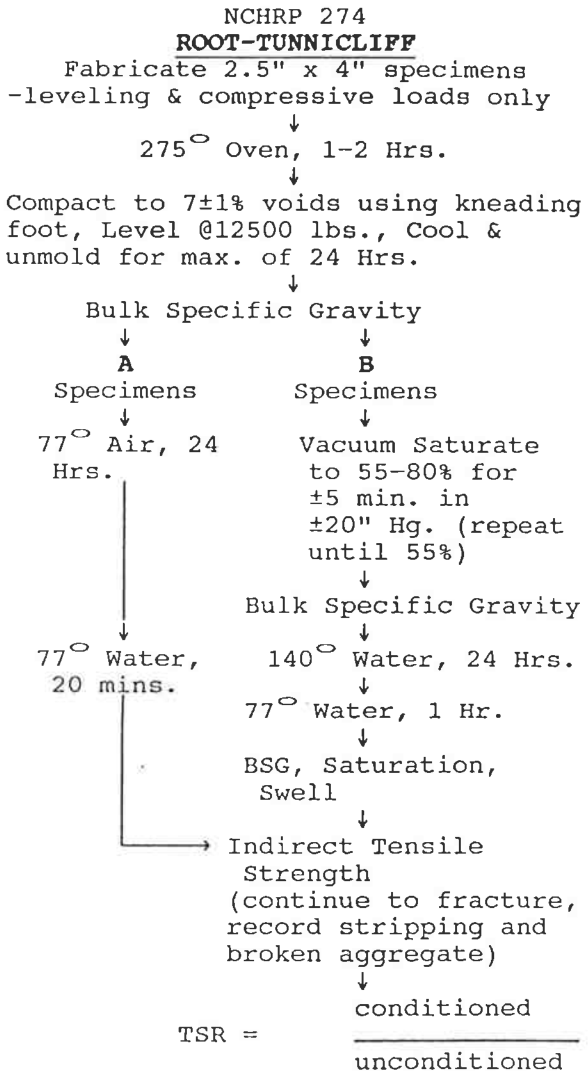
IRS

Fabricate 4" x 4" specimens
-leveling & compressive loads only
↓
140° Oven, 20 Hrs.
↓
Room temp. 2 Hrs.
↓
Bulk Specific Gravity

A Specimens
↓
77° Air bath 27 Hrs.
↓
Axial compression test

B Specimens
↓
140° Water bath 24 Hrs.
↓
77° Water, 3 Hrs.
↓
Axial compression test
↓

$$\mathbf{IRS} = \frac{\mathbf{B}\text{ strength}}{\mathbf{A}\text{ strength}}$$



NCHRP 274

ROOT-TUNNICLIFF

Fabricate 2.5" x 4" specimens
-leveling & compressive loads only
↓
275° Oven, 1-2 Hrs.
↓
Compact to 7±1% voids using kneading foot, Level @12500 lbs., Cool & unmold for max. of 24 Hrs.
↓
Bulk Specific Gravity

A Specimens
↓
77° Air, 24 Hrs.
↓
77° Water, 20 mins.
↓
Indirect Tensile Strength

B Specimens
↓
Vacuum Saturate to 55-80% for ±5 min. in ±20" Hg. (repeat until 55%)
↓
Bulk Specific Gravity
↓
140° Water, 24 Hrs.
↓
77° Water, 1 Hr.
↓
BSG, Saturation, Swell
↓
Indirect Tensile Strength (continue to fracture, record stripping and broken aggregate)
↓

$$\text{TSR} = \frac{\text{conditioned}}{\text{unconditioned}}$$

TABLE 2

AASHTO T-283
MODIFIED LOTTMAN
Fabricate 2.5" x 4" specimens
-leveling & compressive loads only
↓
Cool @ room temp. for
2 ±1/2 Hrs.
↓
140° Oven, 16 Hrs.
↓
275° Oven 2 Hrs.
↓
Compact to 7±1% voids using kneading foot, Level @12500 lbs., Cool to 77° Air & unmold for 72-96 Hrs.
↓
Bulk Specific Gravity, voids

A Specimens
↓
77° Air bath
24 Hrs.
↓
Wrap & Place in
77° Water, 2 Hrs.

B Specimens
↓
Vacuum Saturate in
±20" Hg. for ±5 min.
↓
Rest 30 min.
↓
BSG - if not 55% minimum saturation, more vacuum saturation
↓
Wrap & Freeze for
16 Hrs.
↓
140° Water bath,
24 Hrs.
↓
77° Water, 2 Hrs.
↓
Indirect Tensile
Strength
↓

$$\text{TSR} = \frac{\text{conditioned}}{\text{unconditioned}}$$

IRM_R
OSHD M_R
Fabricate 2.5" x 4" specimens
-leveling & compressive loads only
Compact by standard number of blows (Typ. ±5% Voids) level @12500 lbs., cool to 77°F, unmold
↓
Cool @ room temp. for
2 ±1/2 Hrs.
↓
140° Oven, 16 Hrs.
↓
275° Oven 2 Hrs.
↓
Bulk Specific Gravity
↓
Cool 77° Air, 24 Hrs.
↓
(1) M_R Test
↓
Vacuum Saturate at 1.2" Hg Abs. for 30 min.
↓
Rest specimen immersed for 2-5 min.
↓
77° Water bath, 3 1/2 Hrs.
↓
(2) M_R Test
↓
Vacuum Saturate in 1.2" Hg Abs. for 30 min.
↓
Wrap & freeze 15 Hrs.
↓
140° Water bath, 24 Hrs.
↓
77° Water bath, 3 Hrs.
↓
(3) M_R Test
↓
$$\text{Wet TSR} = \frac{(2)}{(1)}$$

$$\text{IRM}_R\ \text{TSR} = \frac{(3)}{(1)}$$

TABLE 3a
Tests Comparison

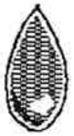
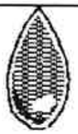
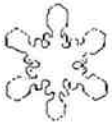
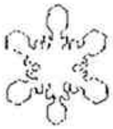
Tests	Specimen Size	Test Stress -Breakage Diagram 77	Destructive Final Test/ Loading Rate	Moisture or Vacuum Saturated	Freeze/Thaw
IRS AASHTO T-165	4" x 4" 1 Dry 1 Wet	 Triaxial Compression	Yes 0.2"/min.	 Moisture	
Root-Tunnicliff NCHRP 274	4" x 2.5" 1 Dry 1 Wet	 Diametral Tensile Strength	Yes 2"/min.	 Vacuum Saturated	
Modified Lottman AASHTO T-283	4" x 2.5 1 Dry 1 Wet/Frozen	 Diametral Tensile Strength	Yes 2"/minute	 Vacuum Saturated	
IRM$_R$ OSHD M$_R$ TM-315	4" x 2.5" 1 Dry/Wet/Frozen	 Diametral Tensile Modulus	No	 Vacuum Saturated	

TABLE 3b
Tests Comparison

Tests	Flattening of Specimen, Strength Correction	Voids %	Saturation Specifications	Other Data Recorded
IRS AASHTO T-165	No	Mix Design (Typical 5%±)	None	--
Root-Tunnicliff NCHRP 274	No	7 ± 1 %	55 - 80% once	Visual Stripping & Fractured Aggregate
Modified Lottman AASHTO T-283	Yes	7 ± 1 %	55 - 80% once	Visual Stripping
IRM^{R} OSHD M^{R} TM-315	No	Mix Design (Typical 5%±)	30 minutes at 1.2" Hg Abs. Twice repeated	--

2.6 Conditioning Procedures

The following is a more detailed description of the three conditioning procedures used in this study.

2.6.1 Water Bath soaking allows non-pressurized water to infiltrate into the specimen. This technique applies to IRS only.

2.6.2 Vacuum-Saturation forces moisture into the test specimen.[9] This procedure simulates short term moisture damage when asphalt concrete pavement approaches saturation in the field. Vacuum-saturation consists of immersing the specimens in a decanter filled with water and applying a vacuum to the decanter for a specified time period.[16] The vacuum draws air out of the specimen, which is replaced by the water surrounding the specimen when the vacuum is released.

This method applies to the IRM_R, Modified Lottman and Root-Tunnicliff tests but there were different degrees of saturation achieved for each test..

2.6.3 Freeze-Thaw (following vacuum saturation) induces mechanical damage to the specimen.[9] This procedure simulates long term, accelerated moisture damage caused by forces of the environment and traffic.

The accelerated conditioning induces internal tensile stress to the asphalt concrete mixture structure through the development of internal water pressures on void fissures of the asphalt-fines matrix and at the asphalt-aggregate interfaces. The pressures are produced prior to and by ice formation, and by the differential thermal expansion stresses between water and asphalt concrete mixture when the frozen, saturated mixture is subjected to the warm-water [thawing] bath. In addition, the warm-water bath allows for emulsification to take place if the asphalt used in the mixture has this potential.

Another result of [this] conditioning is that it seems to test the durability of the aggregates in the mixture, tending to break down the weaker, porous ones [in a manner] similar to that which has been observed with weak aggregates in asphalt concrete pavement mixtures subjected to moisture.[11] The visual inspection of aggregate breakage of the specimens is noted in Table 7c & 7d Appendix F.

This conditioning procedure applies to IRM_R and Modified Lottman Tests only.

3.0 OSHD TEST PROGRAM

The routine Oregon State Highway Division (OSHD) testing program for bituminous mix designs is to identify weather-susceptible asphalt concrete by the use of asphalt stripping tests. When the asphalt concrete fails to meet the minimum stripping index criteria, treatment with anti-strip additive and/or lime treatment of aggregate is considered. The routine OSHD design testing consists of determination of:

1) Hveem stability after first and second compaction
2) Bulk Specific Gravity after first and second compaction
3) Maximum Specific Gravity, "Rice Method"
4) Percent of Voids after first and second compaction
5) IRS, T-165
6) IRM_R (vacuum saturation and freeze-thaw conditioning)

For this study, the Modified Lottman and Root-Tunnicliff Tests were performed in addition to the routine testing program for each of the fifteen mix designs evaluated.

3.1 MIX DESIGN VARIABLES

The fifteen mix designs varied in aggregate sources, asphalt suppliers, asphalt grades and mix gradations. There were seven asphalt brands, six asphalt grades, ten Oregon "B" Mixes and five Oregon "C" Mixes. The mixes used with Oregon "B" or "C" gradations had nominal 3/4" and 1/2" maximum aggregate sizes respectively (See Table 8, Appendix F for a complete description of mix characteristics) The study design used only dense-graded mixes.

3.2 VARIATIONS IN ASPHALT AND AGGREGATE TREATMENTS

Three combinations of asphalt and aggregate treatments were tested for each mix design. These are: 1) virgin asphalt with no aggregate treatment; 2) virgin asphalt with lime-treated aggregate; and 3) asphalt with anti-strip additive with no aggregate treatment. All three non-treated and treated types of each mix were correlated with the results of the other tests.

3.2.1 Virgin asphalt with no aggregate treatment

This mix type was used as a reference value to determine possible increases in stripping resistance with the two treated types for each mix.

3.2.2 Virgin asphalt with lime-treated aggregate

Hydrated lime slurry was used on the fifteen mix designs to change the aggregate surface characteristics by forming a calcium-hydroxyl-silicate crust on the aggregate prior to mixing. During the mixing, the asphalt penetrates into the pores of the calcium hydroxyl silicate crust on the surface of the aggregate, thus producing a bond or interface between the asphalt and the aggregate.

3.2.3 Asphalt with anti-strip with no aggregate treatment

Anti-stripping agents used were cationic surfactants which increased the wetting ability of the asphalt to bond to the aggregate. The bond is formed by the non-polar end of the hydrocarbon of the anti-stripping agent attaching to the asphalt while the amine group forms ammonium salts with the hydrogen ions in the aggregate. Also the asphalt coat on the aggregate will have greater adhesion than without the anti-stripping agent.

3.3 TEST RESULTS

For the complete test data for the 15 projects see Appendix F, Tables 7a-7e and 8.

4.0 EVALUATION AND COMPARISON OF THE TESTS

None of the four tests predicted the same degree of asphalt stripping across the range of asphalt and aggregate tested.

From other reports[12] on stripping, the modulus ratio after freeze-thaw is expected to almost always be less than that after Vacuum-Saturation, and severe stripping is associated with very low ratios. In general, this was found to be true in this study, as the T-283 and the IRM_R tests had the lowest indexes overall (see Figure 1). However, from the tests performed in this study, the Freeze/Thaw ratios were not definitively correlated between the two tests.

Not having the triplicate specimens for each test may have influenced the results.

4.1 Rank-Order Evaluation

The hypothesis used in this analysis is that the most stripping-susceptible aggregates have the lowest test index and therefore have the lowest rank, while the least stripping susceptible aggregates have the highest rank. This hypothesis also assumes that the most stripping susceptible aggregates will show the greatest improvement in test index when treated with lime or anti-strip additive (See Figure 2). Stripping index results for each of the four tests evaluated were plotted in rank order of increasing test index for the untreated mixes. The results for the lime treated aggregate test index and the anti-strip additive test index were then plotted in the same rank order (See Figures 3 to 6).

Figures 3 to 6 show the results of the rank order evaluation. As shown in Figure 3, the IRS test is the only test with results which agreed with the hypothesis. That is, when lime-treated and anti-strip additive test index results are plotted in the same rank order as the untreated test index results, they show a general improvement in the index with treatment for the most stripping-susceptible aggregates identified by the IRS test. There is little or no improvement for the least stripping susceptible aggregates. As expected, the greatest improvement in stripping index occurs with the lime treated aggregate. The IRS test produced six projects with index results below the 75 percent minimum recommended by OSHD specifications.

The Root-Tunnicliff and the Modified Lottman tests did not fit the rank-order hypothesis model (See Figures 4 and 5 respectively). Neither test showed consistently higher stripping index for lime treated aggregate compared to anti-strip additive. The modified Lottman test produced only three projects with TSR's below the 70 percent minimum. The Root-Tunnicliff produced no projects with TSR below the 70 percent minimum. This may be due to the variation caused by lower compactive effort at the "in place" void content.

The OSHD resilient modulus test only marginally fit the rank-order hypothesis model and showed a greater inconsistency in the effectiveness of the lime-treated aggregate and anti-strip additive. The resilient modulus test was the most severe test of the four evaluated, with 10 tests below the 70 percent minimum recommended by OSHD specifications.

Within the rank-order evaluation, there was only one project which was identified as the most consistent stripper by the average ranking for all four tests. This was the Queen Avenue/Corvallis-Lebanon Highway Project (QU) (See Figure 10). The IRS test predicted this project would be susceptible to stripping and that lime treatment of aggregate or anti-strip additive in the asphalt would improve the resistance to stripping. The Root-Tunnicliff test only marginally predicted stripping susceptibility, but like the IRS indicated both lime treatment and anti-strip additive would improve resistance to stripping. Both the modified Lottman and the OSHD resilient modulus test predicted stripping susceptibility, but unlike the other tests, neither predicted that lime treatment would improve resistance to stripping, while both predicted that anti-strip additive would improve resistance to stripping.

There were cases where the test index was higher for the vacuum saturated specimen than for the dry specimen. One explanation is the water increased the surface tension in the wet specimen, thus creating a higher index.

In Figures 7 to 9, the test index results are listed in rank order of the plain IRS test index for all of the untreated aggregate, lime-treated aggregate, and anti-strip additive tests respectively. These figures clearly show the lack of correlation between the four tests evaluated.

4.2 Average Results Analysis

In separate analysis, all of the results for the four different tests and three different types of treatment were averaged for all 15 projects. The results are shown in Figure 10. From this analysis it appears that the Root-Tunnicliff test is the least severe of the four tests evaluated, while the OSHD resilient modulus test is the most severe. Both the IRS and the IRM_R tests produce higher results with lime treatment, while the Root-Tunnicliff and the Modified Lottman tests produce higher results with anti-strip additive. It appears that the tests are simulating distinctly different stripping failure modes.

The results also show that resilient modulus and Root-Tunnicliff tests have the greatest standard deviation in test results, while the IRS and modified Lottman have the least. It is not clear if this is the result of "scatter" in test results or due to the ability of particular tests to discriminate between stripping and non-stripping specimens.

4.3 R-Squared Correlation Values between Tests

A regression analysis was performed to determine the extent of the correlation between many of the test results obtained. An R^2 value was obtained comparing the 15 mix designs' results (stripping index ratios, absolute strengths, or moduli) with other sets of 15 results: e.g., the R^2 value comparing the 15 results for lime-treated IRS with lime-treated IRM_R was 0.05 (see Table 4b) Similarly, the R^2 of compressive strength of lime treated IRS specimens before water bath compared with after water bath treatment was 0.50 (see Table 4a).

Table 5 shows the R^2 values between the stripping indexes tested. It is clear that none of the tests evaluated in this study correlate with each other.

Table 6 shows the R^2 values between strength or modulus values for the same test. In this statistical analysis, the unconditioned strengths (or modulus) for the untreated specimens were correlated with the unconditioned strengths for the lime-treated and anti-strip additive specimens. The hypothesis in this analysis is that the more repeatable test is the one for which the unconditioned specimens have the highest degree of correlation. These results indicate the IRS test is the least repeatable and the IRM_R test is the most repeatable of the four tests evaluated.

As shown in Table 6, there was no correlation of stripping test results with the visual rating of stripping performed on the Root-Tunnicliff and modified Lottman specimens due to the difficulty for the technicians to reliably visually rate the specimens under varying conditions of surface moisture and lighting, even when a special light was used.

Tables 4a-4e provides a complete summary of all the correlation coefficient results obtained in this study.

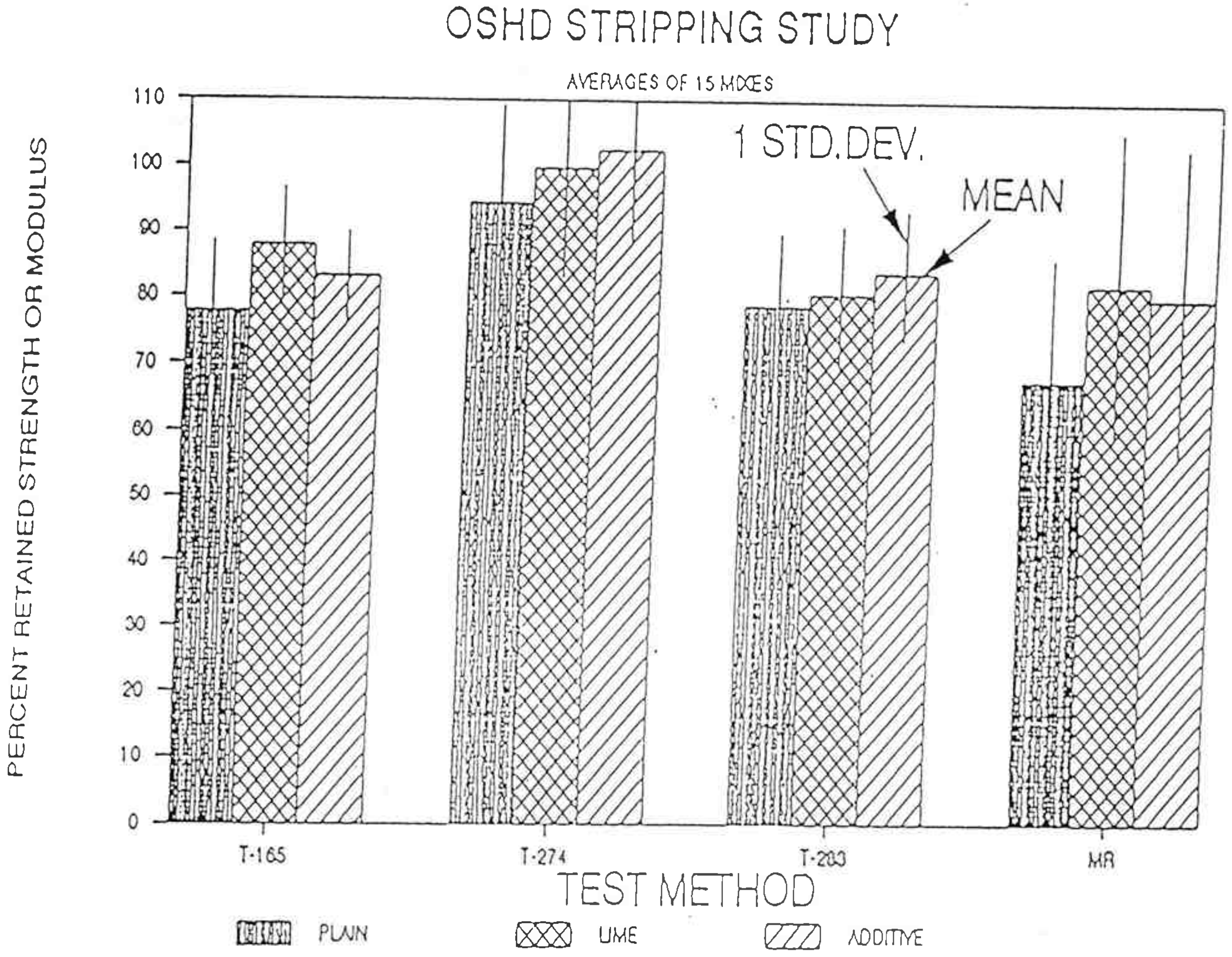

OSHD STRIPPING STUDY
AVERAGES OF 15 MIXES
PERCENT RETAINED STRENGTH OR MODULUS
110
100
90
80
70
60
50
40
30
20
10
0
1 STD.DEV.
MEAN
T-165
T-274
T-283
MR
TEST METHOD
PLAIN
LIME
ADDITIVE

FIGURE 1

PROJECT	ABBREVIATION
Queen Avenue/Corvallis-Lebanon Highway	QU
Sunnyside Road Interchange	SU
Powell Butte Junction	PB
Williamson River/Modoc "C"	WC
SCL Medford/Phoenix	SC
Murphy Road-Lava Butte	MU
Oregon 99-ECL Roseburg	OR
Pendleton/John Day	PE
Region 4 Preservation	R4
Pocahontas Road/Auburn Avenue	PR
Lostine-Trout Creek	LO
Williamson River/Modoc "B"	WB
Farewell Bend	FA
Phase 2 "Delta"	DE
Phase 2 "Builders"	BU

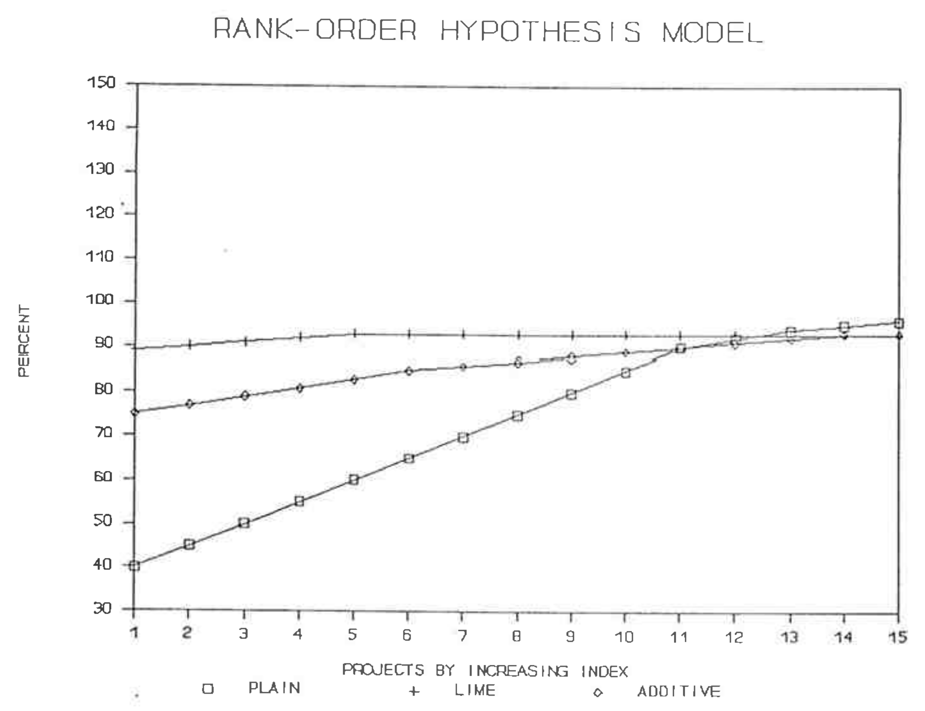


FIGURE 2

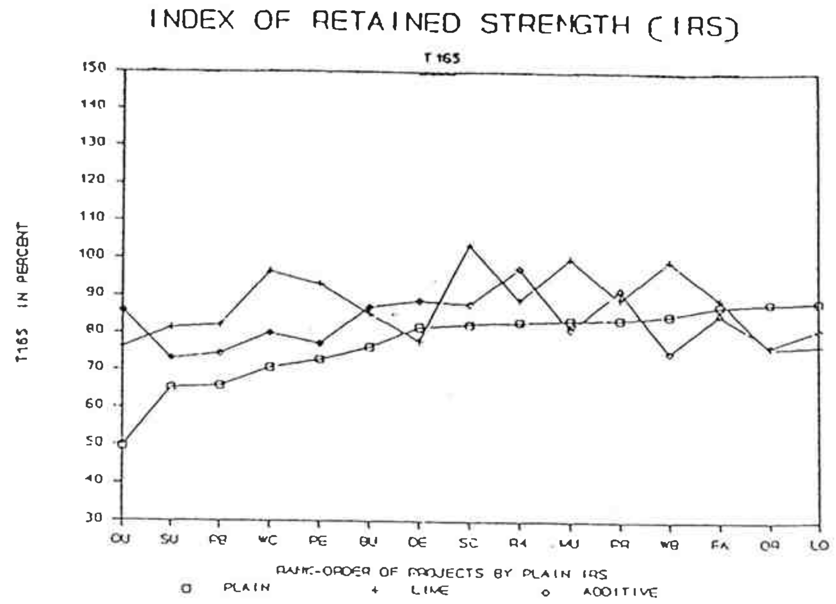


FIGURE 3

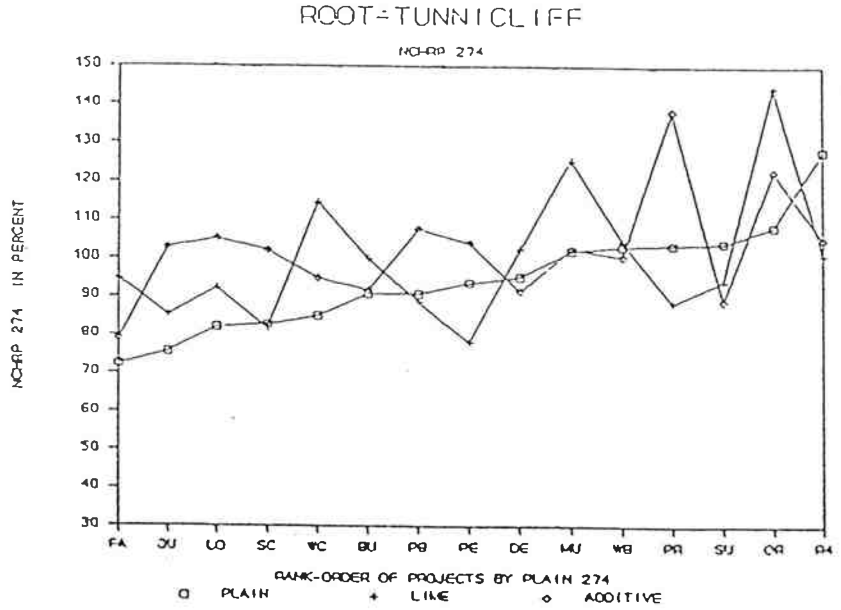


FIGURE 4

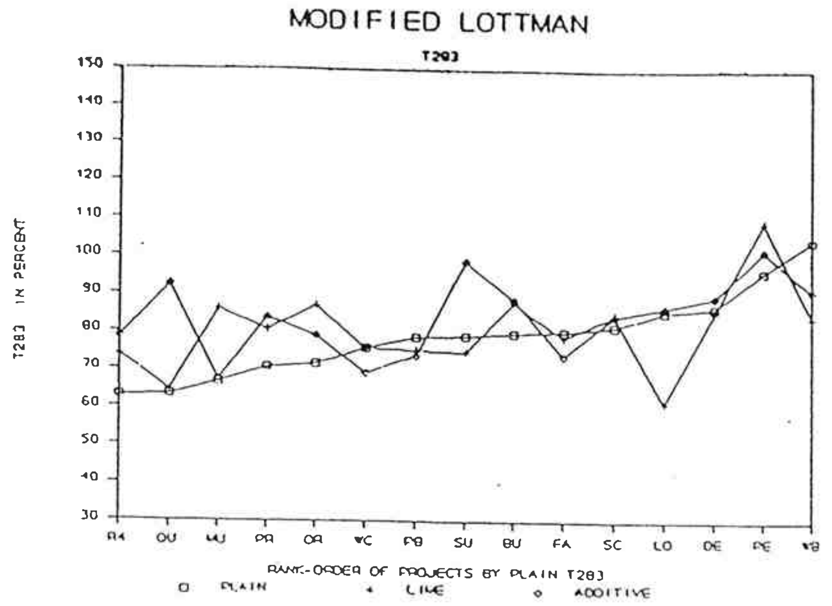


FIGURE 5

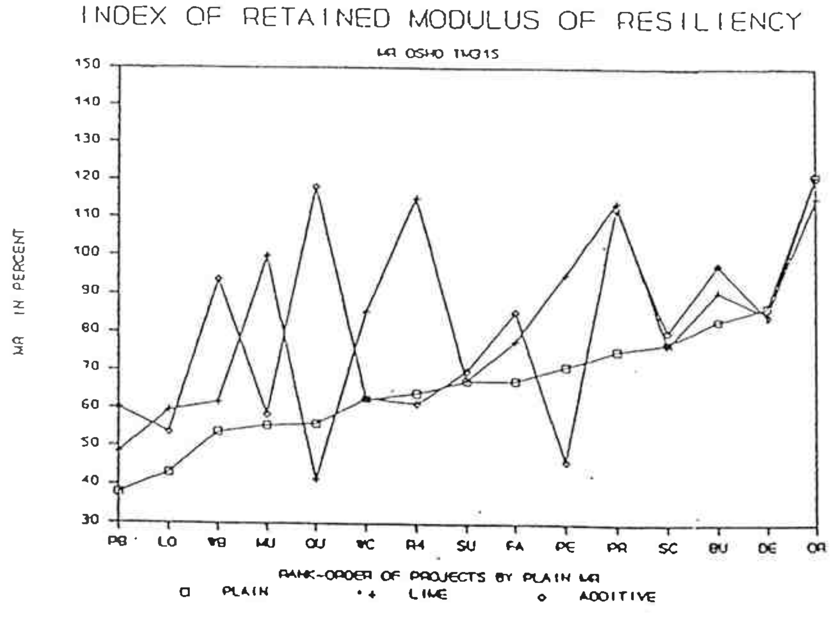


FIGURE 6

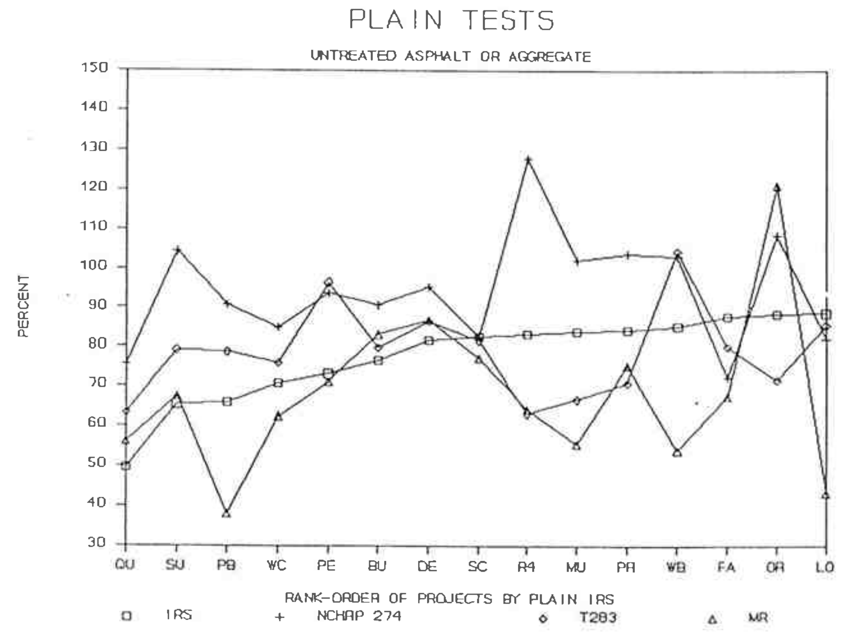


FIGURE 7

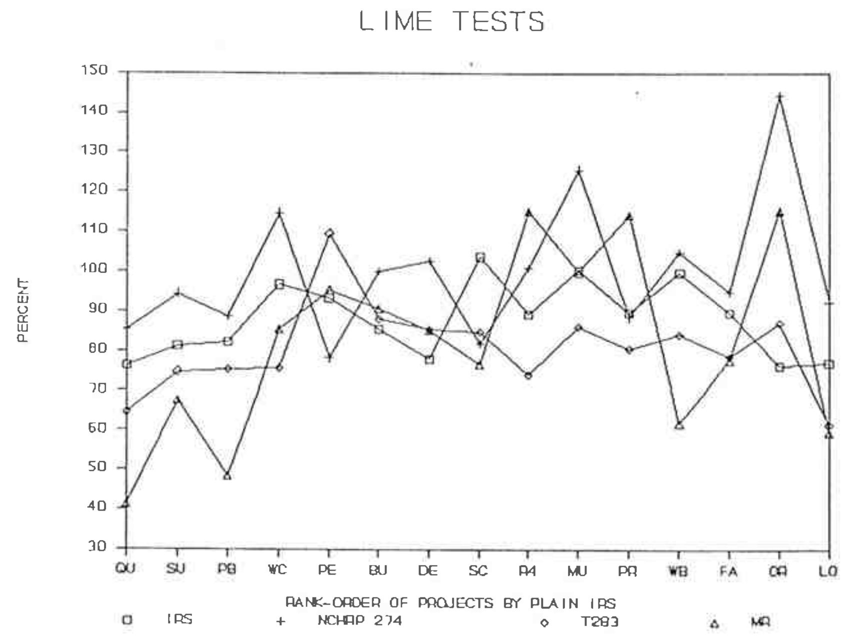


FIGURE 8

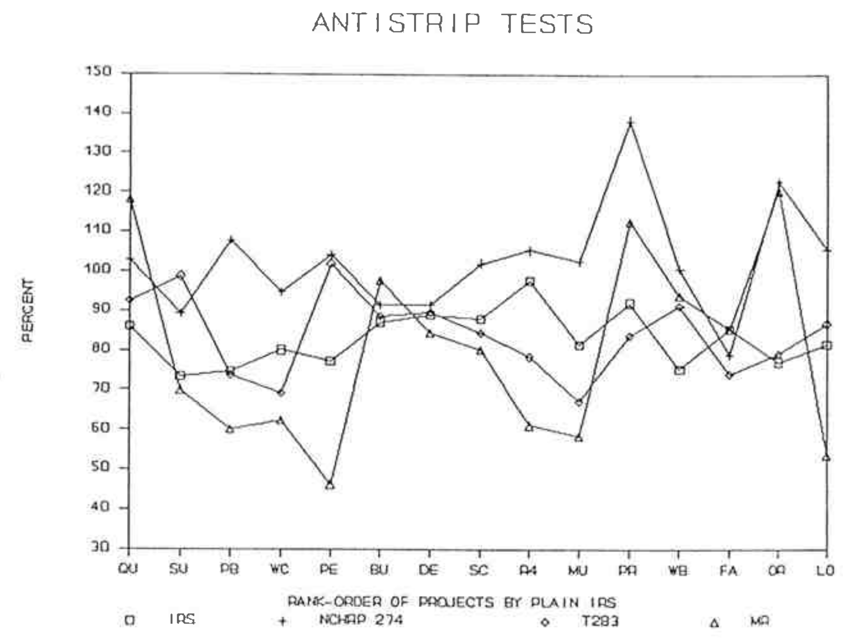

ANTISTRIP TESTS
PERCENT
150
140
130
120
110
100
90
80
70
60
50
40
30
QU
SU
PB
WC
PE
BU
DE
SC
A4
MU
PA
WB
FA
OA
LO
RANK-ORDER OF PROJECTS BY PLAIN IRS
□ IRS
+ NCHRP 274
◇ T283
△ MA

FIGURE 9

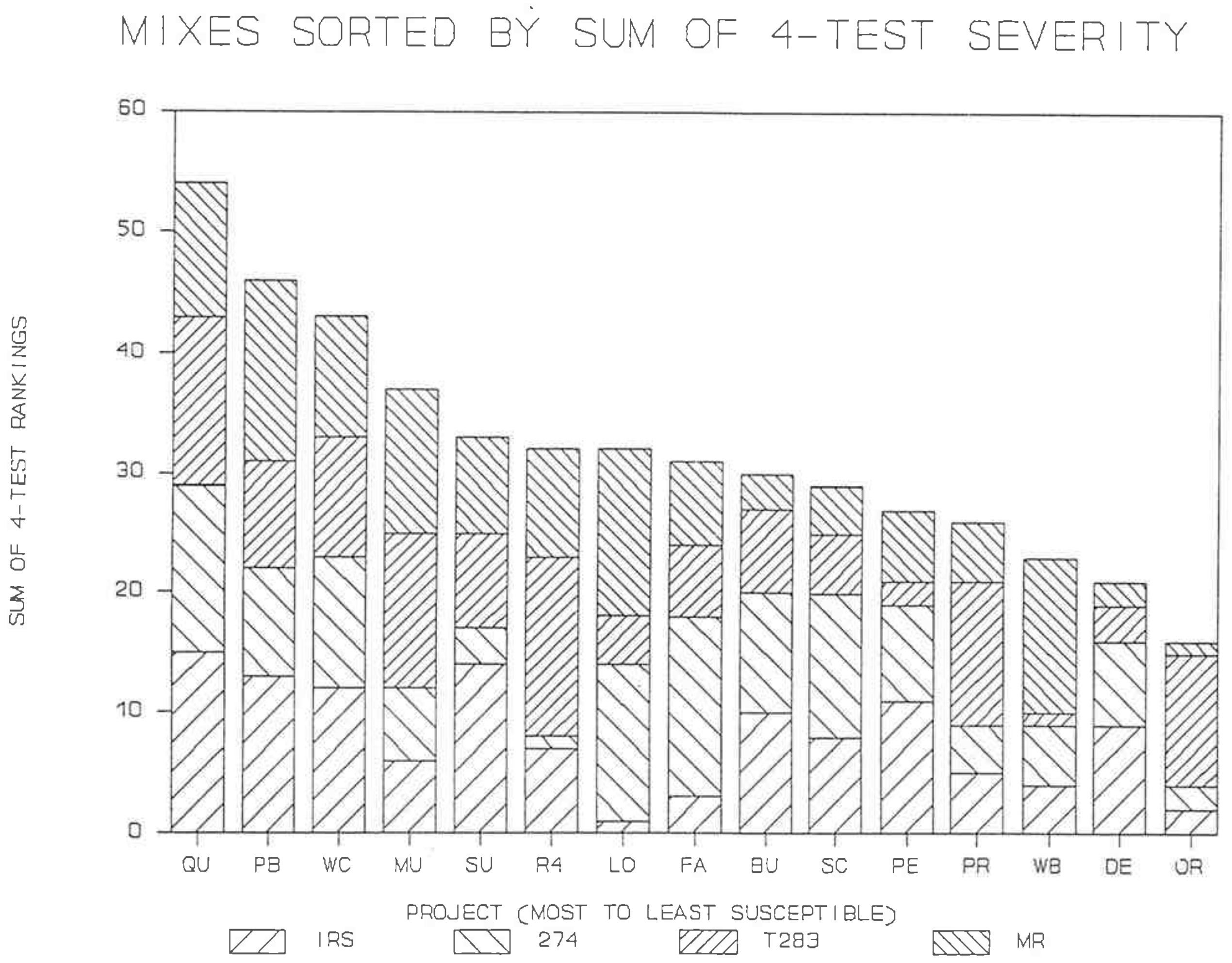

MIXES SORTED BY SUM OF 4-TEST SEVERITY
SUM OF 4-TEST RANKINGS
60
50
40
30
20
10
0
QU
PB
WC
MU
SU
R4
LO
FA
BU
SC
PE
PR
WB
DE
OR
PROJECT (MOST TO LEAST SUSCEPTIBLE)
IRS
274
T283
MR

FIGURE 10

TABLE 4a LINEAR REGRESSION FOR R^2

B = Before A = After % = Percent

		T165									T274								
		Plain			Lime			Anti			Plain			Lime			Anti		
		B	A	%	B	A	%	B	A	%	B	A	%	B	A	%	B	A	%
T165 Plain	B		0.47	0.06	0.35	0.40	0.18	0.68	0.48	0.01	0.36	0.33	0.00	0.25	0.16	0.01	0.36	0.20	0.48
	A			0.28		0.47			0.37			0.18			0.20			0.09	
	%						0.07			0.05			0.08			0.14			0.03
Lime	B					0.83	0.12	0.46			0.44			0.45		0.25	0.60		
	A						0.50		0.23						0.45	0.14			
	%									0.00	0.10		0.00	0.15	0.08	0.00			0.01
Anti	B								0.67	0.03	0.52						0.61	0.41	0.25
	A									0.18	0.27		0.00					0.25	
	%										0.06		0.02			0.03	0.02	0.02	0.02
T274 Plain	B											0.71	0.08	0.62	0.57	0.14	0.80	0.70	0.10
	A												0.07		0.81			0.86	
	%															0.15			0.16
Lime	B														0.83	0.16	0.84		
	A															0.55			
	%																		0.02
Anti	B																	0.81	0.18
	A																		0.00
	%																		

TABLE 4b LINEAR REGRESSION FOR R^2

		T283									M_R														
		Plain			Line			Anti			Plain					Line					Anti				
		B	A	%	B	A	%	B	A	%	B	Wet	%	Frozen	%	B	Wet	%	Frozen	%	B	Wet	%	Frozen	%
T165 Plain	B	0.24	0.30	0.01	0.16	0.10	0.02	0.20	0.18	0.07	0.15	0.06	0.00	0.01	0.07	0.06	0.02	0.02	0.01	0.04	0.07	0.00	0.14	0.01	0.02
	A		0.23			0.11			0.07			0.14		0.06			0.11		0.10			0.04		0.03	
	%			0.05			0.05			0.09			0.23		0.10			0.17		0.31			0.11		0.00
Line	B	0.33			0.27		0.00	0.40			0.30					0.25	0.20	0.00	0.14	0.00					
	A					0.28	0.02										0.18								
	%	0.04		0.05	0.04	0.14	0.16			0.07	0.08		0.01		0.03	0.04		0.00		0.05			0.04		0.09
Anti	B	0.24						0.42	0.28	0.25	0.23		0.08		0.00						0.16	0.04	0.08	0.09	0.00
	A	0.20		0.23					0.16		0.19										0.11	0.03		0.07	
	%	0.00		0.22			0.02	0.00	0.02	0.02	0.00		0.02		0.02			0.05		0.18	0.00	0.00	0.00	0.00	0.04
T274 Plain	B	0.48	0.37	0.12	0.69	0.51	0.04	0.60	0.34	0.35	0.49	0.29	0.00	0.14	0.06	0.30	0.20	0.05	0.12	0.03	0.41	0.14	0.18	0.18	0.06
	A		0.53			0.72			0.41			0.70		0.40			0.61		0.49			0.50		0.43	
	%			0.03			0.04			0.00			0.21		0.06			0.12		0.39			0.24		0.00
Line	B	0.70			0.73		0.02	0.85			0.65					0.54	0.43	0.02	0.39	0.03					
	A					0.75	0.00										0.73								
	%	0.30		0.07	0.33	0.38	0.00			0.26	0.43		0.63		0.23	0.58		0.17		0.21			0.22		0.05
Anti	B	0.66						0.81	0.53	0.42	0.57		0.08		0.01						0.48	0.25	0.07	0.24	0.06
	A	0.74		0.38'					0.47		0.86										0.76	0.61		0.60	
	%	0.01		0.07			0.00	0.03	0.08	0.00	0.02		0.02		0.04			0.26		0.16	0.04	0.17	0.28	0.20	0.11

TABLE 4c LINEAR REGRESSION FOR R^2

	T283									M_R														
	Plain			Line			Anti			Plain					Line					Anti				
	B	A	%	B	A	%	B	A	%	B	Wet	%	Frozen	%	B	Wet	%	Frozen	%	B	Wet	%	Frozen	%
T283 Plain B		0.62	0.32	0.84	0.65	0.03	0.74	0.62	0.28	0.77	0.60	0.08	0.52	0.01	0.74	0.59	0.01	0.59	0.12	0.60	0.53	0.00	0.41	0.05
A			0.00		0.49			0.46			0.22		0.25			0.24		0.24			0.22		0.11	
%						0.19			0.24			0.10		0.01			0.01		0.08			0.00		0.05
Line B					0.79	0.03	0.79			0.80					0.71	0.58	0.01	0.53	0.06					
A						0.08										0.59								
%									0.06	0.01		0.00		0.21	0.00		0.03		0.23			0.05		0.01
Anti B								0.69	0.54	0.66		0.14		0.02						0.54	0.46	0.00	0.42	0.03
A									0.06	0.36										0.28	0.29		0.27	
%										0.44		0.30		0.01			0.02		0.05	0.34	0.27	0.00	0.24	0.01
M_R Plain B											0.90	0.20	0.61	0.00	0.92	0.85	0.02	0.76	0.15	0.91	0.76	0.00	0.66	0.04
Frozen											0.72			0.36				0.83					0.88	
%												0.16					0.01		0.40			0.45		0.30
Line B																0.96	0.04	0.92	0.30	0.84				
Frozen																0.95			0.54				0.79	
%																	0.06					0.24		0.01
Anti B																					0.75	0.00	0.62	0.10
Frozen																					0.85			0.08
%																						0.38		

TABLE 4d VISUAL STRIPPING

			T274						T283					
			Plain		Line		Anti		Plain		Line		Anti	
			B	A	B	A	B	A	B	A	B	A	B	A
T165	Plain	B	0.01	0.02	0.04	0.01	0.00	0.01	0.44	0.27	0.20	0.15	0.24	0.55
		A		0.10		0.07		0.01		0.22		0.17		0.11
		%	0.09	0.05		0.21	0.02	0.00	0.04	0.00	0.00	0.00	0.02	0.20
	Line	B	0.08	0.34		0.01			0.22	0.08	0.22	0.05		
		A		0.37		0.00				0.16		0.13		
		%	0.00	0.17	0.01	0.02			0.01	0.16	0.03	0.21		
	Anti	B	0.00				0.02		0.36				0.14	0.28
		A						0.02						0.31
		%	0.12	0.06			0.33	0.15	0.00	0.05			0.04	0.02
NCHRP 274	Plain	B	0.00	0.22	0.01	0.05	0.02	0.03	0.18	0.03	0.15	0.00	0.13	0.12
		A		0.35		0.14		0.09		0.02		0.00		0.10
		%	0.01	0.06	0.37	0.14	0.42	0.10	0.07	0.01	0.12	0.00	0.01	0.00
	Line	B	0.15	0.68	0.09	0.18			0.12	0.00	0.08	0.00		
		A		0.53		0.10				0.01		0.02		
		%	0.00	0.08	0.00	0.00			0.01	0.14	0.00	0.13		
	Anti	B	0.06				0.01		0.17				0.03	0.07
		A						0.09						0.01
		%	0.16	0.02			0.00	0.03	0.50	0.14			0.05	0.21
T283	Plain	B	0.00	0.46	0.21	0.44	0.19	0.35	0.04	0.00	0.00	0.03	0.02	0.04
		A		0.24		0.21		0.24		0.01		0.02		0.04
		%	0.02	0.15	0.07	0.20	0.14	0.06	0.00	0.04	0.00	0.03	0.00	0.00
	Line	B	0.00	0.37	0.04	0.23			0.02	0.01	0.00	0.07		
		A		0.38		0.10				0.03		0.06		
		%	0.02	0.00	0.05	0.06			0.29	0.03	0.17	0.00		
	Anti	B	0.08		0.03		0.04	0.18	0.03		0.02		0.00	0.00
		A	0.03	0.28		0.30	0.03	0.12	0.01	0.09		0.17	0.03	0.00
		%	0.10	0.45			0.02	0.08	0.05	0.02			0.06	0.00

TABLE 4e VISUAL STRIPPING

			T274						T283					
			Plain		Lime		Anti		Plain		Line		Anti	
			B	A	B	A	B	A	B	A	B	A	B	A
IRM$_R$	Plain	B	0.01	0.44	0.04	0.15	0.12	0.14	0.01	0.00	0.02	0.00	0.07	0.01
	Frozen			0.21		0.11		0.05		0.23		0.19		0.10
		%	0.00	0.00	0.00	0.00	0.00	0.01	0.29	0.44	0.23	0.25	0.20	0.26
	Line	B	0.00	0.43	0.06	0.15			0.01	0.04	0.00	0.05		
	Frozen			0.42		0.13				0.09		0.06		
		%	0.02	0.18	0.02	0.01			0.33	0.09	0.18	0.03		
	Anti	B	0.02		0.02		0.06	0.09	0.00		0.00		0.02	0.00
	Frozen		0.03	0.13		0.05	0.01	0.00	0.10	0.23		0.16	0.01	0.09
		%	0.00	0.18			0.05	0.15	0.08	0.29			0.04	0.07
NCHRP 274	Plain	B		0.32	0.05	0.01	0.16	0.25	0.03					
		A			0.07	0.15	0.36	0.61		0.01				
	Line	B				0.48	0.46				0.04			
		A						0.45				0.09		
	Anti	B						0.59					0.04	
		A												0.01
T283	Plain	B	0.03							0.49	0.69	0.30	0.50	0.58
		A		0.01							0.52	0.78	0.58	0.62
	Line	B			0.04							0.52	0.73	
		A				0.09								0.51
	Anti	B					0.04							0.48
		A						0.01						

TABLE 5

R-SQUARED CORRELATION VALUES BETWEEN TEST METHODS FOR RETAINED STRENGTH RATIO OR MODULUS RATIO (PERCENT)

Virgin Asphalt No Aggregate Treatment

	T165	NCHRP 274	AASHTO T283	OSHD TM 315
AASHTO T165	--	0.08	0.05	0.10
NCHRP 274	--	--	0.03	0.06
AASHTO T283	--	--	--	0.01
OSHD TM 315	--	--	--	--

Virgin Asphalt Lime Treated Aggregate

	T165	NCHRP 274	AASHTO T283	OSHD TM 315
AASHTO T165	--	0.00	0.16	0.05
NCHRP 274	--	--	0.00	0.21
AASHTO T283	--	--	--	0.23
OSHD TM 315	--	--	--	--

Anti-Strip No Aggregate Treatment

	T165	NCHRP 274	AASHTO T283	OSHD TM 315
AASHTO T165	--	0.02	0.02	0.04
NCHRP 274	--	--	0.00	0.11
AASHTO T283	--	--	--	0.01
OSHD TM 315	--	--	--	--

TABLE 6

R-SQUARED CORRELATION VALUES BETWEEN TYPE OF ANTI-STRIP TREATMENT FOR "BEFORE" COMPRESSIVE STRENGTH, TENSILE STRENGTH, OR MODULUS

	COMPRESSIVE STRENGTH AASHTO T165		TENSILE STRENGTH NCHRP 274	
	LIME	ANTI	LIME	ANTI
PLAIN BEFORE	0.35	0.68	0.62	0.80
LIME BEFORE	--	0.46	--	0.84

	TENSILE STRENGTH AASHTO T283		RESILIENT MODULUS OSHD TM 315	
	LIME	ANTI	LIME	ANTI
PLAIN BEFORE	0.84	0.74	0.92	0.91
LIME BEFORE	--	0.79	--	0.84

R-SQUARED CORRELATION VALUES BETWEEN TEST METHODS AND VISUAL RATING FOR RETAINED STRENGTH RATIO OR MODULUS RATIO VS. VISUAL RATING

	Visual Rating After Conditioning		
	PLAIN	LIME	ANTI
AASHTO T165	0.05	0.02	0.15
NCHRP 274	0.06	0.00	0.03
AASHTO T283	0.15	0.06	0.08
OSHD TM 315	0.00	0.01	0.15

5.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this study, the IRS Test Method continues to be considered a valid and useful stripping test. The IRM_R test appears to have the greatest potential for future improvement due to superior repeatability and apparent greater severity of the test. The Root-Tunnicliff and Modified Lottman tests were the most difficult to perform and the least promising of the tests evaluated.

5.1 Conclusions

1) One hypothesis was that for a specific test method, the mix designs showing the least resistance to stripping would be the ones most improved by treatment with lime or anti-strip additive. This was only apparent for the IRS (T-165) Test (See Figures 3 to 6).

2) Another hypothesis was that the four tests were expected to predict stripping potential with some similarity for a particular mix design. This was not true when the same four figures mentioned above are compared, and in the bar graph of mixes sorted by sum of four test (severity) rankings. The rankings (1=least affected, 15=most affected by a test treatment as indicated by test ratio) of the four test methods for each mix were averaged to obtain the rankings shown in the graphs. Had the four methods agreed closely, the array of rankings would be expected to be much further separated and well defined. In addition, no two tests correlated well over the 15 mixes, as examined by the R^2 statistics. A possible conclusion from this was that either a) the tests predict different types of stripping, or that b) at most one test consistently predicts stripping.

3) When stripping severity (lowness of ratio of treated to untreated strength) is observed between tests, the most

notable point is that the Root-Tunnicliff treatment is least severe. Speculatively, at least, it might have the least ability to differentiate between stripping and non-stripping mixes.

4) Though it seemed a very good idea, using visual observation of broken surfaces of failed specimens to determine stripping was not effective, as the visually observed stripping (recorded for T-274 and T283) correlated very poorly with stripping ratios determined by the four test methods. Defining degrees of stripping was not easily standardized as observed by different technicians with varying light sources and varying specimen surface wetness.

5) A hypothesis was that lime-treated or anti-strip-treatment specimens might show a general increase in stripping index over the plain specimens when averaged over all mixes. As examined by R^2 statistics, this was not clearly shown. Although, it was indicated for IRM_R <u>on average</u>.

6) Even considering that ODOT uses the other two tests routinely, the Root-Tunnicliff and the Modified Lottman specimen fabrication procedures (controlled voids requiring customized compaction by experimentation for each mix) required much more effort and delays than the IRS and IRM_R, which both use standardized compaction and water treatments.

7) During data recording, an intermediate modulus ratio (vacuum-saturated to unconditioned) was measured and recorded for the IRM_R test. R^2 statistical examination of this intermediate IRM_R result was conducted during the analysis of the other four methods, but no correlation was found. In fact, this particular method (modulus of vacuum-

saturated specimens) frequently showed increased instead of reduced modulus after saturation. This was speculatively attributed to entrapped water pore pressure which did not disperse during the nearly instantaneous resilient modulus load pulses. Other possible causes are a slight aging of asphalt during conditioning in water, or the random variability of the test procedure. It was noted that with similar conditioning, the Root-Tunnicliff test also frequently indicated little or no strength reduction in the conditioned specimens.

5.2 Recommendations to improve the IRM_R testing procedures are:

1) Evaluate the need for an environmental chamber to enclose specimen and apparatus during testing. For this study, the test specimens were kept at room temperature during testing. The chamber could further improve the accuracy of the resilient modulus.

2) Further study of the Gilbert Baladi-type briquet/transducer/loading frame to possibly improve transducer precision during testing.

3) Continue to use and specify blunt and/or hemispherical transducer tips to avoid the adverse effects of the sharper conical tips of former ODOT transducers.

4) Remove ("scalp") the largest aggregates retained on the 3/4" sieve when less than 5% by weight of the total mix. Add the equivalent amount of aggregate to the 1/2" sieve size. The addition of the 3/4" to the 1/2" percentage would reduce testing variability in individual briquets (specimens). To verify the variability reduction, the effects of "scalping" large aggregates might be noted in

future comparative studies.

5) Use 1/2" loading strip as specified in ASTM D-4123, instead of the 3/4" loading strips supplied with the Retsina Mark VI equipment.

5.3 General Recommendation For All Tests

Evaluation of the amount of scatter in test results to determine if it is due to the use of only one test specimen in each condition instead of the standard or recommended triplicate specimens for each condition in the test methods T-165, T274 and T-283. A comparative study of triplicate specimens versus one specimen tested for this study should be performed. This evaluation could be based on work done by other researchers.

6.0 IMPLEMENTATION

Based on the study results several findings will be implemented or incorporated into the routine OSHD asphalt concrete mixture testing program:

1) The asphalt concrete construction specifications (Section 403) were rewritten to include mandatory IRS criteria of 75% and the IRM_R criteria of 70% for the 1989 paving season. Preliminary results of this study indicated a justification for the change. No two of the four test methods showed equal prediction of stripping across the current range of ODOT mixes and materials sources. Correlation of two test methods is needed to attempt to screen out all potentially stripping mixes. Neither Root-Tunnicliff nor Modified Lottman was adopted in place of the current ODOT tests (IRS and IRM_R), as both were considered less accurate and more difficult to run. Root-Tunnicliff seemed less definitive as mentioned in the conclusions.

Mix designs will be checked for stripping susceptibility by testing samples of AC mixture produced on the project. The IRS and IRM_R test will be performed on a sample obtained from the first 2,000 tons of AC mixture. If necessary, changes in the mix design will be made to achieve adequate stripping resistance in field mix.

2) The intermediate testing of vacuum saturated modulus will be deleted from OSHD TM 315-89. The modulus ratio after vacuum saturation is not as severe as IRM_R obtained after freezing/thawing. In the future, the specimen will be vacuum saturated and then go directly to the freezer, thus reducing the elapsed time of the test by about 12 hours.

3) For this study, ODOT obtained and implemented the use of an improved resilient modulus apparatus, the Retsina Mark VI system. This system is superior to ODOT's previous Retsina Mark IV in having: a) an automatic recording and printing option; b) a larger load frame which will accommodate the testing of 6-inch diameter cores or briquets if desired; c) a greatly increased load cell capacity (1000 lbs. as opposed to 200 lbs.); d) a digital instead of a dial readout; and e) blunt hemispherical transducer contact tips which reduce measurement error due to tip penetration into the asphalt concrete test briquet surfaces.

4) The Gilbert Baladi-type briquet holder and loading frame will be fabricated under a separate research project and will be used in an attempt to improve the accuracy and the precision of the IRM_R.

5) Due to the tendency of mixes to decrease in stripping resistance with lower asphalt cement contents, ODOT will consider changing from its current requirements of minimum

stripping resistance *at the midpoint* of allowable asphalt content*, to minimum resistance requirements *at the lowest allowable* asphalt content.

*(allowable content range = recommended plus or minus a specified fractional percent)

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