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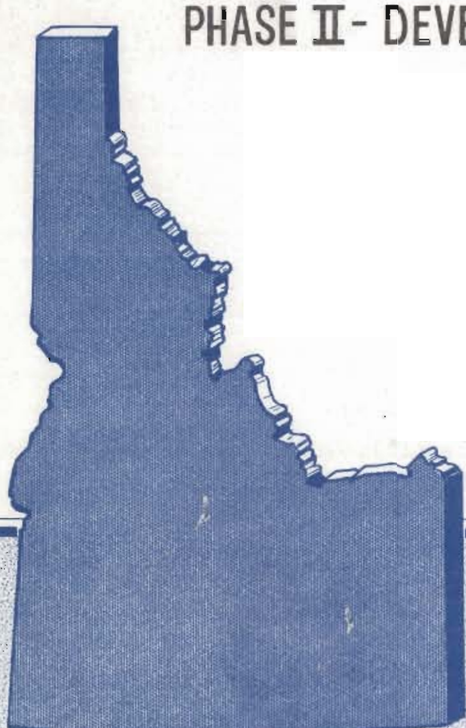
PHASE I - EVALUATION OF EXISTING TEST PROCEDURES

PHASE II - DEVELOPMENT OF A STANDARD TEST PROCEDURE



JANUARY 1972

RESEARCH PROJECT NO. 37

STATE OF IDAHO DEPARTMENT OF HIGHWAYS

in cooperation with

U.S. DEPARTMENT OF TRANSPORTATION BUREAU OF PUBLIC ROADS

USE OF MINERAL FILLER TO IMPROVE
POOR AGGREGATE FOR PLANTMIX PAVEMENT

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Mr. Erickson reviewed and approved the procedure for Phase II. Physical testing was performed by Dick O. Sanchez and James K. Armitage, Engineering Technician V. Both phases of the report were prepared by the Moscow Laboratory, typed by Mrs. Sharon Gregg, Stenographer II, and Mrs. Donna Parkes, Senior Clerk, and edited by the Research Section.

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INTRODUCTION

A serious shortage of aggregate suitable for highway construction exists in several major areas of Idaho. Poor aggregate must, therefore, be upgraded by use of a mineral filler for plantmix pavements.

In Phase I of this study, laboratory tests were conducted on various asphalt-mineral filler-aggregate mixtures using a standard good aggregate to determine which tests provide reliable, repeatable results in appraising mixture qualities of resistance to deformation, cohesion, abrasion resistance, durability, and strength. Three different mineral fillers, hydrated lime, portland cement, and limestone dust, were incorporated in varying amounts in specially designed well-graded constant total volume asphalt mixtures. The specimens were tested by the Hveem Relative Stability Test, the Moisture Vapor Susceptibility Test, the Minnesota Cold Water Abrasion Test, and the Immersion-Compression Test. These test results were then compared with those from the same tests using control specimens containing no mineral filler.

In Part A of Phase II, three different sources of poor aggregate were evaluated as to the effect of (1) different amounts of hydrated lime, portland cement and limestone dust used as mineral fillers, (2) variable filler-asphalt ratios vs constant filler-asphalt ratios on asphalt mix design values, and (3) immersion-compression test wet-dry strength ratios using a 1-day immersion period @ 140°F. vs a 4-day immersion period @ 120°F. Two other poor aggregate sources were evaluated in Part B of Phase II as to the effect of (1) optimum vs optimum minus 1% asphalt ratios on immersion-compression test wet-dry strength ratios (2) vacuum saturation of specimens prior to immersion on immersion-compression test wet-dry strength ratios, (3) immersion-compression test wet-dry strength ratios using a 1-day immersion period @ 140°F. vs a 4-day immersion period @ 140°F., (4) twenty-five freeze and thaw cycles on stripping, (5) repeatability of immersion-compression test wet-dry strength ratios, and (6) immersion-compression test specimen air void content when determined by both the Rice Method and the vacuum saturation method. Analysis of all test results permitted development of a proposed standard test procedure for use of mineral filler to improve poor aggregate.

CONCLUSIONS

Results from Phase I provide the following conclusions:

1. Each mineral filler affects an asphalt aggregate mixture differently and increasing the amount of mineral filler in a mixture can decrease the optimum asphalt content.
2. The Hveem Relative Stability Test shows good sensitivity to variation in filler-asphalt ratio in an asphalt mixture.
3. The Moisture Vapor Susceptibility Test shows (a) fairly good sensitivity to variation in filler-asphalt ratio, (b) fair sensitivity to the effect of moisture vapor and water on the mixture, and (c) no consistent relationship between Hveem relative stability values and percentage of moisture and volatiles in the mixture.
4. The Minnesota Cold Water Abrasion Test (a) shows that the asphalt content must be reduced below 5 percent before any appreciable abrasion loss occurs, (b) was developed using specimens with lower asphalt contents than are normally used in present-day construction, and (c) does not provide meaningful results when present-day asphalt contents are used.
5. The Immersion-Compression Test shows good sensitivity to both variation in filler-asphalt ratio and loss of cohesion by mixtures from water action.
6. Maximum coefficient of variation for specimens containing identical amounts of the same constituents should be 15% for individual relative stability values and 10% for individual unconfined compression strength values.

Results from Phase II show that:

1. Hydrated lime, portland cement and limestone dust all have merit as mineral fillers and can be used to improve poor aggregate. The choice of a particular mineral filler depends primarily on the amount of filler required,

aggregate source and gradation, and the asphalt used.

2. Constant filler-asphalt ratio specimens provide erratic index of retained strength values and thus should not be given further consideration.
3. The Immersion-Compression Test immersion period of 1 day @ 140°F. is just as severe as the immersion period of 4 days @ 120°F. and little difference was shown between one or four days at 140°F.
4. The present Immersion-Compression Test needs to be modified. Vacuum saturation of specimens prior to immersion is required to make test results fully meaningful. A 10 minute dry vacuum period followed by a 10 minute immersed vacuum period causes as severe an index of retained strength value reduction as does any other combination.
5. Repeatability of Immersion-Compression Test index of retained strength values is poor and needs further study to determine the reasons for the differences. A new method of specimen compaction needs to be developed.
6. Determination of mixture air void content by the vacuum saturation specific gravity method permits a fast and reasonably accurate method of calculating air void content of Immersion-Compression Test specimens.
7. Twenty-five cycles of freeze-thaw from 0°F. to 120°F. after vacuum saturation and immersion produced moderate to severe stripping in Bannock 142s Immersion-Compression Test specimens but produced little or no stripping in Twin Falls 63 specimens.

RECOMMENDATIONS

Recommendations based upon conclusions and past experience are:

1. The Moisture Vapor Susceptibility Test needs modification to more nearly duplicate asphalt stripping conditions in the field.
2. The Minnesota Cold Water Abrasion Test should not be used as it does not provide meaningful results at the higher asphalt contents being used in present-day asphalt surface course construction.
3. The standard test method should be use of the Hveem Relative Stability Test and a modified Immersion-Compression Test to evaluate use of a mineral filler to improve asphalt mixtures containing poor aggregate.
4. Percentage of air voids in Hveem Relative Stability Test specimens should be determined using Rice method specific gravity. Specimen volumes should be computed from bulk specific gravity by weighing the specimen originally in air, then in water and then again in air to correct for absorption of water.
5. Immersion-Compression Test should be modified by:
   a. Compacting test specimens by a kneading compactor to provide an air void content similar to that obtained in Hveem Relative Stability Test specimens. A meaningful comparison could then be made of the two sets of test values.
   b. Vacuum saturating test specimens prior to immersion for 1 day @ 140°F. Vacuum saturation should be a 10 minute dry vacuum period followed by a 10 minute immersed vacuum period.
   c. Determining the mixture air void content in test specimens by the vacuum saturation specific gravity method.
   d. Subjecting test specimens containing aggregate having suspected or known stripping tendencies to 25 freeze-thaw cycles from 0°F.

to 120°F. after vacuum saturation and immersion for 1 day @ 140°F.

6. Consideration needs to be given to making a 2-1/2 inch high Immersion-Compression Test specimen. After vacuum saturation and immersion, the specimen would be tested for indirect tensile strength. Additional investigation is needed in this area.
7. The Indirect Tensile Strength Test should be developed and correlated with the modified Immersion-Compression Test. Once correlation has been accomplished, consideration should be given to replacing the use of unconfined compression strength with indirect tensil strength to develop an Immersion-Tensile Strength Test.

DISCUSSION - PHASE I

PERTINENT LITERATURE

Pertinent literature was carefully examined to obtain information relevant to the use of mineral fillers, test methods, specific gravity and air voids, and temperature control in the development of asphalt mixtures. This information is contained in a detailed report (1) in the Department's library.

MIXTURE COMPONENTS

An 85-100 penetration asphalt cement, representative of asphalt used on construction projects, was used for all tests in this investigation. Test results listed in Appendix B indicate the physical properties of the asphalt.

Idaho Department of Highways Pit Source Ada 53 near Boise is a good aggregate source that has been used on a number of highway construction projects having good performance records. It is principally granitic in origin and was crushed to meet Idaho Department of Highways 1965 Standard Specifications for a Class "D" Plantmix Surface Course representative of field use. Gradation and physical properties of the mineral aggregate are listed in Appendix B. The megascopic classification is in the detailed report (1).

Time and money limited this study to three mineral fillers. Hydrated lime was selected because of its past favorable use in Colorado(2), Utah and Wyoming (3). Portland cement and limestone dust were chosen because of their ready availability and reported suitability (4). Lack of sensitivity to water action of all three fillers (5) further supported their use in this investigation. Particle size distribution and chemical analysis of the mineral fillers are shown in Appendix B.

METHOD OF INVESTIGATION

Hveem Relative Stability Test. Asphalt mixtures were designed using the Hveem Relative Stability Test. The Idaho Department of Highways has successfully used that test, Idaho Test Method T-9, for asphalt pavement design since 1950. Hveem stability values are influenced by the type and concentration of filler (6), and there is a high degree of correlation between the test results and asphalt pavement performance (7) (8) (9). The test procedure is in Appendix A and the necessary calculations are in Appendix D.

Test Evaluation. The three existing laboratory tests indicated below were evaluated to determine which might best indicate loss of cohesion, durability and strength in an asphalt mixture due to water action. This can cause serious cracking in a surface course and lead to eventual failure.

Moisture Vapor Susceptibility Test. This test, California Test Method No. 307, is the Hveem Relative Stability Test performed on specimens that have been exposed to moisture vapor for 75 hours. It has been successfully correlated with actual pavement performance (10). The test procedure is in Appendix A and the required calculations are in Appendix D.

Minnesota Cold Water Abrasion Test. This test utilizes the abrasive action of one specimen upon another from rotation of the specimens in a water-filled Deval cylinder. It is an abrasion type of test that has been used successfully by the Minnesota Highway Department to evaluate the durability of mixtures to asphalt stripping (11). The test procedure is in Appendix A and the calculations are in Appendix D.

Immersion-Compression Test. Idaho Department of Highways has used the Immersion-Compression Test, ASTM Designation D 1075-54, for several years to determine the effect of water on asphalt mixture index of retained strength. Other states have also expressed confidence in this test (2) (3). The 1-day immersion period at 140°F. used is believed to be as severe as any condition normally encountered in the field (5). The test procedure is in Appendix A and the calculations are in Appendix D.

Mineral Filler. Past experience has shown that 3% hydrated lime, 4% portland cement or 5% limestone dust are the practical limits of those mineral fillers that can be used in an asphalt mixture to improve desired physical properties. Use of lesser or greater amounts of those mineral fillers would then provide the necessary range of test values for most effective evaluation. Hence types and amounts of mineral filler by weight of aggregate used in test specimens were:

1. No filler
2. 1%, 2.5% and 4% hydrated lime
3. 2%, 4% and 6% portland cement
4. 2%, 5% and 8% limestone dust

Mineral filler was mixed with the aggregate first before the asphalt was added to simulate field conditions.

Temperature Control. Variations in the mixing and compacting viscosities of asphalt concrete produce changes in stability, density, and voids of the compacted mixtures (12) (13). Hence the mixing and compacting temperatures of all test specimens were controlled throughout this study.

Constant Total Volume Specimens. A constant total solid volume of asphalt and mineral filler was used with a constant solid volume of aggregate in constant total volume specimens to permit accurate control of air voids in all test specimens (14) (15). This procedure was utilized to minimize effects of variation in air void content on the different test results. Because filler-asphalt ratio (ratio of volume of mineral filler used to volume of asphalt used) fluctuates moderately during normal hotplant mixing operations, it was necessary to examine the effect of its variation on the physical properties of the surface course. Thus planned variations in filler-asphalt ratio were designed to see which test or tests best evaluated the difference in values.

Trial Mixture Specimens. A set of trial mixture specimens was developed for each type and amount of mineral filler to determine the initial asphalt content and corresponding Hveem relative stability value, weight per cubic foot, and percentage of air voids for each particular type of mixture. Mixture air void contents were calculated using Rice Method specific gravity (16).

Initial asphalt contents were selected that were not at optimum asphalt content. Optimum aphalt content is the most asphalt that can be used consistent with a relative stability value of 35 or 30 minimum and a mixture air void content of 3 to 5 percent. Initial asphalt content was selected at less than optimum asphalt content in all cases.

Initial asphalt contents for the four basic control mixtures (no filler, 2.5% hydrated lime, 4% portland cement, and 5% limestone dust) were selected first based upon relative stability value, slope of the relative stability curve, and variations in filler-asphalt ratio planned for the six other mixture combinations. Initial asphalt contents for the remaining six mixture combinations were based upon controlling factors of relative stability value, slope of the relative stability curve, and the need for comparison with the respective values obtained by planned variations in filler-asphalt ratio for the same mixture combinations.

Initial asphalt contents for all ten mixture combinations are shown in Table I.

TABLE I
INITIAL ASPHALT CONTENT, HVEEM RELATIVE STABILITY, AGGREGATE WT./FT.^{3}, PERCENTAGE OF AIR VOIDS, PLANNED ASPHALT CONTENT, AND FILLER-ASPHALT RATIOS FOR DIFFERENT MIXTURE COMBINATIONS USING PIT SOURCE ADA 53

Filler	Initial Asphalt Content (%)	Hveem Relative Stability	Aggregate Wt./Ft.^{3} (Lb./Ft.^{3})	Air Voids (%)	Planned Asphalt Content (%)	Filler-Asphalt Ratio
No filler	7.0	41	128.9	7.2	7.0	---
1% hydrated lime	7.0	37	129.5	6.1	7.5	0.054
2.5% hydrated lime	6.8	38	130.0	7.3	6.8	0.146
4% hydrated lime	6.7	30	131.0	7.2	6.1	0.257
2% portland cement	7.0	46	130.4	5.7	7.5	0.084
4% portland cement	6.8	33	131.4	5.8	6.8	0.184
6% portland cement	6.1	37	134.3	6.2	6.1	0.302
2% limestone dust	6.9	37	130.5	6.4	7.6	0.095
5% limestone dust	6.3	30	132.8	5.2	6.3	0.281
8% limestone dust	5.9	31	133.4	6.1	5.1	0.538

Increasing the amount of mineral filler reduced the initial asphalt content each time for all three types of filler. This trend is similar to that in another investigation (17).

Test Specimens. Test specimens for the different tests were prepared using the indicated types and amounts of mineral filler by weight of aggregate. The four basic control mixtures (no filler, 2.5% hydrated lime, 4% portland cement and 5% limestone dust) were made at their initial asphalt content. A constant total solid volume of asphalt and mineral filler was determined for each control mixture, and that same total solid volume of asphalt and filler was used in the other mixture combinations containing that filler. By replacing a given solid volume of asphalt with an equal solid volume of filler (or vice versa) to achieve the desired percentages of mineral filler, it was possible to examine the effect of three different filler-asphalt ratios on the different test values for mixtures containing a particular filler. The resulting asphalt contents, called Planned Asphalt Contents, and the filler-asphalt ratios for each different mixture combination are also contained in Table I.

Planned Asphalt Content. Planned asphalt contents shown in Table I did not vary greatly from their respective initial asphalt contents due to the reduction in initial asphalt content with increasing amount of mineral filler. Thus, while variation in filler-asphalt ratio was quite satisfactory, variation in planned asphalt content from initial asphalt content was not as great as desired. It was large enough, however, to produce appropriate low or marginal values for two of the tests. This permitted a good comparison to be made between the sensitivities of the different tests.

HVEEM RELATIVE STABILITY TEST

Relative stability values are shown in Table II together with the coefficients of variation. Also included are average values for percentage of air voids, aggregate weight per cubic foot, and percentage of moisture and volatiles in the specimens. Detailed test results are in Appendix D.

TABLE II
HVEEM RELATIVE STABILITY TEST VALUES FOR
MIXTURE COMBINATIONS USING PIT SOURCE ADA 53

Filler	Average Relative Stability Value	Coefficient of Variation (%)	Average Air Voids (%)	Average Aggregate Wt./Ft.^{3} (Lb/Ft^3)	Moisture & Volatiles (%)
No filler	45	8.6	7.1	128.2	0.033
1% hydrated lime	27	24.3	4.5	129.7	0.159
2.5% hydrated lime	26	13.8	6.4	129.8	0.068
4% hydrated lime	41	3.4	8.3	127.6	0.147
2% portland cement	24	20.8	4.6	130.8	0.048
4% portland cement	30	13.5	5.6	132.0	0.076
6% portland cement	42	7.1	5.8	133.5	0.116
2% limestone dust	18	10.4	3.4	130.6	0.015
5% limestone dust	26	14.9	6.0	132.0	0.050
8% limestone dust	44	4.7	9.1	131.0	0.020

Average coefficient of variation for individual relative stability values is 12.2%. Both 1% hydrated lime and 2% portland cement have very large coefficients of variation which may be due to the asphalt contents of 7.5%. Nevertheless, examination of the values in Table II indicates that maximum coefficient of variation should be 15%, the higher confidence limit at 95% confidence level for the population mean of those coefficients of variation.

Except for portland cement mixture combinations, it was not possible to maintain the desired constant percentage of air voids in specimens having the same filler. Also, mixtures containing 4% hydrated lime and 8% limestone dust could not be compressed to the same constant volume as the other specimens with the filler.

MOISTURE VAPOR SUSCEPTIBILITY TEST

Hveem relative stability values are shown in Table III along with their coefficients of variation. Also included are average values for percentage of air voids, aggregate weight per cubic foot, and percentage of moisture and volatiles in the specimens. Detailed test results are in Appendix D.

TABLE III
MOISTURE VAPOR SUSCEPTIBILITY TEST VALUES FOR
MIXTURE COMBINATIONS USING PIT SOURCE ADA 53

Filler	Average Relative Stability Value	Coefficient of Variation (%)	Average Air Voids (%)	Average Aggregate Wt./Ft.^{3} (lb/ft^3)	Moisture & Volatiles (%)
No filler	33	5.4	6.9	129.1	0.384
1% hydrated lime	30	9.5	5.3	129.7	0.203
2.5% hydrated lime	28	7.1	6.0	130.4	0.424
4% hydrated lime	29	10.1	9.2	127.8	0.529
2% portland cement	16	20.5	4.5	130.7	0.262
4% portland cement	21	21.7	4.8	132.7	0.251
6% portland cement	33	10.7	5.7	134.2	0.346
2% limestone dust	19	16.9	4.2	130.9	0.252
5% limestone dust	22	5.9	4.4	133.2	0.299
8% limestone dust	46	7.4	8.9	131.4	0.393

Average coefficient of variation for individual relative stability values is 11.2%. However, three of the mixture combinations have large coefficients of variation. Examination of the values in Table III again indicates that maximum coefficient of variation should be 15%, the higher confidence limit at 95% confidence level for the population mean of those coefficients of variation.

Except for 4% hydrated lime and 8% limestone dust, it was possible to maintain reasonably constant percentages of air voids in specimens having the same type of filler thereby permitting development of reasonably constant total volume specimens. This may have been due to both improved technique in making specimens and greater uniformity in aggregate size and shape.

The increase in total percentage of moisture and volatiles in specimens from that of the Hveem Relative Stability Test ranges from 0.44% for 1% hydrated lime to 0.382% for 4% hydrated lime. However, except for 1% hydrated lime and 4% portland cement, the increase is quite consistent with the average being 0.299%.

MINNESOTA COLD WATER ABRASION TEST

Specimens with planned asphalt contents were evaluated for abrasion loss (loss of material from the specimen measured as a percentage of original specimen weight) which is the only value obtained from the test. Abrasion losses are contained in Table IV. Abrasion losses for specimens tested in an earlier pilot study at the Moscow Materials Laboratory (18) are included in Table V.

TABLE IV
MINNESOTA COLD WATER ABRASION TEST VALUES FOR PLANNED ASPHALT CONTENT SPECIMENS USING PIT SOURCE ADA 53

Filler	Planned Asphalt Content (%)	Abrasion Loss (%)
No filler	7.0	2.9
1% hydrated lime	7.5	3.0
2.5% hydrated lime	6.8	2.3
4% hydrated lime	6.1	3.0
2% portland cement	7.5	2.4
4% portland cement	6.8	2.9
6% portland cement	6.1	3.2
2% limestone dust	7.6	3.7
5% limestone dust	6.3	3.5
8% limestone dust	5.1	7.0

TABLE V
MINNESOTA COLD WATER ABRASION TEST RESULTS FROM UNPUBLISHED IDAHO DEPARTMENT OF HIGHWAYS REPORT ENTITLED "ANALYSIS OF MINERAL FILLER INVESTIGATION PILOT STUDY"

	Idaho Department of Highways Pit Source		
	Bingham 68 (Asphalt Content-5.4%)	Cassia 129 (Asphalt Content-5.5%)	Clark 27 (Asphalt Content-5.2%
Filler	Abrasion Loss (%)		
No Filler	4.7	3.4	7.0
1% hydrated lime	1.2	3.2	7.9
2% hydrated lime	1.3	6.4	2.5
1% portland cement	2.7	3.1	4.5
2% portland cement	1.5	2.2	4.2
1% powdered shale*	5.2	2.2	10.7
2% powdered shale*	4.8	3.8	7.4
1% limestone dust	2.0	-	5.3
2% limestone dust	1.6	2.7	5.2

*Calcined shale rock (primary constituents-silica and aluminum) ground to a fine powder (95% passing #200 sieve).

Except for the 8% limestone dust mixture combination, the abrasion losses in Table IV are less than 3.7%. These results are consistent with those in Table V which range from 1.2% to 5.3% for 21 out of 26 test results.

All but one Minnesota Cold Water Abrasion Test values in Table IV are in the range of from 2.3% to 3.7% abrasion loss. However, the great majority of asphalt contents in the original study (11) were from 4.0% to 5.0% as compared to asphalt contents of 5.5% to 7.6% in this investigation. Hence it was decided to conduct a short series of tests using specimens with no filler and asphalt contents of 6.0%, 5.0%, 4.0%, and 3.0% to determine roughly at what critical asphalt content the abrasion loss exceeded 15%, the criteria established by the Minnesota Highway Department for maximum permissible abrasion loss. Upon roughly determining the critical asphalt content to be 4.0%, another series of tests was conducted using asphalt contents of 0.2% difference on either side of 4.0% to examine that range more closely. The resulting abrasion losses are shown in Table VI.

TABLE VI
MINNESOTA COLD WATER ABRASION TEST VALUES FOR SPECIMENS CONTAINING NO FILLER WITH REDUCED ASPHALT CONTENTS USING PIT SOURCE ADA 53

Asphalt Content (%)	Abrasion Loss (%)	Asphalt Content (%)	Abrasion Loss (%)
6.0	3.8	4.4	11.5
5.0	6.2	4.2	16.6
4.0	18.1	4.0	18.5
3.0	Fell apart when removed from mold.	3.8	31.7
		3.6	43.2

It is thus evident from Table VI that the asphalt content must be reduced below 5.0% before an appreciable loss occurs. Study of the original paper (11) shows that of the 128 different asphalt cement mixture combinations evaluated in Series II (12 with 85-100 pen., 11 with 100-150 pen., 40 with 150-200 pen., and

65 with 200-300 pen.,), 118 mixture combinations had asphalt contents in the range of 3.75% to 5.0%. Hence the test was developed using specimens with lower asphalt contents than are normally used in asphalt pavements constructed today.

IMMERSION-COMPRESSION TEST

The 75.5% index of retained strength (ratio of immersed strength to dry strength) for planned asphalt content specimens with no filler in Table VII indicates that a mineral filler is needed to provide a minimum acceptable value of 85% index of retained strength. Acceptable values were provided by 2.5% hydrated lime, 6% portland cement and 5% limestone dust.

TABLE VII
IMMERSION-COMPRESSION TEST VALUES FOR PLANNED ASPHALT CONTENT SPECIMENS USING PIT SOURCE ADA 53

	Dry Specimens		Immersed Specimens			
Filler	Average Strength (psi)	Coeff. of Variation (%)	Average Strength (psi)	Coeff. of Variation (%)	Index of Retained Strength (psi)	Filler-Asphalt Ratio
No filler	233	4.3	176	6.2	75.5	-
1% hydrated lime	289	4.5	221	15.6	76.5	0.054
2.5% hydrated lime	327	2.9	277	2.5	84.7	0.146
4% hydrated lime	508	2.5	415	8.2	81.7	0.257
2% portland cement	262	4.7	188	4.8	71.8	0.084
4% portland cement	283	4.7	218	4.7	77.0	0.184
6% portland cement	254	10.2	236	5.3	93.0	0.302
2% limestone dust	302	6.1	249	3.9	81.9	0.095
5% limestone dust	339	5.7	290	6.8	85.5	0.281
8% limestone dust	469	3.2	346	7.5	73.8	0.538
Average Values		4.9		6.5		

Average coefficient of variation for individual strength values is 4.9% for the dry planned asphalt content specimens and 6.5% for the immersed planned asphalt content specimens. However, the average coefficient of variation for all individual strength values is 5.7% with only one mixture combination having a value appreciably over 10.0%. Examination of values in Table VII thus indicates that maximum coefficient of variation should be 10%, the higher confidence limit at 95% confidence level for the population mean of those coefficients of variation.

COMPARISON OF TESTS

Different combinations of tests are compared to determine intensity of association of relationships and appraise their importance.

Relative Stability and Moisture Vapor Susceptibility Tests. Relative stability values for the two tests have been plotted in Figure 1. The linear correlation coefficient of 0.79 for these two sets of values is only fair. However, the values for 8% limestone dust cause a reduction of several percent in the correlation coefficient value.

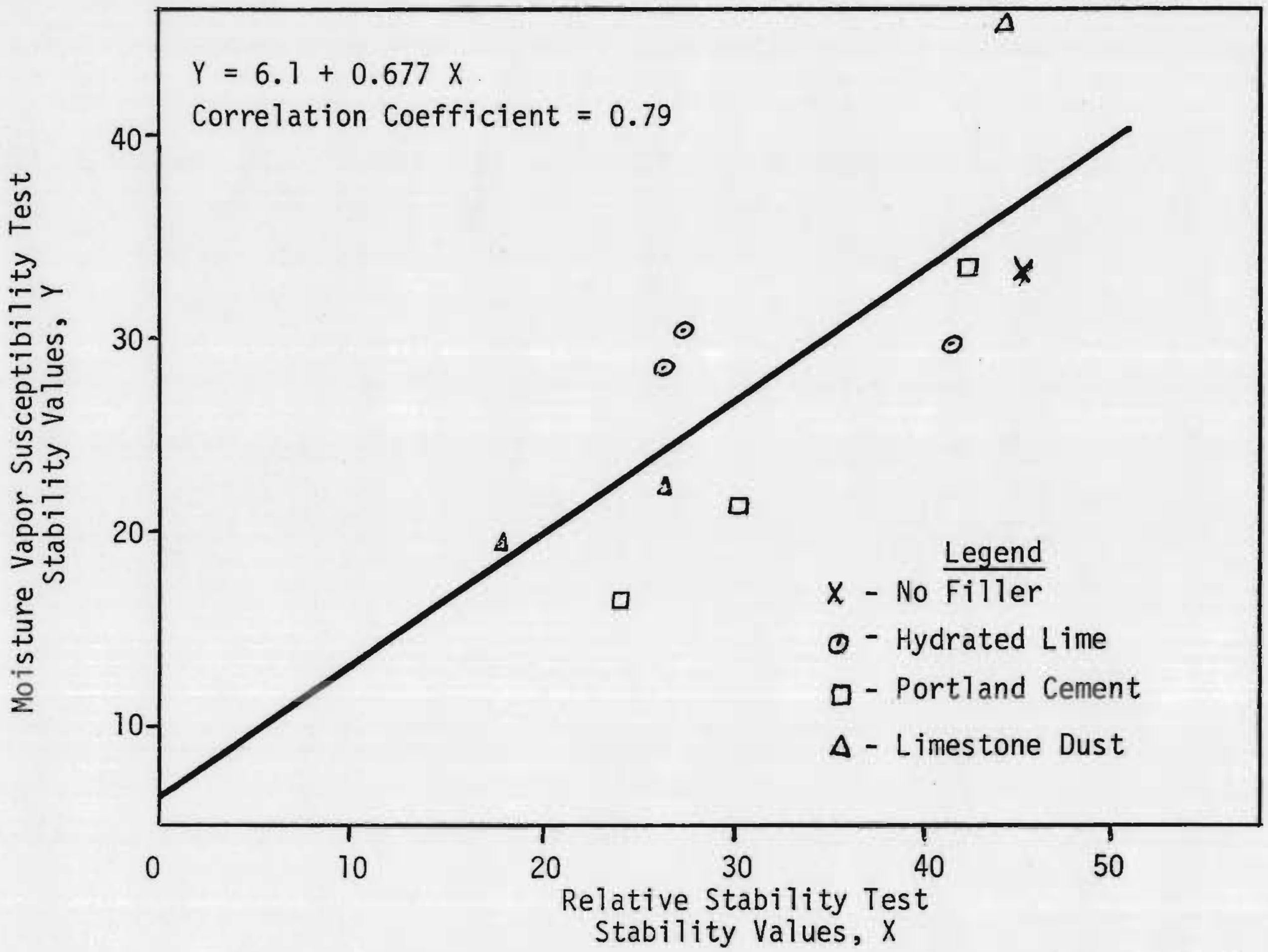

Figure 1 - Relative Stability from Relative Stability Test vs Relative Stability from Moisture Vapor Susceptibility Test for Planned Asphalt Content Specimens Using Pit Source Ada 53.

Figure 2 is, in part, a plot of the relative stability values for the two tests against their filler-asphalt ratios. This comparison shows (a) good sensitivity of the Relative Stability Test to variation in filler-asphalt ratio, (b) fairly good sensitivity of the Moisture Vapor Susceptibility Test to variation in filler-asphalt ratio, and (c) only fair sensitivity of the Moisture Vapor Susceptibility Test to the effect of moisture vapor and/or water on the specimens.

The linear correlation coefficient for percentage of moisture and volatiles in the specimen for the two sets of values is 0.11 which is very poor. No information of value can be gained from plotting those values either by themselves or against the filler-asphalt ratios.

Relative Stability, Moisture Vapor Susceptibility and Minnesota Cold Water Abrasion Test. Linear correlation coefficients for both sets of relative stability values plotted against the abrasion loss values are 0.37 and 0.69 which are very poor. No information of value can be gained from these plots or by plotting the abrasion loss values against the filler-asphalt ratios.

Relative Stability, Moisture Vapor Susceptibility and Immersion-Compression Tests. Figure 2 also shows the dry and immersed strengths for planned asphalt content specimens plotted against the filler-asphalt ratios. That plot shows good sensitivity of the Immersion-Compression Test specimens to variation in filler-asphalt ratio and also to loss of cohesion from water action.

Dry and immersed unconfined compression strengths for planned asphalt content specimens have been plotted in Figure 3. The linear correlation coefficient of 0.97 is excellent.

Minnesota Cold Water Abrasion and Immersion-Compression Tests. Linear correlation coefficients for the dry and immersed unconfined compression strengths for planned asphalt content specimens plotted against respective abrasion loss values

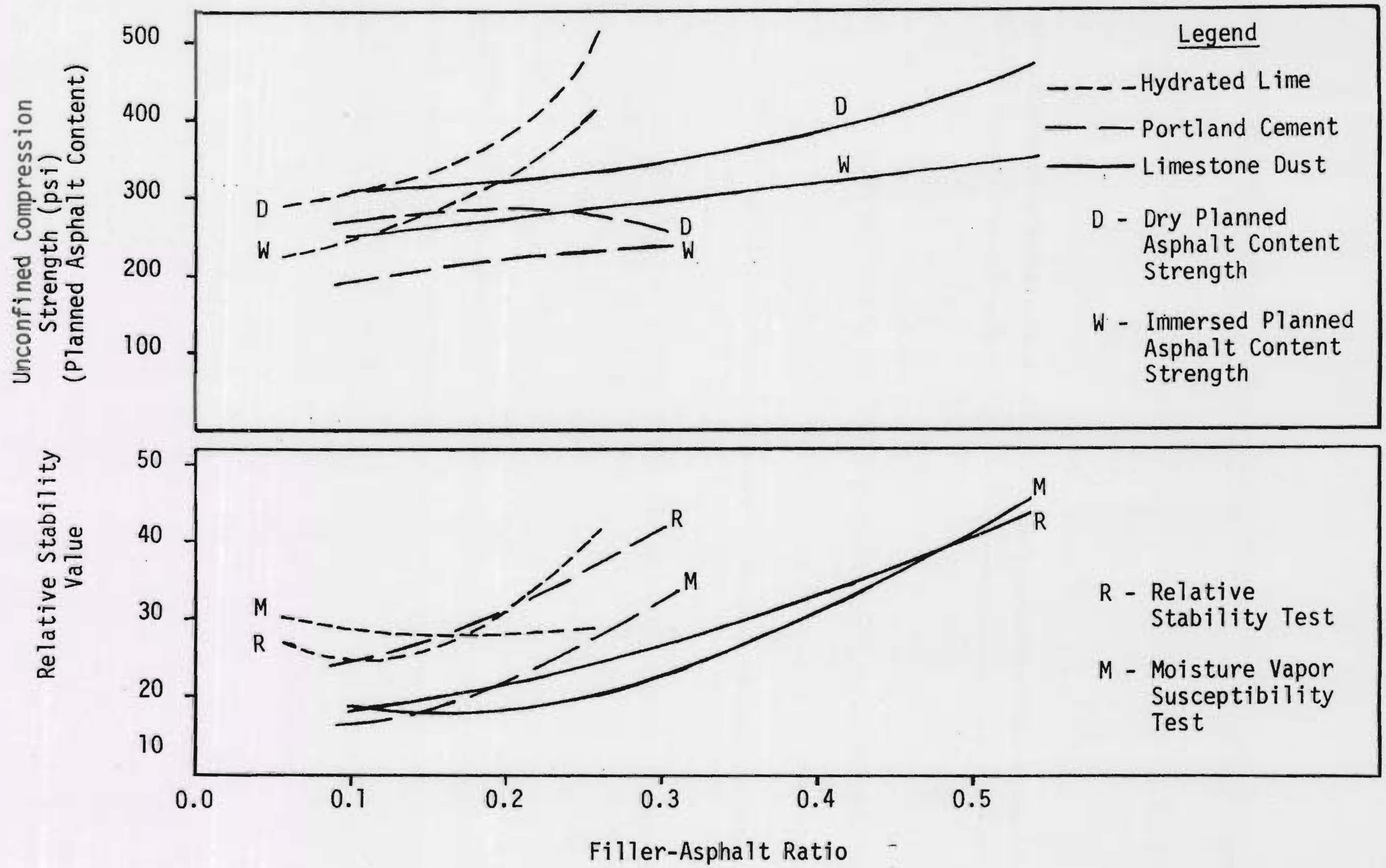

Figure 2. Relative Stability Values and Unconfined Compression Strength (Planned Asphalt Content) vs Filler-Asphalt Ratio

are 0.54 and 0.43, respectively, which are very poor. No information of value can be gained from those plots or by plotting abrasion loss values against filler-asphalt ratios.

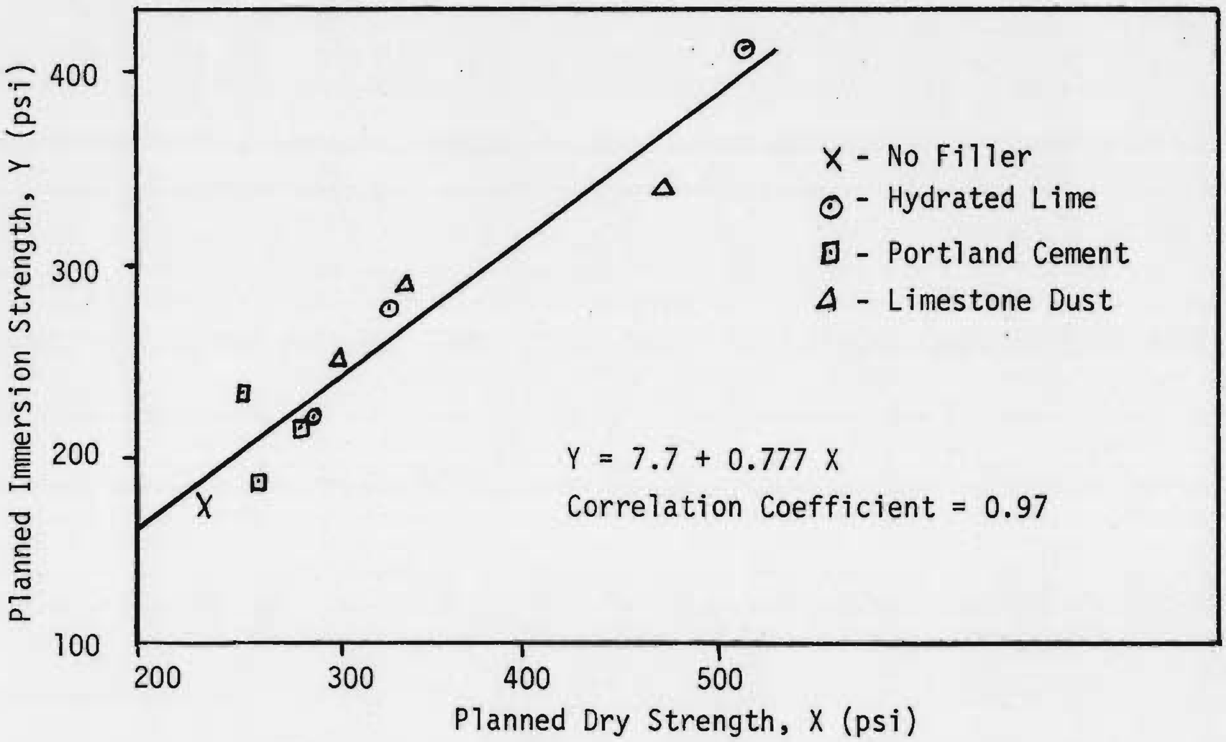

Figure 3. Planned Dry vs Immersed Unconfined Compression Strength Using Pit Source Ada 53.

DISCUSSION - PART A OF PHASE II

MIXTURE COMPONENTS

Asphalt and mineral filler used have been discussed in Phase I. A 1965 Class "D" Plantmix surface course gradation was used for Highway Department pit sources Bonner 46, Idaho 93 and Oneida 36 which are poor aggregate. Gradation and physical properties of the mineral aggregate are shown in Appendix G.

METHOD OF INVESTIGATION

The three different sources were evaluated as to the effect of (1) different amounts of hydrated lime, portland cement and limestone dust used as mineral fillers, (2) variable filler-asphalt ratios versus constant filler-asphalt ratios on trial mixture series values for Hveem relative stability, aggregate weight per cubic foot and Rice method percentage of air voids, and (3) Immersion-Compression Test index of retained strength values using a 1-day immersion period at 140°F. as compared to a 4-day immersion period at 120°F. Trial mixture series were made for each source for no filler, 1% and 2% hydrated lime, 1% and 2% hydrated lime slurry, 1% and 2% portland cement, 1% and 2% limestone dust, and the respective four different constant filler-asphalt ratio combinations. Optimum asphalt contents were then selected for each case and the Immersion-Compression Test was performed using the two different immersion conditions. The detailed test procedure is in Appendix F.

HVEEM RELATIVE STABILITY TEST

Hveem Relative Stability Test values together with associated optimum asphalt contents, weights per cubic foot, and Rice method percentages of air voids for each type and amount of mineral filler are shown in Table VIII for the three different pit sources. In general, addition of a mineral filler reduced the optimum asphalt content for all three sources, decreased the relative stability for Bonner 46 and Idaho 93, and increased the aggregate weight per cubic foot in the majority of cases.

IMMERSION-COMPRESSION TEST

Table IX contains the average dry and immersed unconfined compression strengths, index of retained strength (ratio of immersed strength to dry strength), and theoretical percentage of air voids for each type and amount of mineral filler for the three different pit sources. Theoretical percentage of air voids is based upon the Rice method specific gravity from the Hveem Relative Stability Test rather than the actual Rice method specific gravity of the sample itself.

TABLE VIII

HVEEM RELATIVE STABILITY TEST VALUES WITH RESPECTIVE VALUES OF OPTIMUM ASPHALT CONTENT, AGGREGATE WEIGHT PER CUBIC FOOT, AND RICE METHOD PERCENTAGE OF AIR VOIDS FOR DIFFERENT MIXTURE COMBINATIONS USED

Filler	Pit Source Bonner 46				Pit Source Idaho 93				Pit Source Oneida 36			
	Opt. Asph. Cont. (%)	Rel. Stab.	Aggreg. Wt./Ft.^{3} (Lb./Ft.^{3})	Air Voids (%)	Opt. Asph. Cont. (%)	Rel. Stab.	Aggreg. Wt./Ft.^{3} (Lb./Ft.^{3})	Air Voids (%)	Opt. Asph. Cont. (%)	Rel. Stab.	Aggreg. Wt./Ft.^{3} (Lb./Ft.^{3})	Air Voids (%)
No filler	7.2	39	142.9	3.8	7.0	45	142.7	4.3	6.6	38	130.5	4.3
1% hydrated lime	7.3	37	141.2	4.0	6.8	45	143.0	4.2	6.6	39	131.0	4.1
2% hydrated lime	6.8	32	142.9	4.1	6.4	41	144.0	4.2	6.2	37	131.3	4.6
Const. F-A Ratio H.L.	6.8	35	142.9	4.1	6.6	39	142.9	4.0	6.3	37	131.1	4.3
1% H.L.S.	7.0	43	143.7	4.0	7.1	35	141.3	4.4	6.3	37	131.7	4.1
2% H.L.S.	7.4	37	141.8	4.0	6.4	36	143.1	4.1	5.9	40	133.0	3.9
Const. F-A Ratio H.L.S.	7.0	33	142.8	4.2	6.7	36	142.2	4.2	5.8	43	131.4	3.9
1% portland cement	7.4	35	143.8	4.0	7.0	41	142.5	4.1	6.5	35	130.8	4.4
2% portland cement	7.0	39	143.0	4.0	6.6	40	143.5	4.1	6.3	39	131.3	4.1
Const. F-A Ratio P.C.	6.6	37	144.6	3.9	6.6	40	144.0	4.2	6.5	40	130.3	4.0
1% limestone dust	7.3	43	142.7	4.0	6.8	36	142.1	4.1	6.5	39	131.1	4.0
2% limestone dust	7.0	41	144.2	4.0	6.5	45	143.8	3.9	6.3	39	132.2	4.0
Const. F-A Ratio L.D.	7.0	38	143.4	4.0	6.6	40	143.2	4.0	6.2	40	132.0	3.9

H.L. - hydrated lime
H.L.S. - hydrated lime slurry
P.C. - portland cement
L.D. - limestone dust
Const. F-A Ratio- constant filler-asphalt ratio

TABLE IX

IMMERSION-COMPRESSION TEST VALUES FOR DRY AND IMMERSED UNCONFINED COMPRESSION STRENGTH, PERCENTAGE OF AIR VOIDS, AND INDEX OF RETAINED STRENGTH FOR MIXTURES USED

PIT SOURCE BONNER 46

FILLER	DRY		IMMERSED (1 day @ 140°F.)			IMMERSED (4 days @ 120°F)		
	Comp. Str. (psi)	Air Voids (%)	Comp. Str. (psi)	Air Voids (%)	IRS (%)	Comp. Str. (psi)	Air Voids (%)	IRS (%)
No Filler	247	5.8	272	5.7	110	246	5.3	100
1% H.L.	277	4.0	270	3.5	97	273	3.5	99
2% H.L.	309	4.3	251	4.3	81*	317	4.5	103**
CFAR H.L.	372	5.4	329	5.7	88	325	7.0	87
1% H.L.S.	247	6.1	325	6.1	132	301	6.5	122
2% H.L.S.	277	4.0	345	3.7	125	328	4.0	118
CFAR H.L.S.	344	5.9	371	6.3	108	346	5.4	101
1% P.C.	278	4.1	294	4.2	106	308	4.3	111
2% P.C.	258	5.0	283	5.2	110	275	5.3	107
CFAR P.C.	325	7.1	349	7.7	107	303	7.2	93
1% L.D.	263	5.1	274	4.4	104	259	5.0	99
2% L.D.	281	4.9	259	4.9	92	290	5.7	103
CFAR L.D.	312	5.4	339	4.9	109	294	5.7	94

PIT SOURCE IDAHO 93

FILLER	DRY		IMMERSED (1 day @ 140°F.)			IMMERSED (4 days @ 120°F.)		
	Comp. Str. (psi)	Air Voids (%)	Comp. Str. (psi)	Air Voids (%)	IRS (%)	Comp. Str. (psi)	Air Voids (%)	IRS (%)
No Filler	271	5.9	265	5.7	98	262	5.7	97
1% H.L.	283	5.1	244	5.2	86*	299	5.1	106**
2% H.L.	392	5.4	335	5.4	86	327	5.4	84
CFAR H.L.	275	5.2	370	5.3	135**	284	5.3	103*
1% H.L.S.	316	4.4	329	4.6	104**	247	4.6	78*
2% H.L.S.	265	6.3	366	6.3	138	354	6.0	134
CFAR H.L.S.	250	5.7	317	5.7	127*	375	5.7	150**
1% P.C.	271	5.0	190	4.8	70*	276	4.8	102**
2% P.C.	296	5.9	220	5.7	74*	288	5.7	97**
CFAR P.C.	260	5.8	294	6.8	113*	331	6.8	127**
1% L.D.	270	5.7	308	5.7	114*	343	5.5	127**
2% L.D.	308	5.5	275	5.5	89	242	5.5	79
CFAR L.D.	247	5.7	295	5.7	119*	346	5.7	140**

TABLE IX (CONTINUED)

IMMERSION-COMPRESSION TEST VALUES FOR DRY AND IMMERSED UNCONFINED COMPRESSION STRENGTH, PERCENTAGE OF AIR VOIDS, AND INDEX OF RETAINED STRENGTH FOR MIXTURES USED

PIT SOURCE ONEIDA 36

	DRY		IMMERSED (1 day @ 140°F.)			IMMERSED (4 days @ 120°F.)		
FILLER	Comp. Str. (psi)	Air Voids (%)	Comp. Str. (psi)	Air Voids (%)	IRS (%)	Comp. Str. (psi)	Air Voids (%)	IRS (%)
No Filler	284	7.2	220	7.4	<u>78</u>	227	7.2	<u>80</u>
1% H.L.	325	7.5	274	7.5	<u>84</u>	258	7.5	<u>79</u>
2% H.L.	418	7.6	330	7.6	<u>79</u>	322	7.6	<u>77</u>
CFAR H.L.	317	7.3	280	7.3	88*	407	7.3	128**
1% H.L.S.	320	8.3	245	8.3	<u>77</u>	276	8.2	86
2% H.L.S.	272	7.4	288	7.4	106	326	7.5	120
CFAR H.L.S.	267	8.6	218	8.8	<u>82</u>	230	8.6	86
1% P.C.	329	7.3	274	7.3	<u>83</u>	254	7.1	<u>77</u>
2% P.C.	321	7.3	316	7.3	98	274	7.3	85
CFAR P.C.	262	6.3	220	6.3	<u>84</u>*	320	6.3	122**
1% L.D.	236	7.2	247	7.0	105	276	7.0	117
2% L.D.	256	7.4	275	7.3	107	310	7.3	121
CFAR L.D.	275	7.1	246	7.1	90	288	7.1	105

LEGEND

H.L.	-	hydrated lime
H.L.S.	-	hydrated lime slurry
P.C.	-	portland cement
L.D.	-	limestone dust
CFAR	-	constant filler-asphalt ratio
Comp. Str.	-	unconfined compression strength
IRS	-	index of retained strength

1. Underlined values have an index of retained strength of less than 85%.

2. An asterisk marks the lowest value of significantly different corresponding 1 day and 4 day index of retained strength values. A double asterisk marks the highest value.

Table IX shows that in general the immersion period of 1 day @ 140°F. is just as severe as the immersion period of 4 days @ 120°F. The underlined values indicate an index of retained strength of less than 85%, and there are ten such values for the 1 day @ 140°F. immersion period and seven such values for the 4 days @ 120°F. immersion period for the three sources. Further comparison is made between corresponding 1 day @ 140°F. and 4 days @ 120°F. index of retained strength values that are significantly different at the 5% protection level. An asterisk marks the lowest of the two values while a double asterisk indicates the highest value. In ten out of twelve cases, the 1 day immersed index of retained strength value is lower than the corresponding 4 day retained strength value. These two comparisons thus support the conclusion that the index of retained strength for 1 day @ 140°F. is just as valid as that for 4 days @ 120°F.

Figures 4, 5, and 6 show that hydrated lime, portland cement and limestone dust all have merit as mineral fillers and can be used to improve poor aggregate. Choice of a particular mineral filler depends on amount of filler required, aggregate source and gradation, need for an anti-stripping agent, and type of asphalt used. Figures 4, 5, and 6 also show that index of retained strength values for the constant filler-asphalt ratio specimens are quite erratic, lying generally either well above or well below corresponding values for 1% and 2% filler.

DISCUSSION - PART B OF PHASE II

MIXTURE COMPONENTS

Asphalt and mineral filler used have been discussed in Phase I. A 1965 Class "D" Plantmix surface course gradation was used for Highway Department pit sources Bannock 142s and Twin Falls 63. Gradation and physical properties of the two mineral aggregates are shown in Appendix G.

METHOD OF INVESTIGATION

The two different sources were evaluated as to the effect of (1) 2% hydrated

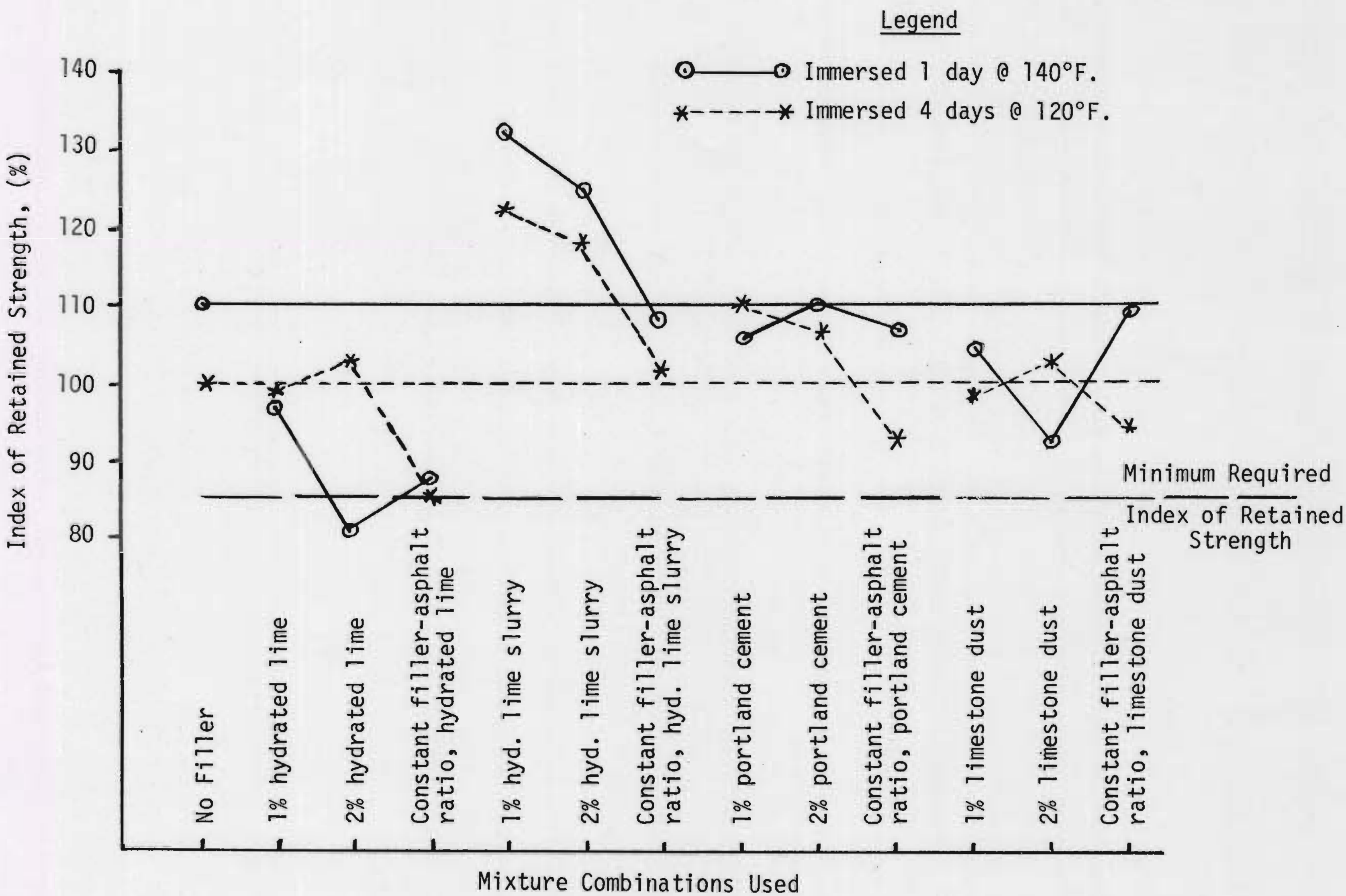

Figure 4. Index of Retained Strength vs Mixture Combinations Used for Pit Source Bonner 46

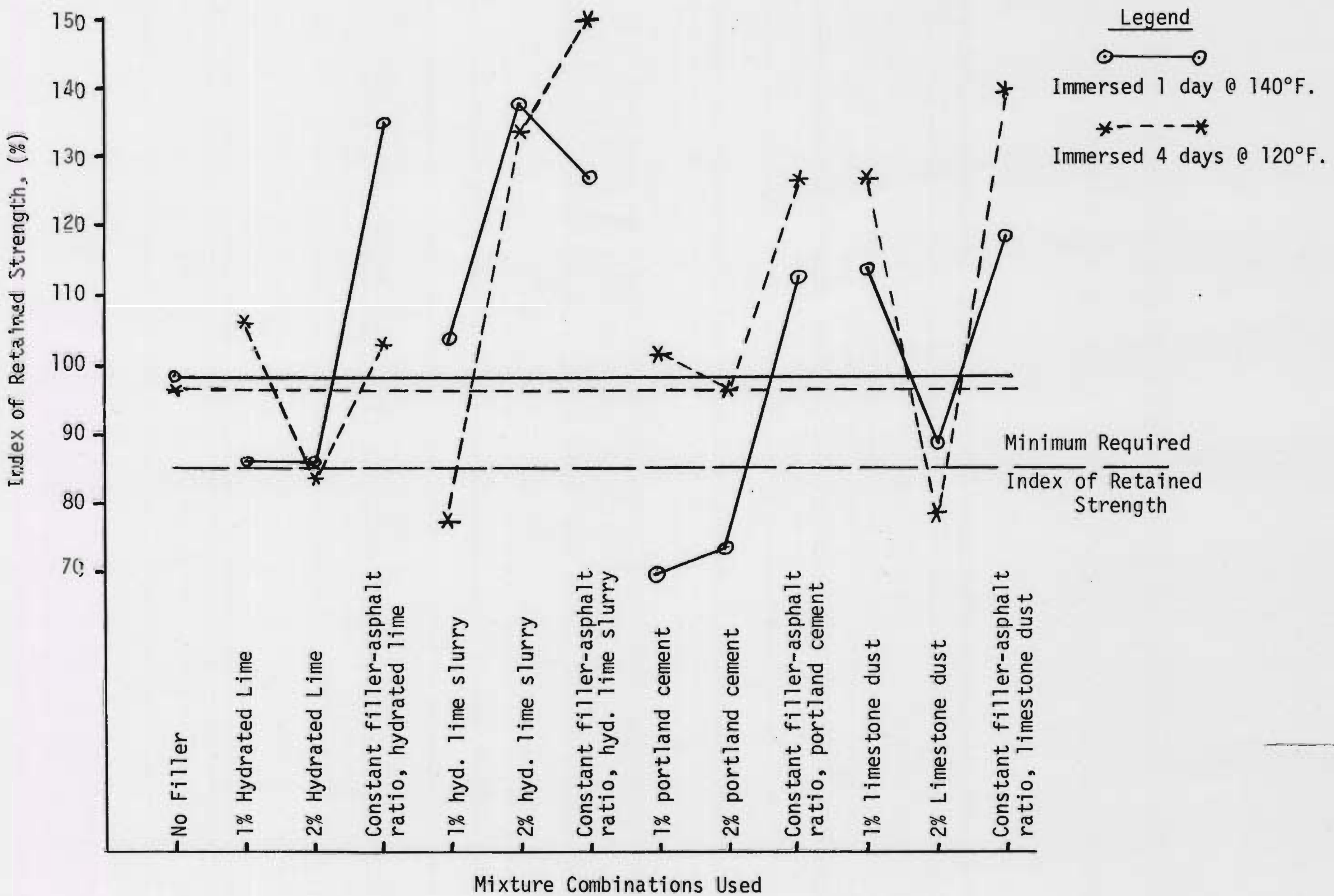

Figure 5. Index of Retained Strength vs Mixture Combinations Used for Pit Source Idaho 93.

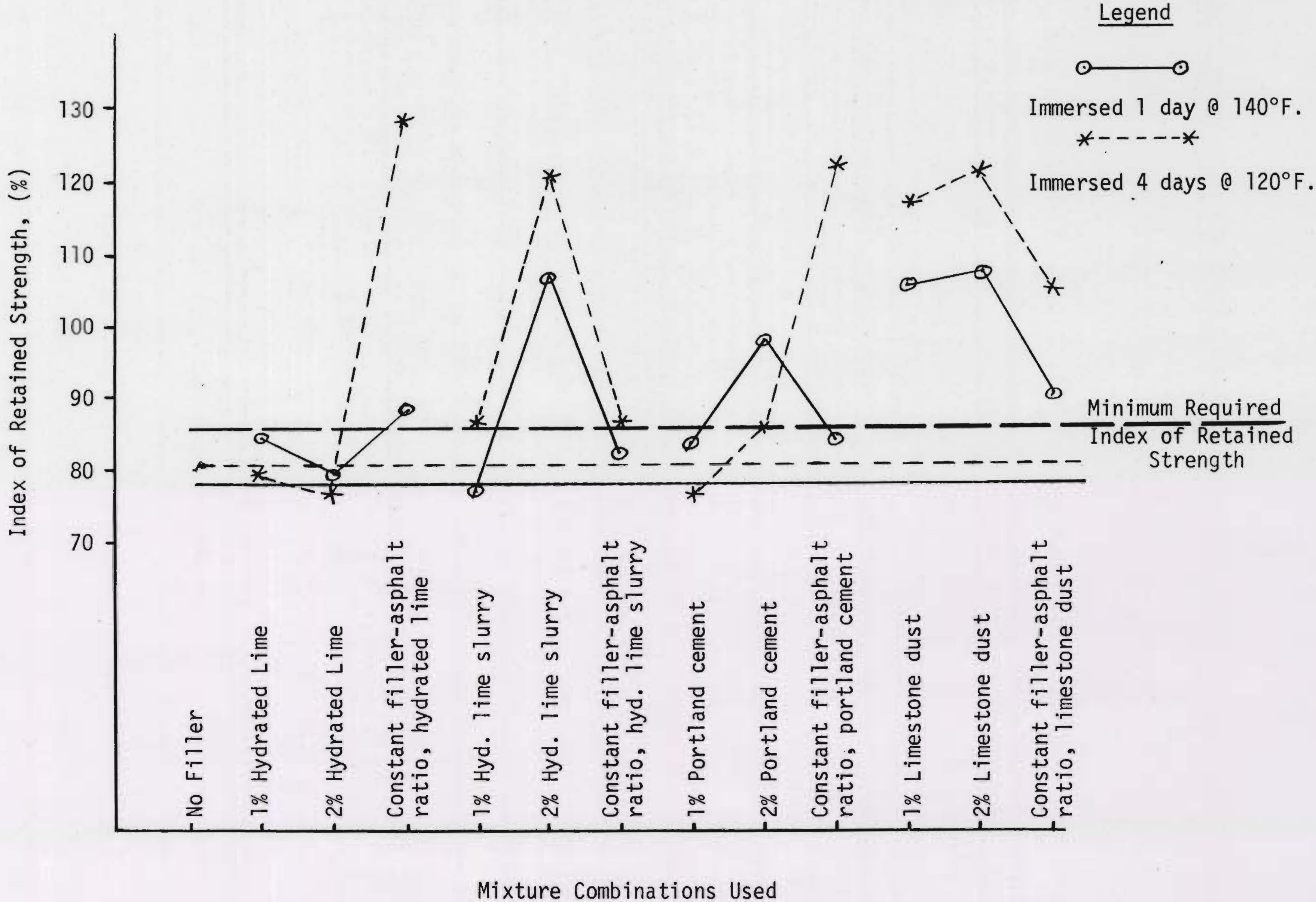

Figure 6. Index of Retained Strength vs Mixture Combinations Used for Pit Source Oneida 36.

lime and 2% hydrated lime slurry, and (2) vacuum saturation, and different immersion periods and temperatures on Immersion-Compression Test index of retained strength values. Trial mixture series were first made for each source for no filler, 2% hydrated lime and 2% hydrated lime slurry. Rice method percentage of air voids were then determined for all trial mixture specimens and optimum asphalt contents were selected for each case together with asphalt contents of optimum minus 1%.

The Immersion-Compression Test was performed on both optimum and optimum minus 1% asphalt content specimens vacuum saturated immediately prior to immersion using both a 1-day immersion period @ 140°F. and a 4-day immersion period @ 140°F. For pit source Twin Falls 63, the Immersion-Compression Test was also performed on a third set of specimens that were not vacuum saturated prior to being immersed for 1-day @ 140°F. Respective index of retained strength values were obtained and two specimens from each set were examined for stripping, after which the Rice method percentage of air voids were determined for each specimen. The third specimen was subjected to 25 cycles of freeze-thaw from 0°F. to 120°F., after which it was examined for stripping and the Rice method percentage of air voids determined.

Upon completion of the entire procedure, it was performed a second time to evaluate the repeatability of all test results. In addition, the Immersion-Compression Test was performed on a third set of specimens that were not vacuum saturated prior to immersion for 1-day @ 140°F. Detailed test procedure is in Appendix F.

HVEEM RELATIVE STABILITY TEST

Hveem Relative Stability Test values together with associated asphalt contents, weights per cubic foot, and Rice method percentages of air voids for each type and amount of mineral filler are shown in Table X for the two pit sources. In general, addition of a mineral filler had no significant effect on either

TABLE X

HVEEM RELATIVE STABILITY TEST VALUES WITH RESPECTIVE VALUES OF ASPHALT CONTENT, AGGREGATE WEIGHT PER CUBIC FOOT, AND RICE METHOD PERCENTAGE OF AIR VOIDS FOR DIFFERENT MIXTURE COMBINATIONS USED

	BANNOCK-142-s				TWIN FALLS-63			
FILLER	Asph. Cont. (%)	Rel. Stab.	Aggreg. Wt./Ft^3 (Lb/Ft^3)	Air Voids (%)	Asph. Cont. (%)	Rel. Stab.	Aggreg. Wt./Ft^3 (Lb./Ft^3)	Air Voids (%)
No Filler @ Optimum Asphalt	5.0	33	139.1	3.7	8.3	36	118.2	5.0
No Filler @ (Optimum-1%) Asphalt	4.0	41	134.3	11.0	7.3	41	119.2	6.8
2% Hyd. Lime @ Optimum Asphalt	4.9	29	139.4	4.2	8.2	36	120.5	4.4
2% Hyd. Lime @ (Optimum-1%) Asphalt	4.0	39	132.8	8.6	7.2	44	119.8	7.1
2% Hyd. Lime Slurry @ Optimum Asphalt	4.8	34	138.8	4.0	8.1	36	120.3	3.9
2% Hyd. Lime Slurry @ (Opt.-1%) Asphalt	4.0	42	134.9	9.0	7.1	44	119.3	6.7

Asph. Cont. - Asphalt Content

Rel. Stab. - Hveem Relative Stability Test Value

Aggreg. Wt./Ft^3 - Aggregate Weight per Cubic Foot

Opt. - Optimum

Hyd. - Hydrated

relative stability or optimum asphalt content. However, reducing the asphalt content by one percent increased relative stability and percentage of mixture air voids while decreasing aggregate weight per cubic foot in all but one case.

IMMERSION-COMPRESSION TEST

Table XI contains the average dry and immersed unconfined compression strengths, index of retained strength, and Rice method percentage of air voids for each type and amount of mineral filler for the two pit sources. Repeatability values have been placed below the original values for ease of comparison.

Pit source Bannock 142s has a history of poor service due to stripping action while pit source Twin Falls 63 has a similar history due to high asphalt absorption. Accordingly, the Immersion-Compression Test should reflect these facts by furnishing correspondingly low index of retained strength values. The regular Immersion-Compression Test immersed 1 day @ 140°F. index of retained strength values shown in Table XI and Figures 7 and 8 are generally quite high and indicate potentially good service. The corresponding immersed 1 day or 4 days @ 140°F. index of retained strength value for vacuum saturated specimens are much lower and do not meet the minimum required index of retained strength of 85% in 31 out of 48 cases. This strongly indicates that vacuum saturation of specimens prior to immersion is needed to make the test results truly meaningful.

Table XI also shows that in general the immersion period of 1 day @ 140°F after vacuum saturation is just as severe as the immersion period of 4 days @ 140°F. after vacuum saturation. This trend is also clearly shown in Figures 7 and 8. The underlined values in Table XI indicate an index of retained strength of less than 85%, and they are evenly distributed between 1 day @ 140°F. and 4 days @ 140°F. immersed vacuum saturated index of retained strength values for the two sources. Further comparison is made between corresponding 1 day @ 140°F and

TABLE XI (CONTINUED)

IMMERSION-COMPRESSION TEST VALUES FOR DRY AND IMMERSED UNCONFINED COMPRESSION STRENGTH, PERCENTAGE OF AIR VOIDS (RICE METHOD), AND INDEX OF RETAINED STRENGTH FOR MIXTURES USED

PIT SOURCE TWIN FALLS - 63

FILLER	DRY		IMMERSED 1 Day @ 140°F. Vacuum Saturated			IMMERSED 1 Day @ 140°F. Regular			IMMERSED 4 Days @ 140°F. Vacuum Saturated		
	Comp. Str. (psi)	Air Voids (%)	Comp. Str. (psi)	Air Voids (%)	IRS (%)	Comp. Str. (psi)	Air Voids (%)	IRS (%)	Comp. Str. (psi)	Air Voids (%)	IRS (%)
No Filler-Orig.-Opt. Asph	227	8.7	219	8.6	97*⊕	272	9.0	120	166	9.1	73*
No Filler-Repeat-Opt. Asph.	213	9.5	200	10.2	94	228	9.2	107	181	9.3	85
No Filler-Orig.-Opt.-1% Asph.	229	10.6	168	10.5	73	185	10.9	81	154	11.0	68
No Filler-Repeat-Opt.-1% Asph.	234	10.9	207	11.6	89**	242	11.4	103	141	11.5	60*
2% Hyd. Lime-Orig.-Opt. Asph.	295	7.3	219	7.6	74⊕	280	7.7	95	200	7.3	68
2% Hyd. Lime-Repeat-Opt. Asph.	307	7.9	194	7.9	63⊕	275	8.2	90	186	7.9	61
2% Hyd. Lime-Orig.-Opt.-1% Asph.	292	9.4	208	9.7	72⊕	294	9.6	101	198	9.5	68
2% Hyd. Lime-Repeat-Opt.-1% Asph.	275	10.5	170	9.5	62⊕	224	9.8	81	199	9.8	72
2% Hyd. Lime Slurry-Orig.-Opt. Asph.	271	6.2	203	7.7	75*	202	7.0	75	268	6.5	99**
2% Hyd. Lime Slurry-Repeat-Opt. Asph.	260	6.2	302	7.0	116	318	6.9	122	278	6.7	107
2% Hyd. Lime Slurry-Orig.-Opt.-1% Asph.	294	9.3	235	10.0	80	260	10.3	88	256	10.2	87
2% Hyd. Lime Slurry-Repeat-Opt.-1% Asph.	270	9.6	277	9.8	103	277	10.1	103	286	10.2	106

1. Underlined values have an index of retained strength of less than 85%.

2. Brackets indicate significantly different original and repeatability values.

3. An asterisk marks the lowest value of significantly different corresponding 1 day and 4 day immersed, vacuum saturated, index of retained strength values. A double asterisk marks the highest value.

4. A ⊕ marks the lowest value of significantly different corresponding regular and vacuum saturated 1 day index of retained strength values.

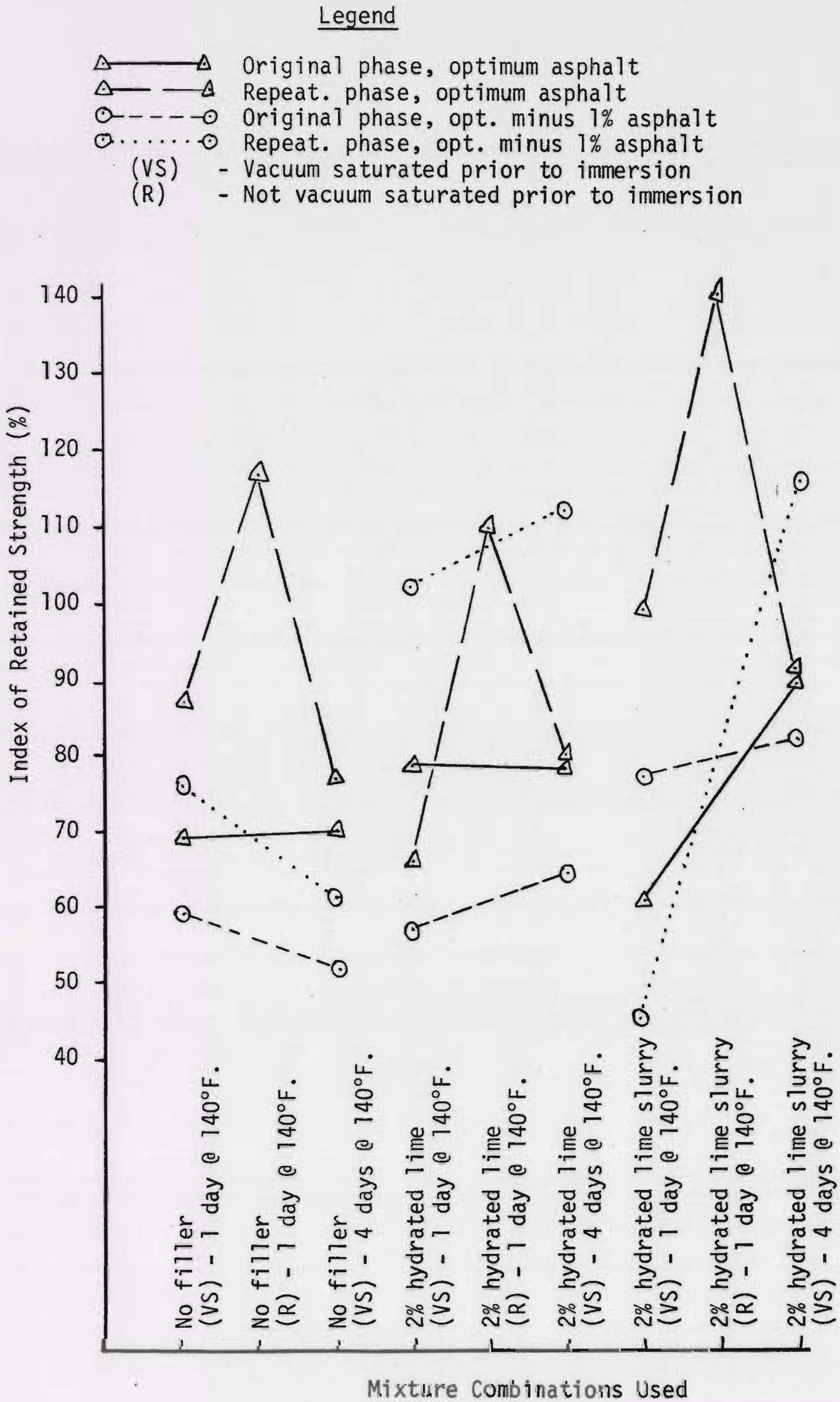

Figure 7. Index of Retained Strength vs Mixture Combinations Used for Pit Source Bannock 142s.

Legend

Original phase, optimum asphalt
Repeat. phase, optimum asphalt
Original phase, opt. minus 1% asphalt
Repeat. phase, opt. minus 1% asphalt
(VS) - Vacuum saturated prior to immersion
(R) - Not vacuum saturated prior to immersion

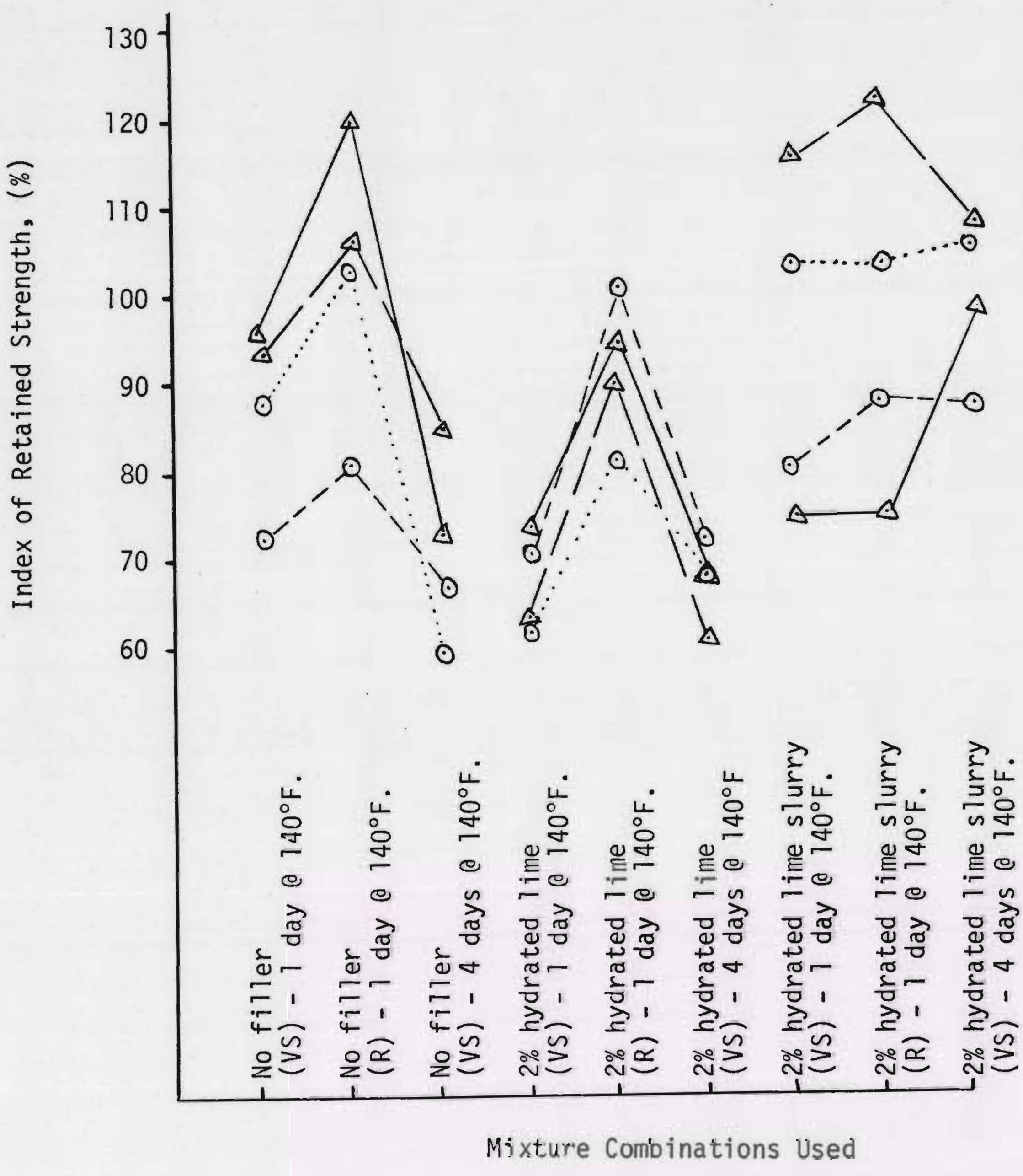

Figure 8. Index of Retained Strength vs Mixture Combinations Used for Pit Source Twin Falls 63.

4 days @ 140°F. vacuum saturated index of retained strength values that are significantly different at the 5% protection level. An asterisk marks the lowest of the two values while a double asterisk indicates the highest value. In three out of five cases, the 1 day vacuum saturated index of retained strength is lower than the corresponding 4 day vacuum saturated retained strength value. These two comparisons thus support the conclusion that the 1 day @ 140°F. immersed vacuum saturated strength is just as valid as the 4 days @ 140"F. immersed vacuum saturated strength.

Repeatability of test values is also shown in Table XI. Twelve out of thirty repeat index of retained strength values are significantly different from the original test values. Thus repeatability is poor and needs further study to determine the reasons for the differences. Figures 7 and 8 show the poor repeatability in a graphic manner. It should be noted, however, that in ten out of the twelve cases, either the original or repeat value had an index of retained strength of 85% or more while the other value did not. Of the eighteen comparisons having no significant difference, such was the case only twice.

It is believed that repeatability could be improved if test samples were molded in the kneading compactor rather than by the double plunger method. Air voids would more closely approximate those obtained in the Hveem Relative Stability Test and should thus help reduce variability in repeating index of retained strength values. This would, however, increase the time it takes to make the test specimens.

Twenty-five cycles of freeze-thaw from 0°F. to 120°F. after vacuum saturation and immersion 1 day @ 140°F. produced no stripping or light stripping in Bannock 142s dry specimens and moderate or severe stripping in the immersed specimens. However, freeze-thaw cycling produced little or no stripping in any of the Twin Falls 63 specimens. This was attributed to the extensive rock fracture in Twin

Falls 63 aggregate during specimen compaction that permitted weakening of specimens during the immersion period. Hence the freeze-thaw cycling continued the deterioration of the fractured aggregate rather than possibly effecting stripping action. It is thus evident that immersion-compression test specimens containing aggregate having known or suspected stripping tendencies should be subjected to freeze-thaw cycling.

AIR VOIDS DETERMINATION

In Table XII, percentage of air voids in Immersion-Compression Test specimens as determined by the Rice specific gravity method are compared to percentage of air voids as determined on the same specimens by the vacuum saturated specific gravity method. An asterisk marks values of vacuum saturated method air voids that are greater than the corresponding Rice method air void values. Also, a horizontal bar has been placed between corresponding vacuum saturated method and Rice method values that are significantly different. Significant difference is based upon the average difference between values for the entire set. Values crossed out were not used in the statistical analysis.

As the Rice method measures almost total air voids and the vacuum saturated method measures permeable air voids, the difference between the two values should be the impermeable air voids. Hence the vacuum saturation method air voids value should always be less than the Rice method air voids value. It is noted, however, that in 30 out of 126 cases, the vacuum saturation method air voids value is greater than the corresonding Rice method air voids value. This can be attributed to random distribution in most cases since only 6 out of the 30 cases have significantly different Rice method and vacuum saturation method air void values.

Of the 126 comparisons, 34 have a difference of 0.1% or less, 52 have a difference of 0.2% or less, 60 have a difference of 0.3% or less, 72 have a difference of 0.4% or less, and 80 have a difference of 0.5% or less. Nineteen of

TABLE XII

COMPARISON OF PERCENTAGE OF AIR VOIDS IN IMMERSION-COMPRESSION TEST SPECIMENS AS DETERMINED BY THE RICE GRAVITY METHOD AND BY THE VACUUM-SATURATED (30 MIN. DRY & 30 MIN. WET) IMMERSED WEIGHT METHOD

		BANNOCK 142-s							TWIN FALLS 63						
CONDITION	METHOD	ORIGINAL-AIR VOIDS (%)						AVE	ORIGINAL-AIR VOIDS (%)						AVE
No Filler, Opt.	RG								7.8	~~11.4~~	8.1	8.4	~~9.4~~	8.0	8.9
	VS								8.1*	~~8.7~~	8.5*	8.3	~~8.9~~	8.0	8.3
No Filler, Opt.-1%	RG								9.9	11.7	10.3	11.3	10.4	10.9	10.6
	VS								10.5*	10.2	10.7*	10.5	10.5*	11.0*	10.6
2% HL, Opt.	RG	7.0	7.1	7.1	7.5	7.3	6.3	7.1	7.4	7.4	7.2	7.3	8.4	7.1	7.5
	VS	6.7	7.5*	7.4*	7.6*	6.8	6.0	7.0	7.6*	7.2	7.1	6.5	7.7	6.6	7.1
2% HL, Opt.-1%	RG	9.8	9.6	9.7	10.5	10.3	10.1	10.0	9.1	10.0	9.3	9.2	10.4	9.5	9.6
	VS	10.0*	9.6	9.6	10.1	10.4*	10.3*	10.0	9.3*	8.9	9.4*	9.2	10.0	10.1*	9.5
2% HLS, Opt.	RG	7.6	8.0	7.9	8.4	8.8	7.6	8.1	7.3	6.5	5.8	7.2	8.6	7.2	7.1
	VS	7.8*	7.8	7.9	8.3	8.4	7.6	8.0	6.8	6.4	4.8	7.0	7.3	5.8	6.4
2% HLS, Opt.-1%	RG								10.6	9.2	10.7	9.7	9.6	10.7	10.1
	VS								10.5	8.6	11.1*	9.5	9.5	10.6	10.0
		REPEATABILITY-AIR VOIDS (%)							REPEATABILITY-AIR VOIDS (%)						
No Filler, Opt.	RG	7.8	6.9	7.5	7.7	7.5	7.3	7.5	9.3	9.0	9.6	9.6	10.8	10.3	9.8
	VS	7.1	7.2*	7.4	8.1*	7.6*	7.3	7.5	8.4	8.2	9.8*	9.6	8.6	7.6	8.7
No Filler, Opt.-1%	RG	10.6	10.6	10.3	9.9	10.4	9.6	10.2	~~11.6~~	11.5	11.3	11.8	11.6	12.1	11.6
	VS	10.6	10.5	10.5*	9.9	10.3	9.7*	10.2	~~9.3~~	10.8	10.9	11.1	11.1	11.6	10.8
2% HL, Opt.	RG	6.9	7.0	6.8	6.9	7.0	7.1	6.9	7.7	7.6	8.5	6.8	8.4	~~8.3~~	7.9
	VS	6.2	6.2	6.2	6.3	6.5	7.0	6.4	6.5	6.5	7.5	5.6	7.2	~~8.3~~	6.6
2% HL, Opt.-1%	RG	8.9	9.3	10.6	9.6	8.6	8.8	9.3	10.3	9.5	9.5	8.9	10.1	9.4	9.6
	VS	8.3	9.1	8.9	8.7	8.4	8.7	8.7	10.2	9.8*	9.7*	9.2*	10.5*	9.4	9.8
2% HLS, Opt.	RG	7.8	7.8	8.5	10.1	7.3	8.8	8.4	6.5	6.1	6.9	7.2	7.7	6.7	6.9
	VS	7.9*	7.6	7.8	8.7	7.3	7.6	7.8	5.6	4.7	6.4	6.8	6.8	5.9	6.0
2% HLS, Opt.-1%	RG	10.3	9.4	10.4	10.3	8.0	11.1	9.9	~~10.5~~	9.2	10.3	10.2	10.0	9.9	10.0
	VS	10.2	9.2	10.2	9.1	8.2*	10.5	9.6	~~8.9~~	8.6	9.9	9.5	9.5	9.6	9.3

HL - Hydrated lime
HLS - Hydrated lime slurry

RG - Rice method air void content
VS - Vacuum-saturated air void content

An asterisk marks the vacuum saturation method air void values that are greater than the corresponding Rice Method air void values. A horizontal bar denotes differences that are significantly different. Values crossed out were not used in the statistical analysis.

the 126 comparative differences are significantly different. It is therefore believed that the magnitude of the differences would be further reduced with increased experience in vacuum saturation methods.

It can thus be seen that determination of mixture air void content by the vacuum saturation method has great potential value in that it permits a fast and reasonably accurate method of calculating air void content of immersion-compression test specimens. This would permit a fast comparison of air void content between specimens in the same set prior to immersion. If one of the specimens has a significantly different air void content, that knowledge would be most valuable in helping to analyze the index of retained strength test results.

DISCUSSION-SUPPLEMENTARY DATA FROM RESEARCH PROJECT NO. 24

Certain data from Immersion-Compression tests performed in the Moscow Laboratory for Research Project No. 24 is a valuable supplement to the data from Part B of Phase II of this project and is thus fully relevent to the present discussion. That data and appropriate discussion will therefore be included at this point to further support the conclusions and recommendations made for this project.

MIXTURE COMPONENTS

A 120-150 asphalt cement meeting Idaho Department of Highways 1967 Standard Specifications was used in this part of the investigation. Hydrated lime was used as the mineral filler.

Idaho Department of Highways Pit Source Bingham 77 has exhibited an extensive stripping tendency. The aggregate is principally limestone and quartzite in origin and was crushed to the gradation shown in Appendix G.

METHOD OF INVESTIGATION

Bingham 77 was evaluated as the effect of (1) no filler, 1% hydrated lime, 1% hydrated lime slurry, and 1% hydrated lime plus 1% hydrated lime slurry, (2) no additive, 1/2% additive, and 1% additive, and (3) various vacuum saturation conditions on Immersion-Compression Test index of retained strength values. Trial mixture series were first made for no filler, 1% hydrated lime, and 1% hydrated lime slurry. Rice method percentage of air voids were then determined for all trial mixture specimens and optimum asphalt contents were selected for each case.

The Immersion-Compression Test was performed on the specimens using various vacuum saturation conditions immediately prior to immersion for 1-day at 140°F. The different vacuum saturation conditions examined were:

1. Dry vacuum for 30 minutes, then wet vacuum for 30 minutes
2. Dry vacuum for 10 minutes, then wet vacuum for 10 minutes
3. Dry vacuum for 10 minutes, then wet vacuum for 20 minutes
4. Dry vacuum for 20 minutes, then wet vacuum for 20 minutes
5. Dry vacuum for 10 minutes, then wet vacuum for 10 minutes, then place the water filled chamber under 30 p.s.i. air pressure for 20 minutes.

In certain cases the Immersion-Compression Test was performed on specimens using the regular method without vacuum saturation prior to immersion for 1-day @140°F.

When time permitted, mixture air void content was determined by both the Rice method and the vacuum saturation method previously discussed. However, in a number of cases the mixture air void content was determined only by the vacuum saturation method. Detailed procedures for specimen preparation and testing were similar to those outlined in Appendix F.

HVEEM RELATIVE STABILITY TEST

Hveem Relative Stability Test values together with associated optimum asphalt contents, weights per cubic foot, and Rice method percentage of mixture air voids for each type and amount of mineral filler are shown in Table XIII. No additive was used in any of the combinations. In general, addition of hydrated lime, both dry and as a slurry, had no effect on the optimum asphalt content and the aggregate weight per cubic foot. It did, however, slightly reduce both the relative stability value and the mixture air void content.

TABLE XIII
HVEEM RELATIVE STABILITY TEST VALUES WITH RESPECTIVE VALUES OF OPTIMUM ASPHALT CONTENT, AGGREGATE WEIGHT PER CUBIC FOOT, AND RICE METHOD PERCENTAGE OF AIR VOIDS FOR MIXTURES USING AGGREGATE FROM PIT SOURCE BINGHAM 77

Filler	Opt. Asph. Cont. (%)	Rel. Stab.	Aggreg. Wt./Ft.^{3} (Lb./Ft.^{3})	Mixture Air Voids (%)
No Filler	5.1	41	138.8	3.4
1% Hydrated Lime	5.1	39	138.8	3.0
1% Hyd. Lime Slurry	5.1	36	138.8	3.0

Opt. Asph. Cont. - Optimum Asphalt Content
Rel. Stab. - Hveem Relative Stability Test Value
Aggreg. Wt./Ft.^{3} - Aggregate Weight per Cubic Foot
Hyd. - Hydrated

IMMERSION-COMPRESSION TEST

Table XIV shows the average dry and immersed unconfined compression strengths, index of retained strength, and Rice method percentage of air voids for each mineral filler and additive combination for Pit Source Bingham 77. Vacuum saturated immersed index of retained strength values have been placed in the last column for ease of comparison.

Pit Source Bingham 77 has not given good service in the past and needs upgrading in the ability of the aggregate to retain an asphalt film in the presence of water. Accordingly, the Immersion-Compression Test should reflect this need by furnishing a correspondingly low index of retained strength value for an untreated mixture. The regular Immersion-Compression Test immersed 1 day @ 140°F. index of retained strength values shown in Table XIV for no filler or additive satisfy the criteria for probable good service. However, except for the repeatability case, all of the corresponding immersed index of retained strength values for the various vacuum saturation conditions are much lower and do not meet the minimum required index of retained strength of 85%. A similar situation has occurred for

TABLE XIV

IMMERSION-COMPRESSION TEST VALUES FOR DRY AND IMMERSED UNCONFINED COMPRESSION STRENGTH, PERCENTAGE OF AIR VOIDS (RICE METHOD), AND INDEX OF RETAINED STRENGTH FOR MIXTURES FROM PIT SOURCE BINGHAM 77

Mixture Combination		Dry		Immersed (1-day @ 140°F.)				Immersed (1-day @ 140°F.)			
Filler	Add. (%)	Comp. Str. (psi)	Air Voids (%)	Vacuum Saturation Condition	Comp. Str. (psi)	IRS (%)	Air Voids (%)	Vacuum Saturation Condition	Comp. Str. (psi)	IRS (%)	Air Voids (%)
No Filler	None	190	8.8	None	197	104*	9.5	V-30, S-30	125	66	9.2
								V-20, S-20	133	70	
								V-10, S-10, A-20	120	63	
								V-10, S-10	127	67	
No Filler (Repeat)	None	204	9.3	None	219	108	9.2	V-10, S-10	183	90	9.1
No Filler	1	206	9.5	None	222	108	9.3	V-10, S-10	207	101	
								V-20, S-20	242	118	
								V-30, S-30	224	109	9.4
								V-10, S-10, A-20	221	107	
1% HL	1	256	8.3	None	322	126	8.0	V-30, S-30	283	111	8.2
1% HLS	None	255	7.7	None	244	96	7.4	V-10, S-10	253	99	7.5
1% HLS	0.5	283	7.4	None	295	105	7.6	V-10, S-10	260	92	7.4
1% HLS	1	282	6.7	None	340	120*	6.8	V-30, S-30	274	97	6.9
								V-10, S-10	243	86	
								V-10, S-20	257	91	
								V-20, S-20	238	84	
								V-10, S-10, A-10	263	93	
1% HL + 1% HLS	1	337	6.6	None	384	114*	6.6	V-30, S-30	265	79#	6.4
								V-10, S-10	166	49	
								V-20, S-20	179	53	

1. Underlined values of index of retained strength (IRS) are less than 85%.
2. An asterisk marks non-vacuum-saturated values of immersed index of retained strength that are significantly different from various associated immersed vacuum-saturated values.
3. A # indicates vacuum-saturated index of retained strength values that are significantly different from other values in the same group having different vacuum-saturation conditions.
4. Dry vacuum time periods (V-10, etc.), wet vacuum time periods (S-10, etc.) and air pressure time periods (A-10, etc.) are discussed under Method of Investigation.

the values obtained when using a treatment of 1% hydrated lime plus 1% hydrated lime slurry plus 1% additive. The same trend is also in evidence for treatment by 1% hydrated lime slurry plus 1% additive, but in that case the index of retained strength values while much lower than those for no vacuum saturation, do barely meet the minimum requirement.

It is thus evident that vacuum saturation of specimens prior to immersion is required to make Immersion-Compression Test results fully meaningful. The various vacuum saturation conditions shown in Table XIV indicate that a 10 minute dry vacuum period followed by a 10 minute wet vacuum period produces as severe a reduction in index of retained strength value as any of the other combinations. Use of this combination also permits the test to be performed in the shortest possible time.

AIR VOIDS DETERMINATION

Percentage of air voids in Immersion-Compression Test specimens as determined by the Rice specific gravity method are compared to percentage of air voids as de-etermined on the same specimens by the vacuum saturated specific gravity method in Table XV. An asterisk again marks values of vacuum saturated method air voids that are greater than the corresponding Rice method air void values.

In 16 out of 24 cases the vacuum saturated method air voids value is greater than the corresponding Rice method air voids value. This could be attributed to random distribution since there are no significantly different Rice method and vacuum saturated method air void values. However, it is very possible that subjecting the specimen to a vacuum might be slightly enlarging the existing air void space or creating air void space where none previously existed. Nevertheless, of the 24 comparisons, 9 have a difference of 0.1% or less, 13 have a difference of 0.2% or less, 17 have a difference of 0.3% or less and all comparisons have a difference of 0.5% or less. Hence the two methods compare very favorably.

TABLE XV

COMPARISON OF PERCENTAGE OF AIR VOIDS IN IMMERSION-COMPRESSION TEST SPECIMENS AS DETERMINED BY THE RICE GRAVITY METHOD AND BY THE VACUUM-SATURATED IMMERSED WEIGHT METHOD

BINGHAM 77

CONDITION	VACUUM-SAT.	METHOD	NO ADDITIVE			AVE.
No Filler		RG	9.5	8.6	9.6	9.2
	V-30, S-30	VS	9.7*	9.1*	9.7*	9.5
		RG	8.9	9.1	9.2	9.1
	V-10, S-10	VS	8.9	8.8	9.2	9.0
1% Hyd. Lime Slurry		RG	7.5	8.1	7.0	7.5
	V-10, S-10	VS	7.9*	7.6	7.3*	7.6
			1/2% ADDITIVE			
1% Hyd. Lime Slurry		RG	7.0	7.4	7.9	7.4
	V-10, S-10	VS	7.5*	7.9*	8.0*	7.8
			1% ADDITIVE			
No Filler		RG	9.4	9.5	9.3	9.4
	V-30, S-30	VS	9.1	9.7*	9.2	9.3
1% Hydrated Lime		RG	8.5	7.7	8.5	8.2
	V-30, S-30	VS	8.6*	8.0*	8.6*	8.4
1% Hyd. Lime Slurry		RG	6.6	7.0	7.0	6.9
	V-30, S-30	VS	6.7*	7.2*	7.5*	7.1
1% Hydrated Lime plus		RG	5.9	6.5	6.7	6.4
1% Hyd. Lime Slurry	V-30, S-30	VS	6.4*	6.4	6.5	6.4

1. An asterisk marks the vacuum saturation method air void values that are greater than the corresponding Rice method air void values.
2. Dry vacuum time periods (V-10 & V-30) and wet vacuum time periods (S-10 & S-30) are discussed under Method of Investigation.

Future investigations should examine the possibility of determining air void content of Immersion-Compression Test specimens by both methods after the specimens have been compacted by a kneading compactor. By compacting specimens in such a manner, a much more meaningful comparison could be made of index of retained strength values and air void content with test values from the Hveem Relative Stability Test.

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APPENDIX A

INVESTIGATION PROCEDURE

FOR PHASE I

IDAHO DEPARTMENT OF HIGHWAYS PIT SOURCE ADA 53

I. Aggregate Preparation

A. Gradation. Class "D" Plantmix Surface Course from Idaho Department of Highways 1965 Standard Specifications.

B. Tests.
Idaho T-1, Particle Size Distribution of Aggregate
Idaho T-2, Sand Equivalent
AASHO T 89, Liquid Limit
AASHO T 90, Plastic Limit
AASHO T 91, Plasticity Index
Idaho T-75, Fine Aggregate Specific Gravity
Idaho T-76, Coarse Aggregate Specific Gravity and Absorption
IDH Form 897, Average Specific Gravity
Idaho T-15, Idaho Degradation
AASHO T 96, Los Angeles Abrasion
Vo. 34, HRB Proceedings, Bulk-Impregnated Specific Gravity

II. Trial Mix Specimens

A. Tests.
Idaho T-9, Relative Stability of Asphalt Mixtures
Idaho T-25, Mixing Asphalt Mixes
Idaho T-36, Centrifuge Kerosene Equivalent
Idaho T-86, Air Void Determination in Asphalt Mixes by Rice's Method

B. Procedure. Select the initial asphalt content for each case considering relative stability, unit weight of aggregate plus mineral filler, and percentage of air voids for:

a. No filler
b. 1%, 2.5%, and 4% hydrated lime
c. 2%, 4% and 6% portland cement
d. 2%, 5% and 8% limestone dust

by weight of aggregate

III. Asphalt Content for Test Specimens

A. Initial Set. Determine: $V_t = \frac{W_f}{G_f \gamma} + \frac{W_a}{G_a \gamma}$, where:

V_t = total solid volume of asphalt and mineral filler in each specimen,

W_f = weight of mineral filler in each specimen,

W_a = weight of asphalt (initial asphalt content) in each specimen,

γ = unit weight of water taken as 1 gram/cm^3,

G_f = specific gravity of mineral filler used,

G_a = specific gravity of asphalt = 1.000 gm/cm^3,

for specimens containing 2.5% hydrated lime, 4% portland cement, and 5% limestone dust by weight of aggregate.

B. Remaining Sets. Using the appropriate V_t determined above, make the second set of specimens using 1% hydrated lime, 2% portland cement, and 2% limestone dust, and make the third set of specimens using 4% hydrated lime, 6% portland cement, and 8% limestone dust by weight of aggregate. The weight of asphalt per specimen shall be:

$$W_a = \left(V_t - \frac{W_f}{G_f}\right) G_a \gamma,$$ using the appropriate V_t

IV. Tests Performed

A. Relative Stability Test.

Idaho T-9, Relative Stability of Asphalt Mixtures

Idaho T-25, Mixing Asphalt Mixes

Idaho T-86, Air Void Determination in Asphalt Mixes by Rice's Method.

B. Moisture Vapor Susceptibility Test

Test Method No. California 307, Method of Test for Moisture Vapor Susceptibility of Bituminous Mixtures.

C. Minnesota Cold Water Abrasion Test.

ASTM Special Technical Publication No. 94, "The Use of an Abrasion Test as a Measure of Durability of Bituminous Mixtures"

D. Immersion-Compression Test.

ASTM Designation: D 1074-60, Compressive Strength of Bituminous Mixtures

ASTM Designation: D 1075-54, Effect of Water on Cohesion of Compacted Bituminous Mixtures

APPENDIX B

MIXTURE COMPONENTS FOR PHASE I

PHYSICAL PROPERTIES OF 85-100 ASPHALT CONTENT

PROPERTY	RESULT
TESTS ON ORIGINAL ASPHALT	
Penetration of Orig. Sample at 77°F., 100 gm., 5 sec.	89
Flash Point, P.M.C.C. (°F.)	500+
Kinematic Viscosity at 275°F. (cs)	267
Specific Gravity at 77°/77°F.	1.019
Solubility in CCl_4 (%)	99.74
Spot Test, Heptane Xylene Equivalent at 35% Xylene	Negative
TESTS ON RESIDUE FROM THIN FILM LOSS ON HEATING	
Loss on Heating at 325°F., 5 Hours (%)	0.0
Penetration at 77°F., 100 gm., 5 sec.	56
Ratio of Thin Film L.O.H. Pen./Orig. Pen.(%)	62.9
Ductility at 77°F., 5 cm/min (cm)	100+

CHEMICAL ANALYSIS FOR HYDRATED LIME AND LIMESTONE DUST

	Hydrated Lime (%)	Limestone Dust (%)
Free Moist.	0.2	- -
Insol. HCL	2.51	- -
R_2O_3	0.45	- -
Fe_2O_3	0.118	0.14
Al_2O_3	0.332	- -
$CaCO_3$	1.43	97.62
$Ca(OH)_2$	92.94	- -
SO_4	Trace	- -
MgO	1.90	- -
CO_2	0.63	- -
IGN. Loss	23.45	- -
Avail. CaO	68.02	- -
$MgCO_3$	- -	0.70
Insoluble & Silica		1.54

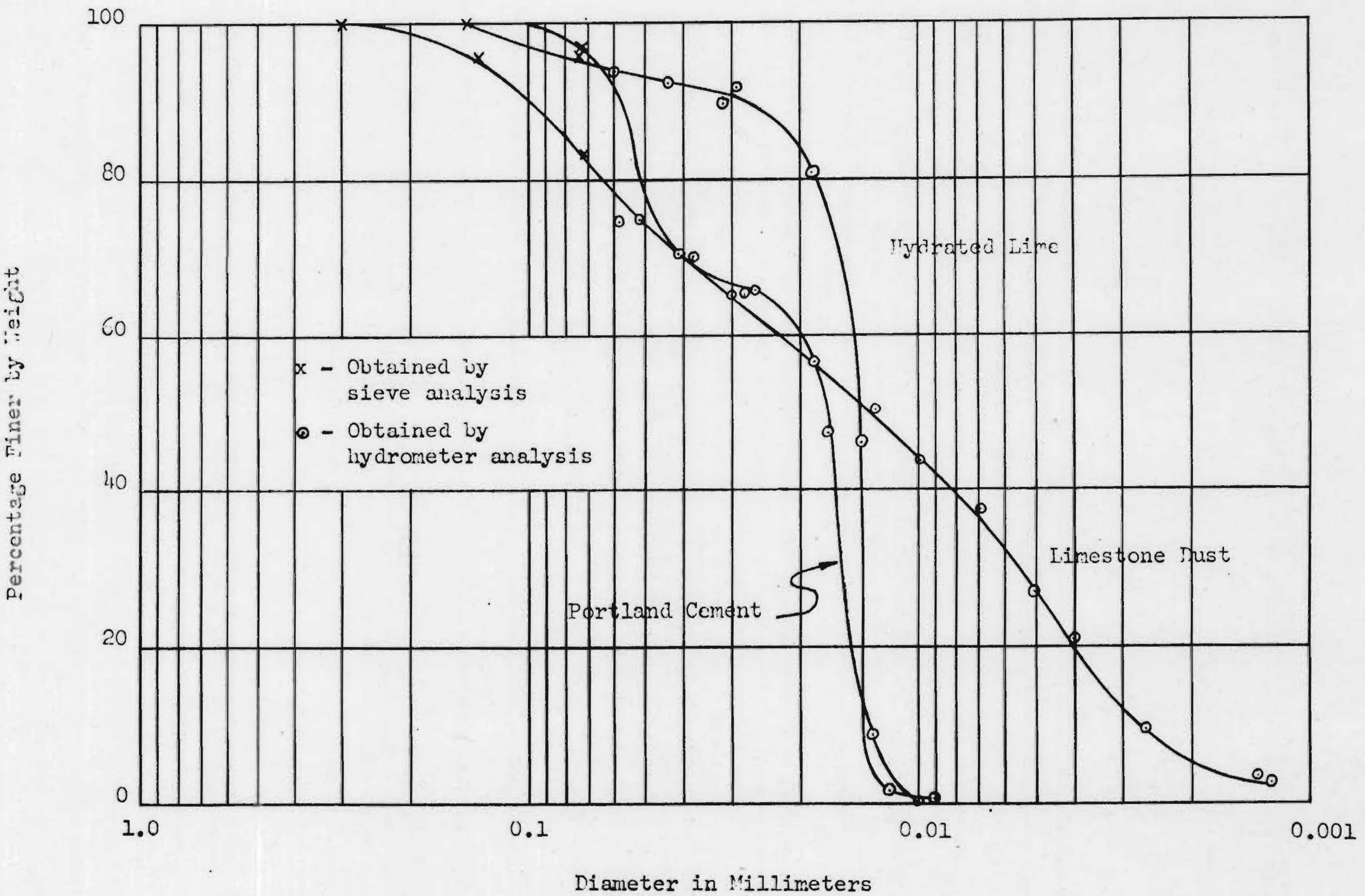
GRADATION AND PHYSICAL PROPERTIES OF MINERAL AGGREGATE FROM PIT SOURCE ADA 53

GRADATION		PHYSICAL PROPERTIES	
Sieve Size	Per Cent Passing	Property	Test Result
3/4"	100	Liquid Limit (%)	No Value
5/8"	100	Plastic Limit (%)	Non Plastic
1/2"	98	Plastic Index (%)	Non Plastic
3/8"	87	Sand Equivalent (%)	58
No. 4	60	Fine Specific Gravity	2.60
No. 6	50	Coarse Specific Gravity	2.57
No. 8	42	Average Specific Gravity	2.59
No. 20	25	Coarse Aggregate Water Absorption (%)	1.1
No. 30	21	Asphalt Absorption by Aggregate (%)	1.34
No. 40	16	Los Angeles Abrasion Test (%) Wear	23.8
No. 50	11	Idaho Degradation Test	
No. 100	6	Original % Minus No. 200	3
No. 200	4	Final % Minus No. 200	10
Dust Ratio (%)	25	Original Sand Equivalent (%)	58
		Final Sand Equivalent (%)	33

$$\frac{\%\ \text{No. } 200}{\%\ \text{No. } 40} \times 100 = \text{Dust Ratio}$$

PHYSICAL PROPERTIES OF MINERAL FILLERS

Filler	Bulk Density gm/cm^3	Hygroscopic Moisture Content (%)	Specific Gravity
Hydrated Lime	0.75	1.01	2.45
Portland Cement	1.47	1.01	3.08
Limestone Dust	1.53	0.0	2.70



Particle Size Distribution of Mineral Fillers

MINERAL FILLER GRAIN SIZE ANALYSIS

(Particle Size Distribution Obtained From Sieve and Hydrometer Analysis)

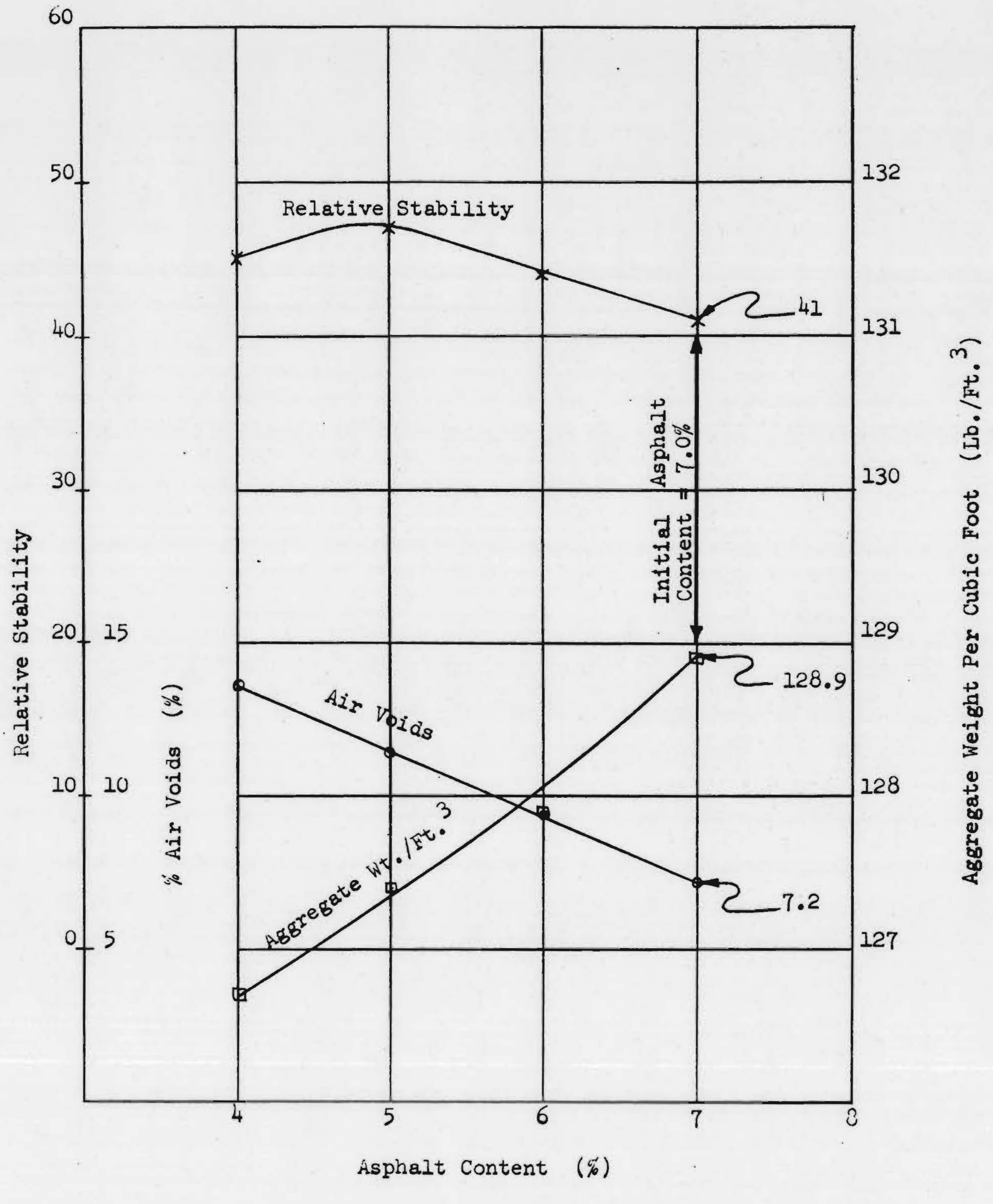
HYDRATED LIME		LIMESTONE DUST		PORTLAND CEMENT	
Percentage finer than P	Diameter in mm. D	Percentage finer than P	Diameter in mm. D	Percentage finer than P	Diameter in mm. D
Trace	0.147*	Trace	0.420*	100.0	0.147*
95.5	0.074*	99.5	0.297*	96.0	0.074*
93.8	0.061	95.0	0.147*	74.3	0.053
92.3	0.044	82.5	0.074*	69.7	0.038
89.5	0.032	74.2	0.059	65.0	0.028
91.6	0.0299	70.4	0.043	65.9	0.026
81.0	0.0107	64.3	0.031	47.3	0.0176
46.0	0.015	66.3	0.0289	9.1	0.0140
1.3	0.0127	56.4	0.0192	0	0.0107
0.4	0.0090	30.4	0.0138	0	0.0075
0	0.0063	43.5	0.0100	0	0.0053
0	0.0044	37.6	0.0072	0	0.00153
0	0.0031	26.7	0.0053	0	0.00127
0	0.000	19.0	0.0039	0	0.00
		9.1	0.00279		
		3.4	0.00151		
		2.6	0.00138		

* Obtained by sieve analysis

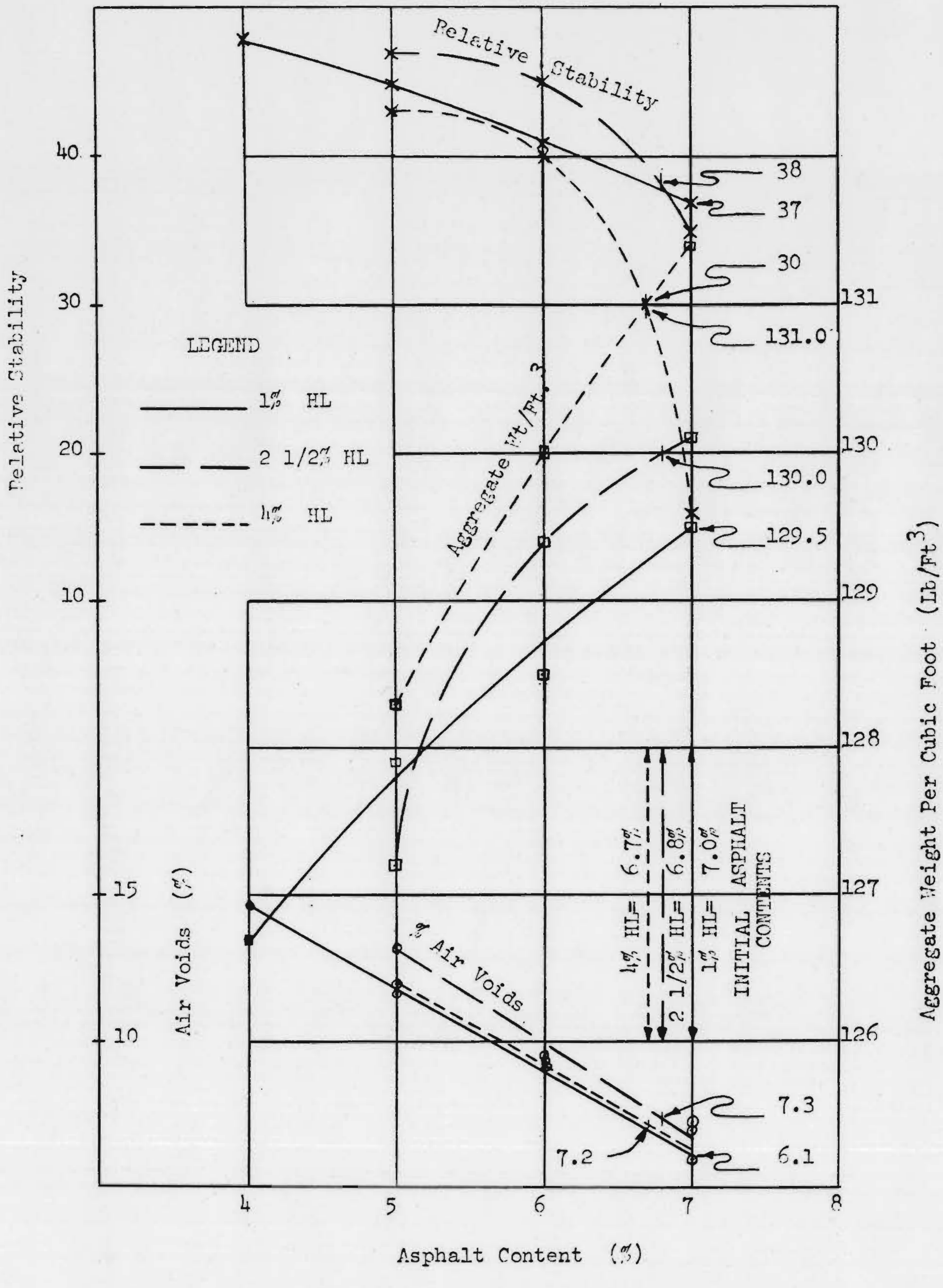
APPENDIX C

INITIAL ASPHALT CONTENTS FOR TRIAL MIXTURE SPECIMENS

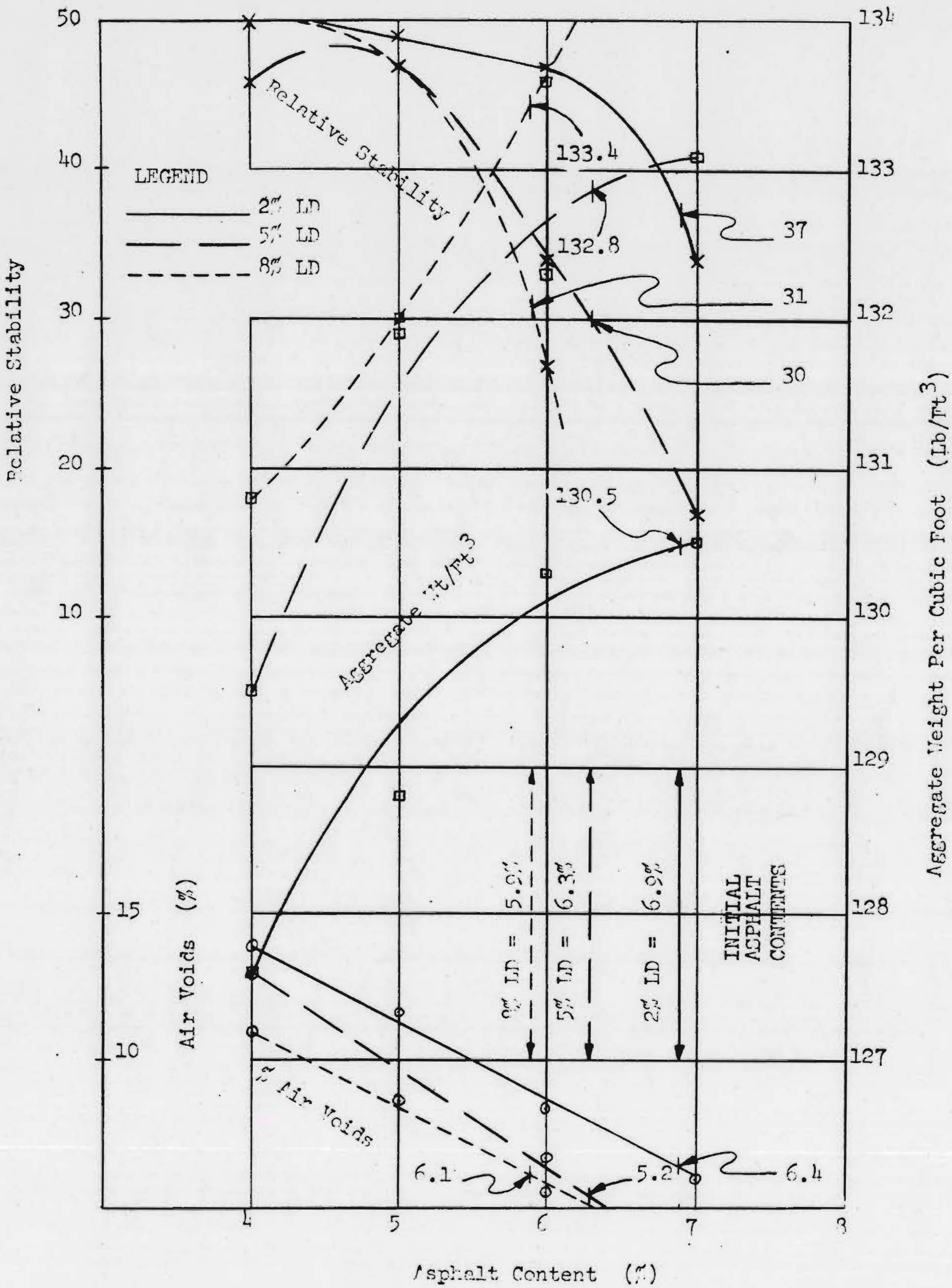
FOR PHASE I



Trial Mixtures for Determination of Initial Asphalt Content for Asphalt Mixture Containing No Mineral Filler



Trial Mixtures for Determination of Initial Asphalt Contents for Asphalt Mixtures Containing 1%, 2 1/2%, and 4% Hydrated Lime



Trial Mixtures for Determination of Initial Asphalt Contents for Asphalt Mixtures Containing 2%, 5%, and 8% Limestone Dust.

Trial Mixture Specimen Data

Filler	Trial Mixture No.	Stability Value				Aggregate Weight per Cubic Foot (lb/ft^3)				Air Voids (%)			
	Asphalt Content (%):	4	5	6	7	4	5	6	7	4	5	6	7
No Filler	1	43	44	40	39	127.6	128.1	128.7	130.0	12.3	10.5	8.7	7.2
	2	43	49	46	38	126.3	127.7	128.0	129.7	13.8	11.5	9.8	7.3
	3	48	49	47	45	126.5	126.3	127.1	126.9	14.6	12.2	9.8	7.1
	Average	45	47	44	41	126.8	127.4	127.9	128.9	13.6	11.4	9.4	7.2
1% Hydrated Lime	1	46	44	40	34	126.1	127.4	128.5	128.9	14.9	11.9	9.0	7.5
	2	49	45	42	40	127.3	128.3	128.4	130.1	14.4	11.5	9.2	6.2
	Average	48	45	41	37	126.7	127.9	128.5	129.5	14.7	11.7	9.1	6.9
	Asphalt Content (%):	5	6	7	7.5	5	6	7	7.5	5	6	7	7.5
2.5% Hydrated Lime	1	47	45	35	18	127.2	129.4	130.1	129.4	13.2	9.5	7.2	6.3
	Asphalt Content (%):	5	6	7	7.3	5	6	7	7.3	5	6	7	7.3
4% Hydrated Lime	1	43	40	16	0	128.3	130.0	131.4	130.5	11.9	9.3	5.9	6.5
	Asphalt Content (%):	4	5	6	7	4	5	6	7	4	5	6	7
2% Portland Cement	1	44	44	43	37	126.6	128.3	127.6	128.8	15.3	11.8	9.9	8.0
	2	57	58	61	58	127.8	129.4	129.3	128.8	13.7	10.1	8.8	7.7
	3	49	49	48	46	128.6	129.5	130.0	130.9	12.4	10.4	8.4	6.3
	4	50	52	55	51	128.5	128.7	129.9	131.2	14.0	12.0	8.6	6.6
	5	48	45	42	39	128.0	130.0	130.8	132.2	13.8	10.3	6.5	5.0
	Average	50	50	50	46	127.9	129.2	129.5	130.4	13.8	10.9	8.4	6.7

Trial Mixture Specimen Data

Filler	Trial Mixture No.	Stability Value					Aggregate Weight per Cubic Foot (lb/ft^3)					Air Voids (%)				
	Asphalt Content (%):	4	5	6	7		4	5	6	7		4	5	6	7	
4% Portland Cement	1	46	41	40	27		127.7	129.3	129.8	130.5		14.5	11.1	9.0	6.5	
	2	50	47	42	29		129.4	129.8	132.5	132.5		13.1	10.9	7.0	5.2	
	Average	48	44	41	28		128.6	129.6	131.2	131.5		13.8	11.0	8.0	5.9	
	Asphalt Content (%):	4	5	6	6.3	6.6	4	5	6	6.3	6.6	4	5	6	6.3	6.6
6% Portland Cement	1	47	45	40			131.3	131.2	134.3			12.2	9.7	6.0		
	2	50	49	36	35	27	130.3	131.1	133.4	133.6	133.5	12.5	9.1	7.2	4.7	5.3
	Average	49	47	38	35	27	130.8	131.1	133.9	133.6	133.5	12.4	9.4	6.6	4.7	5.3
	Asphalt Content (%):	4	5	6	7		4	5	6	7		4	5	6	7	
2% Limestone Dust	1	47	41	37	26		127.1	128.6	131.0	130.6		14.5	11.1	6.4	4.2	
	2	51	55	56	43		128.8	128.7	128.8	130.3		13.3	11.2	8.7	5.0	
	3	63	54	49	35		126.0	128.4	130.0	129.9		13.9	13.0	8.3	6.8	
	4	44	47	44	31		128.3	129.3	131.2	131.2		13.6	10.9	7.1	5.5	
	Average	51	49	47	34		127.6	128.8	130.3	130.5		13.8	11.6	8.3	6.0	
5% Limestone Dust	1	45	43	28	17		130.0	132.2	133.1	132.6		12.6	8.2	6.3	5.0	
	2	47	50	39	16		128.9	131.6	131.5	133.5		13.2	9.2	7.1	3.8	
	Average	46	47	34	17		129.5	131.9	132.3	133.1		12.9	8.7	6.7	4.4	
8% Limestone Dust	1	48	44	20	0		131.1	133.0	134.9	136.5		10.0	7.9	4.7	3.1	
	2	52	50	33	17		130.5	130.9	132.2	134.1		11.8	9.4	6.2	3.9	
	Average	50	47	27	9		130.8	132.0	133.6	135.3		10.9	8.7	5.5	3.5	

APPENDIX D

HVEEM RELATIVE STABILITY TEST DATA

MOISTURE VAPOR SUSCEPTIBILITY TEST DATA

MINNESOTA COLD WATER ABRASION TEST DATA AND

IMMERSION-COMPRESSION TEST DATA

FOR PHASE I

Calculation of Filler-Asphalt Ratios for Relative Stability, Moisture Vapor Susceptibility, Minnesota Cold Water Abrasion, and Immersion-Compression Test Specimens

Filler-Asphalt Ratio = F/A Ratio $= \frac{V_f}{V_a} = \frac{W_f}{G_f W_a}$, Where:

W_a = weight of asphalt in grams

W_f = weight of mineral filler in grams

V_a = solid volume of asphalt in $cm.^3$

V_f = solid volume of mineral filler in $cm.^3$

G_f = specific gravity of mineral filler

Mineral Filler	Filler-Asphalt Ratio
1% hydrated lime	0.054
2.5% hydrated lime	0.146
4% hydrated lime	0.257
2% portland cement	0.084
4% portland cement	0.184
6% portland cement	0.302
2% limestone dust	0.095
5% limestone dust	0.281
8% limestone dust	0.538

Relative Stability Test Data

Filler	Average Relative Stability Value	Aggregate Wt/Ft^3 (Lb/Ft^3)	Specimen Density (Lb/Ft^3)	Specimen Air Voids (%)	Moisture & Volatiles (%)
No filler	45	128.3 128.2	137.3 137.2	7.1, 7.1	0.0334
1% hydrated lime	27	129.7 129.8	139.4 139.5	5.3, 3.8	0.159
2.5% hydrated lime	26	129.9 129.8	138.7 138.6	6.4,6.4	0.0684
4% hydrated lime	41	127.5 127.7	135.3 135.5	8.4, 8.3	0.147
2% portland cement	24	130.7 131.0	140.5 140.8	4.9, 4.3	0.048
4% portland cement	30	132.6 131.4	141.5 140.3	5.1, 6.2	0.076
6% portland cement	42	133.6 133.4	141.7 141.5	5.7, 5.9	0.116
2% limestone dust	18	130.6 130.7	140.5 140.6	3.2, 3.6	0.0148
5% limestone dust	26	132.2 131.8	140.5 140.1	6.0, 6.0	0.0495
8% limestone dust	44	130.6 131.5	137.3 138.2	9.4, 8.8	0.020

Moisture Vapor Susceptibility Test Data

Filler	Average Relative Stability Value	Aggregate Wt/Ft^3 (Lb/Ft^3)	Specimen Density (Lb/Ft^3)	Specimen Air Voids (%)	Moisture & Volatiles (%)
No filler	33	129.1	138.1	6.9	0.384
1% hydrated lime	30	129.7	139.4	5.3	0.203
2.5% hydrated lime	28	130.4	139.3	6.0	0.424
4% hydrated lime	29	127.8	135.6	9.2	0.529
2% portland cement	16	130.7 130.8	140.5 140.6	4.4, 4.7	0.262
4% portland cement	21	132.3 133.1	141.3 142.1	5.1, 4.5	0.251
6% portland cement	33	134.2	142.4	5.7	0.346
2% limestone dust	19	130.9	140.9	4.2	0.252
5% limestone dust	22	133.2	141.6	4.4	0.299
8% limestone dust	46	131.4	138.1	8.9	0.393

Immersion-Compression Test Data for Specimens Having Planned Asphalt Contents

	Dry Specimens		Immersed Specimens	
Filler	Asphalt Content (%)	Average Unconfined Compression Strength (psi)	Average Unconfined Compression Strength (psi)	Index of Retained Strength
No filler	7.0	233	176	75.5
1% hydrated lime	7.5	289	221	76.5
2.5% hydrated lime	6.8	327	277	84.7
4% hydrated lime	6.1	508	415	81.7
2% portland cement	7.5	262	188	71.8
4% portland cement	6.8	283	218	77.0
6% portland cement	6.1	254	236	93.0
2% limestone dust	7.6	304	249	81.9
5% limestone dust	6.3	339	290	85.5
8% limestone dust	5.1	469	346	73.8

APPENDIX E

STATISTICAL ANALYSIS DATA

LINEAR CORRELATION COEFFICIENTS

	RS Test	MVS Test	RS Test	MVS Test	Immersion-Compression Test Planned			MCWA Test Abrasion Loss	
	RS	RS	M&V	M&V	DS	WS	IRS	Plan.	Ind.
RS Test-RS	1.00	0.79	0.15	0.62	0.30	0.28	0.03	0.37	0.45
MVS Test-RS		1.00	0.04	0.47	0.42	0.35	-0.07	0.69	0.46
RS Test-M&V			1.00	0.11	0.14	0.22	0.28	-0.38	-0.09
MVS Test-M&V				1.00	0.64	0.70	0.21	0.12	0.56
Immersion-Compression Test Planned DS					1.00	0.97	-0.06	0.54	0.56
Immersion-Compression Test Planned WS						1.00	-0.19	0.43	0.49
Immersion-Compression Test Planned IRS							1.00	-0.22	-0.25
MCWA Abras. Loss Plan.								1.00	0.37
MCWA Abras. Loss Ind.									1.00

Legend

RS - Relative Stability

MVS - Moisture Vapor Susceptibility

M&V - Moisture and Volatiles

Planned - Planned Asphalt Ratio Specimens

Indicated - Indicated Asphalt Ratio Specimens

DS - Dry Strengths

WS - Immersed Strengths

IRS - Index of Retained Strength

MCWA - Minnesota Cold Water Abrasion

APPENDIX F

INVESTIGATION PROCEDURE

FOR PHASE II

PART A OF PHASE II

IDAHO DEPARTMENT OF HIGHWAYS PIT SOURCES BONNER 46, IDAHO 93, AND ONEIDA 36

I. Aggregate Preparation

A. Gradation and Tests. Same as in Section I of Appendix A.

II. Trial Mix Specimens

A. Tests. Same as in Section II-A of Appendix A.

B. Procedure. 1. Make none trial mixture series using asphalt contents shown in Step 2 and no filler, 1% and 2% hydrated lime, 1% and 2% hydrated lime slurry, 1% and 2% portland cement, and 1% and 2% limestone dust by weight of aggregate.

2. Make four trial mixture series using the following types and amounts of mineral filler by weight of aggregate for the indicated trial asphalt content:

Filler		Trial Asphalt Content (%) 4.0	5.0	6.0	6.5	7.0	7.5	Filler Asphalt Ratio
Hydrated lime	(%)	1.03	1.29	1.55	1.68	1.82	1.95	0.104
Hydrated Lime Slurry	(%)	1.03	1.29	1.55	1.68	1.82	1.95	0.104
Portland Cement	(%)	1.03	1.29	1.55	1.68	1.82	1.95	0.083
Limestone Dust	(%)	1.03	1.29	1.55	1.68	1.82	1.95	0.094

3. Select the optimum asphalt content for each case considering relative stability, unit weight of aggregate plus mineral filler, and percentage of air voids.

III. Tests Performed

A. Immersion-Compression Test. Same as in Section IV-D of Appendix A, using for each source the appropriate optimum asphalt content in each case for:

a. control specimens containing no mineral filler,

b. test specimens for each type and amount of mineral filler indicated in II-B.

PART B OF PHASE II

IDAHO DEPARTMENT OF HIGHWAYS PIT SOURCES BANNOCK 142s AND TWIN FALLS 63

I. Aggregate Preparation.

A. Gradation and Tests. Same as in Section I of Appendix A.

II. Trial Mix Specimens.

A. Tests. Same as in Section II-A of Appendix A.

B. Procedure. Make trial mixture series for each source using appropriate asphalt contents and no filler, 1% and 2% hydrated lime, and 1% and 2% hydrated lime slurry. Select the optimum asphalt content for each case using the same considerations as before.

III. Immersion-Compression Test.

A. Test Specimens. Make test specimens in accordance with ASTM Designation: D-1074-60 for each source using no filler, 2% hydrated lime, and 2% hydrated lime slurry. Prepare half the specimens for each source at the optimum asphalt content and half at optimum asphalt content minus 1%.

B. Procedure. Under Section 5, Procedure of ASTM Designation: D-1075-54, use for each source:

a. Group 1 procedure for one set of test specimens,

b. Group 2 alternate procedure for one set of non-vacuum-saturated test specimens,

c. Group 2 alternate procedure for one set of vacuum-saturated test specimens,

d. Group 2 alternate procedure with a four-day immersion period for one set of vacuum-saturated test specimens.

C. Repeatability. Perform the entire procedure in Section III a second time for each source to evaluate the repeatability of all test results.

APPENDIX G

MIXTURE COMPONENTS FOR PHASE II

GRADATION AND PHYSICAL PROPERTIES OF MINERAL AGGREGATES FROM PIT SOURCES BONNER 46, IDAHO 93 AND ONEIDA 36

GRADATION

SIEVE SIZE	PERCENT PASSING		
	Br-46	Id-93	On-36
3/4"	100	100	100
5/8"	100	100	100
1/2"	95	95	97
3/8"	83	83	80
No. 4	60	60	60
No. 6	48	50	52
No. 8	38	42	44
No. 16	20	25	32
No. 30	17	21	24
No. 40	14	18	20
No. 50	12	15	16
No. 100	9	12	10
No. 200	6.6	8.2	6.4
DUST RATIO	47	46	32

PHYSICAL PROPERTIES

PROPERTY	TEST RESULT		
	Bn-46	Id-93	On-36
Liquid Limit (%)	N.V.	N.V.	N.V.
Plastic Limit (%)	N.P.	N.P.	N.P.
Plastic Index (%)	N.P.	N.P.	N.P.
Sand Equivalent (%)		87	53
Fine Specific Gravity	2.96	2.86	2.59
Coarse Specific Gravity	2.74	2.73	2.45
Average Specific Gravity	2.88	2.81	2.53
Coarse Aggregate Water Absorption (%)	2.60	1.60	2.50
Asphalt Absorption by Aggregate (%)	1.86	1.03	1.00
Los Angeles Abrasion Test (% Wear)	16.4	17.4	18.7
Idaho Degradation Test			
Original % Minus No. 200	5.5	7	5
Final % Minus No. 200	14.0	11	12
Original Sand Equivalent (%)	75	87	53
Final Sand Equivalent (%)	51	68	31