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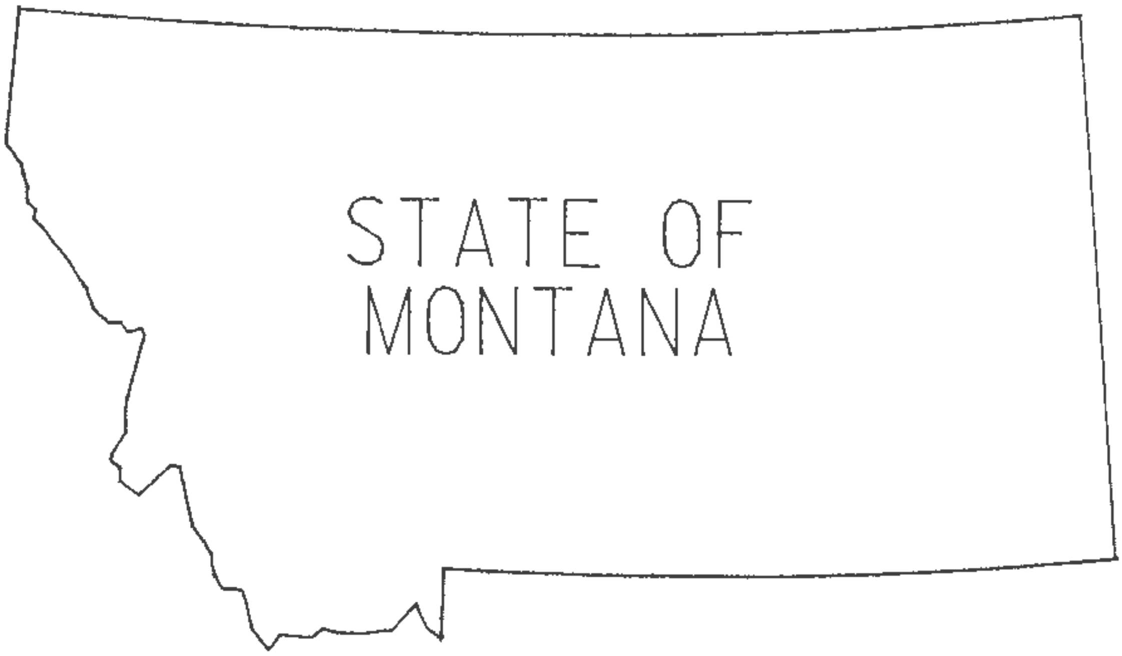

Evaluation of Test Methods to Predict
Moisture Damage in Asphalt Concrete

by

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16. Abstract

The actual moisture suceptibility of 10 bituminous mixtures placed in the field was compared to the moisture suceptibility that was predicted during the laboratory evaluation of the same asphalt aggregate mixture as the mix design was performed. Laboratory mixtures were evaluated using the modified Lottman procedure and the Root Tunnicliff procedure in addition to routine moisture suceptibility testing which includes immersion compression testing.

After two years in the field, cores were taken and the condition of the core and its present suceptibility to moisture damage was determined by performing modified Lottman and Root Tunnicliff testing. A feature of part of the evaluation process was the use of the ACMODAS program to predict the remaining service life of the plant mix cores.

The validity of the process of predicting remaining pavement service using Modified Lottman or Root Tunnicliff testing will not be known until the pavements in the study reach their terminal distress and require repair or rehabilitation. The comparisions of modified Lottman, Root Tunnicliff and Immersion Compression testing data of the same mixtures may be of interest to some people.

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BACKGROUND

The State of Montana has been aware of the susceptibility to moisture damage of some bituminous mixtures for many years. We commonly used hydrated lime to improve these mixtures. We used antistrips such as 0.5% Acra 500 to decrease the stripping of asphalt from bituminous mixtures years ago. Later, when this additive was discontinued, we tested mixtures with newer antistrips. We found that the effectiveness of the antistripping agents decreases with the amount of time the treated asphalt is stored in a hot tank. After designing mixtures with antistrips, we encountered difficulty when the antistrip used did not sufficiently improve the mixture. We discontinued the use of antistrips for construction of plant mix pavements, although it still may be used with maintenance mixes. The use of antistrips has suffered in Montana due to the unavailability of a static inline system to provide uniform blending.

Montana has developed its own test to visually assess stripping. The details of this test are described in the appendix material. Essentially, aggregate is mixed with hot asphalt, "cured", and then immersed in water. After a 24-hour immersion in water, the aggregate is vigorously agitated and dried. The coverage of asphalt remaining on the aggregate is reported.

A test we used to qualify the stripping potential with numerical data is the immersion compression test (AASHTO T-165). It was used in our laboratory as early as the mid-1950's. We have used the test for (1) evaluating aggregate sources and, (2) determining -- during design -- the additive to be incorporated in specific bituminous mixtures. When immersion compression testing has indicated a potential for stripping, the addition of hydrated lime has produced significant improvements in many of the mixtures. As a result, we have frequently used hydrated lime.

On the whole, the utilization of hydrated lime in bituminous mixtures has served us well. In addition, to acting as a bonding agent and increasing the immersion compression; hydrated lime increases adhesion, reduces the plasticity index, reduces volume swell and increases Marshall stability.

The cost of hydrated lime and its incorporation into bituminous mixtures has increased to where we are obligated to make an accurate determination of when hydrated lime is effective and when its use is an unnecessary expense.

To insure that we were up to date in this area, we participated in NCHRP 4-8(3)1 the moisture induced damage study that was principally the work of Dr. Robert Lottman. This study was directed to the evaluation of bituminous mixtures using E Modulus equipment and indirect tensile loading of specimens to failure.

The objective was to predict pavement moisture damage susceptibility by determining the physical properties of test specimens before and after a conditioning process intended to simulate environmental conditions.

During that study, we concluded that the E Modulus test was questionable, but tensile loading of samples had potential, as did resilient modulus testing under very controlled conditions. When the study was completed, the data did not show that any of the test alternatives were superior to the best of their current stage of development. We continued to determine moisture damage susceptibility using the immersion compression test. An added advantage to continuing to use the immersion compression test to determine moisture susceptibility of bituminous mixtures is, we have extensive files of test data and field performance of bituminous mixtures for this method. We based our acceptance of bituminous mixture, immersion compression ratios on the general rule that 59% retained strength or greater was a satisfactory bituminous mixture. We did not formally use the total dry strength of a mixture, but bituminous mixtures with less than 150 psi were suspect even with a "good" retained strength ratio. In 1986, we revised how we evaluated aggregate for moisture damage susceptibility and established 70% or greater retained strength as a satisfactory bituminous mixture.

Bituminous mixtures with this minimum ratio were not used very often. Our objective was to produce the best possible bituminous mixture. If we achieved an increase of 15% in immersion compression by using hydrated lime, we added it to the design recommendations. This usually increased immersion compression ratios of the designed mix to the 80% range.

PROGRAM INITIATION

In 1986, our Federal Highway, Region 8, Administrators started to advance the idea of using Root-Tunnicliff and Modified Lottman bituminous mixture evaluation testing to assess moisture susceptibility. In compliance, we added Modified Lottman testing to our proposed surfacing testing and to our mix design testing as a "trial test". We compared the data that was developed with what the immersion compression, adhesion, and other aggregate and mixture tests indicated.

Comparison of the interpretation of data from a new test with the interpretation of data from familiar tests has limited usefulness if the reliability of the familiar test is being questioned. The true basis for the assessment of a bituminous mixture is how it performs in the environment in the field; and does the behavior of the bituminous mixture follow the predictions that were made on the basis of the testing that was performed.

At this stage in the development process of determining moisture damage susceptibility of bituminous mixtures, the Federal Highway Administration sent us a solicitation for participation in an implementation project. The plan of this project to have four selected states complete a study evaluation of asphalt stripping tests. As we were already engaged in a program in-house, that paralleled the objectives we felt we would benefit by participating in the program. We submitted a proposal that required us to select a project from each of our eleven districts. This selection would provide us with a diverse sampling of both geographic climatic areas and aggregate sources. We planned to evaluate the bituminous mixtures we designed by using Modified Lottman and Root-Tunnicliff testing in addition to our standard tests. Bituminous mixtures that required hydrated lime for either immersion compression or Marshall stability requirements were tested both using hydrated lime and without hydrated lime in the laboratory. This is because the hydrated lime is considered an inhibitor of stripping and other moisture damage susceptibility effects. However, with these bituminous mixtures, no plant mix without hydrated lime was placed in the field.

PROJECT SCOPE

We were awarded a two-year contract for the study we proposed. The contract required us to conduct an evaluation of Modified Lottman and/or Root-Tunnicliff test methods to predict bituminous mixture susceptibility. We had determined we would conduct bituminous mixture evaluation following T283-85 and input the data into the ACMODAS program on selected representative projects in 1987. The ACMODAS program is the PC program written by Dr. Lottman to interpret the data of the T283-85 test procedure and to calculate a life expectancy for a pavement.

Since the Root-Tunnicliff procedure provides quicker results and a freeze-thaw cycle is not necessary, we decided to also include this test in the evaluation.

There is a tendency when evaluating a new procedure to reference it to the current method. In this study, we adhered to this practice for our initial analysis of the test data. For each test section we used AASHTO T165 immersion compression testing to determine bituminous mixture moisture damage susceptibility following procedure 7.1.3 to condition the samples to develop an initial assessment of the bituminous mixtures. These procedures are described in the attachments as MT323 and MT324. Each result of the experimental tests was compared to this "standard". As a more conclusive method of evaluating data from the proposed test procedures, we planned to core the roadway after two years and to test the cores using the Modified Lottman and Root-Tunnicliff testing. The initial prediction of pavement life expectancy made after testing laboratory samples could be compared to the subsequent prediction made after testing the same bituminous mixture two years later using field cores. We thought the consistency of the prediction and the condition of the core, after two years, would provide a reasonably reliable basis for recognizing if the life cycle was accurately predicted by the initial testing.

Montana is a very large and geographically diverse State. We felt if we selected a minimum of two projects from each of the five districts we would have data from representative aggregate sources, and have bituminous mixture in areas extending throughout the State. For our final list of projects, we had eleven pavement sections to evaluate.

For moisture damage susceptible bituminous mixtures that we detect by immersion compression testing, we add 1.4% hydrated lime by total weight of mix. Low immersion compression values are usually increased by 20%

and average range immersion compression values are increased by 10%. We were very interested in learning how the pavement properties are affected by the addition of hydrated lime as determined by Modified Lottman and Root-Tunnicliff laboratory testing of bituminous mixtures.

After completing the Modified Lottman and Root-Tunnicliff test procedures, we planned to use the retained strength ratio (wet strength divided by dry strength X 100) for an "intuitive" assessment of the properties of the mixtures. With +70% retained strength, a bituminous mixture is normally sound and able to withstand saturation and other adverse weathering conditions. With 50%-60% retained strength, the mixture has some moisture damage susceptibility and requires the protection of using hydrated lime or some other system to retard moisture penetration into the bituminous mixture. If the retained strength ratios are less than 50%, the mixture is susceptible to moisture damage and the pavement life will be less than for an aggregate asphalt mixture that is not as susceptible.

We also planned to input the data into the ACMODAS program developed by Dr. Robert Lottman at the University of Idaho. The test data generated in this project under the T-283 and Root-Tunnicliff procedures will be processed using the ACMODAS computer program developed under the NCHRP 4-8(3)1 Project. This program provides for a calculation of the susceptibility of a mixture to moisture damage and a predicted longevity of the resulting bituminous pavement. The computer program requires both the test data and the conditions of anticipated field exposure as input variables. This data processing will be performed using an IBM-PC computer currently available in the Materials Bureau Laboratory. Comparing the life predictions from the original laboratory bituminous mixture and the predicted life remaining from the field cores, we could assess the value of the prediction. Did the pavement life remaining determination, made for an aged and environmentally exposed pavement sample, validate the pavement life projection made with the initial laboratory bituminous mixtures?

Project Implementation

In 1987, we reviewed the projects that were scheduled to be paved. We selected a diverse sampling of geographic/climatic areas and multiple aggregate sources. We planned for at least one project from each of our districts and areas.

Extra aggregate was to be submitted when the aggregate from the projects was submitted for mix design. In addition to performing the mix design which includes immersion compression testing, we planned to complete Modified Lottman and Root-Tunnicliff testing for these aggregate sources. For fabrication of the test specimens, we would use the same asphalts, additive (if any), contractor's target grading, and specified aggregate bin proportions as used in the original mix design.

As our program is focused upon adding one of the newer test methods to our design procedure, the comparison to the immersion compression test results will be very important. The test method that most accurately predicts moisture susceptibility will be considered for incorporation into our routine design procedures. If either the Modified Lottman or Root-Tunnicliff test procedures indicate a significant improvement in predictive capabilities is possible, we would perform that test to supplement the immersion compression test for a few years, to build our experience and data base before starting to rely on it exclusively for moisture damage susceptibility determinations.

TEST PROJECTS

We selected the 11 test projects to represent a diversity of conditions and quality of materials. If a test procedure could be used to successfully predict pavement service with this wide variety of aggregates and conditions, it would be worth adopting.

In the course of the construction year, we procured aggregate for 10 projects and generated Marshall, immersion compression, Lottman, and Root-Tunnicliff data for each. Five of the projects selected for this study required hydrated lime to be added to the bituminous mixture. With these projects, additional laboratory specimens both with and without hydrated lime were prepared for testing using the Modified Lottman and Root-Tunnicliff procedures. The additive, no additive testing would allow us to assess the stripping potential of the bituminous mixtures and to compare these results with the initial conclusions made after immersion compression testing of the same aggregate samples. One project we intended to evaluate was dropped when the aggregate supply was "reclaimed" immediately after the paving was completed. We did not have enough retained aggregate to complete all of the planned testing.

We established base line values using all three moisture damage susceptibility systems and pavement life predictions with Lottman and Root-Tunnicliff testing.

Two years later we went out and cored each of the study projects. We tested the cores and determined Modified Lottman values, Root-Tunnicliff values and again processed this information using the ACMODAS program.

We compared the initial data, the data in two years time and the apparent correlation obtained from the two data sets. We expected longevity predictions at two years to compare by some ratio to initial data. We also thought there might be some relationship between the different test systems. When we did not find definite relationships we studied compaction, aggregate grading, and % AC to determine if the moisture damage susceptibility could be influenced by these factors. The following list is our test project table. The mix design for each of these projects is in the appendix. Although we are primarily interested in general data comparison and correlation, not specific projects, all analysis and discussion is referenced to a project name in addition to the test group numbers identified in this table.

TABLE I. PROJECT/TEST GROUPS

Test Group	Project Name	Project Number
1	Seeley Lake-Inez	RTF 83-1(4)15
2	Ulm-South	RS 330-1(7)0
3	Helena-West	RTF-BRF 8-2(15)34
3a	Helena-West (Hydrated Lime)	RTF-BRF 8-2(15)34
4	Kila-West	F-BRF-HES 1-2(37)99
4a	Kila-West (Hydrated Lime)	F-BRF-HES 1-2(37)99
5	Nashua-North	RS 438-1(4)0
6	Bridger-Fromberg	F-BRF 4-1(5)26
6a	Bridger-Fromberg (Hydrated Lime)	F-BRF 4-1(5)26
7	Three Forks - North	F-HES 8-4(11)99
8	Big Sandy	RRS 10-2(14)71
8a	Sandy (Hydrated Lime)	RRS 10-2(14)71
9	Klein - South	F-HES 16-2(3)29
9a	Klein - South (Hydrated Lime)	F-HES 16-2(3)29
10	Miles City - Northwest	F-HES 18-1(2)1

The test data that was developed is listed. For the classification of the test groups columns 5, 6 and 7, we classed 70% or greater retained strength as good, 70%-55% retained strength as suspect and less than 55% as bad.

TABLE 2. GROUP CLASSIFICATION

Group No.	IC %	Lottman %	Root-Tunnicliff %	Good	Suspect	Bad
1	67.8	65.8	81.4	RT	IC,ML	
2	67.9	78.9	80.0	ML,RT	IC	
3	68.6	52.4	63.6		IC,RT	ML
3a	75.8	58.0	55.3	IC	ML,RT	
4	59.3	51.3	41.5		IC	ML,RT
4a	78.8	79.2	72.9	IC,ML,RT		
5	77.3	81.8	50.6	IC,ML		RT
6	41.5	88.0	44.3	ML		IC,RT
6a	64.0	76.0	67.2	ML	IC,RT	
7	97.1	65.1	67.2	IC	ML,MT	
8	54.5	57.2	51.8		ML	IC,RT
8a	83.3	61.8	80.3	IC,RT	ML	
9	64.5	62.0	69.1		IC,ML,RT	
9a	81.3	79.5	79.0	IC,ML,RT		
10	88.5	78.8	94.2	IC,ML,RT		

From this grouping, we see that moisture damage susceptibility is significant according to some test for six of the sample groups if the borderline group 3a is counted.

Moisture damage susceptibility is probable or the mixture is suspect for six additional sample groups. Thus, there are only three aggregate groups for which none of the moisture damage susceptibility detection tests indicate that the mixture is susceptible to moisture damage. Of these three groups, two of them are mixtures to which 1.4% hydrated lime was added. Only group ten aggregate exhibits a lack of sensitivity to moisture damage without an additive. Conversely, of the ten groups of aggregate evaluated not one group tested universally bad by all three tests being considered. Three of the five mixes where hydrated lime was used for the mix design and in the construction showed "bad" moisture damage susceptibility without addition of the hydrated lime. Into the bituminous mixture these are group 4, group 6 and group 8. For groups 3 and 9, the other two groups where hydrated lime was used the mixes that were suspect without the hydrated lime improved in at least one test parameter when hydrated lime was added to the bituminous mixture.

A project by project review of the moisture damage susceptibility data for each project was performed. In this review note the following:

1) Referenced, Montana Test Methods (MT), are in the back of this report.
2) Sieve sizes to describe aggregate gradations are U.S. standard sieve designations.
3) Immersion compression test samples are fabricated according to MT323 and tested according to MT324. This is similar to AASHTO T165 and T167.

Terms that are referred to in the project by project review are as follows:

Absorption - water absorption of aggregate determined using procedures MT204 and MT205.

Adhesion - the percentage of asphalt adhering to a selected sample of aggregate after the aggregate is coated, soaked 24-hours in distilled water, agitated in a paint shaker and visually assessed following procedure MT309.

Fracture - the percentage of aggregate that has at least one mechanically fractured face, which is determined following MT217.

VMA - Abbreviation for Voids in Mineral Aggregate.

Volume Swell - The percentage of volume change of -10M aggregate after saturating with water for a 24-hour period. Asphalt is used to bond the aggregate to enable measuring the volume.

PROJECT REVIEW

1) Seeley Lake - This mix design was performed in September 1987 with a good aggregate that was more absorptive (2.19% absorption) than most. The adhesion was 80%, the immersion compression was 67.8% and the volume swell of the -10M was 1.5% the fracture was 80% and

the VMA was 14.0%. Marshall stabilities were 1900 pounds. The Lottman retained strength ratio was 66% and the Root-Tunnicliff retained strength ratio was 81%. No additive was recommended. The cores now show 80% adhesion. The Lottman and Root-Tunnicliff values on the cores are both much less than the mix design; 37.0% and 48% respectively. The predicted life of plant mix evaluated during the mix design was 17-18 years. The prediction from field cores two years later was approximately six years. The density of a field core (2.243) was much less than the mix design density of 2.306, so this may be a significant factor.

2) Ulm - South - This project was from another district and another geographic area. The mix design was performed September 2, 1987. This was another good aggregate that was moderately absorptive (1.59% absorption). The adhesion was 80%, the immersion compression was 67.9% and the volume swell of the -10M aggregate was 2.8%. The fracture was 78% and the VMA was 14.0.

Marshall stabilities were 2000 pounds.

The Lottman and Root-Tunnicliff retained strength ratios of the mix design were 79% and 80% respectively. The predicted life of the tested mix design samples with no additive was approximately 15 years with either the Lottman or the Root-Tunnicliff testing. The predictions of the pavement life from testing the field cores taken two years later were 8-10 years, so the deterioration is apparently occurring at a higher rate than estimated in the calculations of pavement service life. The density of the field cores is 2.357 compared to a density of design of 2.341, so density was achieved and high voids are not accelerating the deterioration.

3) Helena - West - This roadway mix design was performed December 1987 with a good moderately, absortive aggregate (1.51% absorbtion). Hydrated lime was added to increase the Marshall stability but this also influenced immersion compression data, adhesion, volume swell and other mixture properties. As designed, the adhesion was 80%, the volume swell was 5.4%, fracture was 72% and the VMA was 16.2%.

The Marshall stabilities were 2160 pounds and the immersion compression was 76% retained strength. The mix design Modified Lottman testing indicated a 13-year service life and the Root-Tunnicliff testing indicated a 20-year service life. Modified Lottman and Root-Turnicliff retained strengths were 55-58%. Cores taken two years later indicated 12 years of remaining service life using Modified Lottman test data and 6.6 years of remaining service life. Modified Lottman and Root-Tunnicliff retained strength ratios had declined to 48%. Obviously, one of the procedures is not generating the correct prediction. The density of a field core was approximately the same as the density of the mix compacted in the lab; 2.32 for the mix design and 2.306 for the field core. Voids are not thought to be a factor in this possibly deteriorating plant mix.

4) Kila - E & W - This mix design was performed November 1987, with a good, moderately absorptive aggregate (1.65% absorption). Hydrated lime was added to increase the immersion compression retained strength, but this also influenced adhesion, Marshall data and other mixture properties. As designed, the adhesion was 85%, the volume swell was 3.2%, fracture was 70% and VMA was 13.8%.

The Marshall stabilities were 2400 pounds and the immersion compression retained strength was 79%.

The mix design Modified Lottman testing indicated that the mix would provide more than 30 years of service. The Root-Tunnicliff testing indicated 20 years of service, still an acceptable service life. The retained strength of Modified Lottman samples was 79% and of Root-Tunnicliff samples was 73%. Cores taken two years later and tested for Modified Lottman data indicated 6.6 years service could be obtained. Root-Tunnicliff testing indicted 8.0 years of service could be expected. Retained strength ratios were 57% for Modified Lottman testing and 65% for Root-Tunnicliff testing. This is a major decrease in life service expectancy. The mix design density of 2.377 is slightly greater than the 2.365 of the field cores. Compaction differences do not appear to be a significant factor in these major changes of predicted service life for this pavement. This data of the mix design and field cores differs an abnormal amount. Some unidentified variable may be affecting this mixture.

5) Nashua - North - This mix design was performed in June 1987 with a good aggregate with 1.03% absorption. The adhesion was 75%, the immersion compression retained strength was 77.3% and the volume swell of the -10M was 4.2%. Fracture was 86% and the VMA was 15.3. Marshall stabilities averaging 1273 pounds were the only indications this was not a good aggregate for bituminous mixtures. The Lottman was 81.8% and the Root-Tunnicliff ratio was 50.6%. No additive was recommended. The cores now show 70% adhesion. The Lottman and Tunnicliff retained strength ratios are not the same; 67.6% for the Modified Lottman, 109.6% for the Root-Tunnicliff test. The predicted life of plant mix evaluated during the mix design was 26.7 years by Lottman testing and 11.1 years by Root-Tunnicliff testing. This relationship is reversed by the field core predictions taken two years later. Predictions based on Modified Lottman data from cores are for a 9.8 year service life. Predictions based on cores by Root-Tunnicliff testing is that the pavement life expectancy is 25.8 years; a 14.7 year increase from the testing during the mix design. The Modified Lottman retained strength ratio was 67.6% and the Root-Tunnicliff retained strength ratio was 110%. The density of a field core (2.368) was greater than the mix design density of 2.330. We decided this was not a significant factor in this reversal of life cycle expectancy, because even though the Root-Tunnicliff test values increased with the density increase, the Modified Lottman predicted life expectancy decreased.

6) Bridger - Fromberg - The mix design was performed August 12, 1987. This was another good aggregate that was moderately absorptive, (1.43% absorption). Hydrated lime was added to increase the immersion retained strength compression and the Marshall stability. With the hydrated lime, the adhesion was 85%, the immersion compression was 64% and the volume swell of the -10M aggregate was 2.2%. The fracture was 74% and the VMA was 13.9.

With Marshall stabilities of 1960 pounds, the only indication that this was not a good bituminous mixture using our conventional criteria was the lower than normal immersion compression ratio.

The Lottman and Root-Tunnicliff retained strength ratios of the mix design were 76% and 67% respectively. The predicted life of the tested mix design samples was 14.4 years with the Lottman and the Root-Tunnicliff testing. The predictions of the pavement life from testing the field cores taken two years later were 8-10 years by the Lottman test and 39 years by the Root-Tunnicliff test. Surprisingly the retained strength ratios were close, 79% for the Modified Lottman testing and 82% for the Root-Tunnicliff testing. This major disparity will help to determine the validity of one test method when the life cycle matches the prediction. With this project, the density of the field cores is 2.357 compared to a density of design of 2.378. Since density was achieved, high voids are not accelerating the deterioration.

7) Three Forks - North - This roadway mix design was performed in September 1987 with an aggregate having a 0.95% absorption. No additive was used for this bituminous mixture. As designed, the adhesion was 75%, the volume swell was 3.3%, fracture was 80% and the VMA was 14.8%.

The Marshall stabilities were 1768 pounds and the immersion compression was 97.1% retained strength. The mix design Modified Lottman data indicated 5.2 years and the Root-Tunnicliff data indicated 14.4 years of service were available. Retained strength ratios of these two tests were 65%-67%. Cores taken two years later tested for Modified Lottman indicated 5.2 years of service and Root-Tunnicliff testing indicated 7.6 years of service. Retained strength ratios were 57% for Modified Lottman testing and 60% for Root-Tunnicliff testing. These two procedures are essentially in agreement on a prediction of the longevity of this pavement from the field cores. The density of a field core was slightly greater than the density of the mix compacted in the lab; 2.363 for the mix design and 2.38 for the field core, so compaction is not believed to be a negative factor.

8) Big Sandy - This mix design was performed in September 1987, with a good, moderately absorptive aggregate with 1.65% absorption. Hydrated lime was added to increase the immersion compression retained strength, but this also influenced adhesion, Marshall data and other mixture properties. As designed, the adhesion was 85%, the volume swell was 5.1%, fracture was 81% and the VMA was 14.2%.

The Marshall stabilities were 2000 pounds and the immersion compression was 83.3% retained strength with the hydrated lime.

The mix design Modified Lottman testing indicated that the mix would provide 20 years of service (80.3% retained strength). The Root-Turricliff testing indicated 9.4 years of service (61.8% retained strength).

Cores taken two years later and tested for Modified Lottman data indicated 9.4 years of service remained and Root-Tunnicliff testing indicted 7.3 years of service could be expected. Retained strength ratios with both procedures were approximately 72%. Core data is relatively consistent for the two test methods. The mix design density of 2.338 is somewhat more than the 2.309 density of the field cores. The level of compaction may be a factor in reduction of predicted life service when comparing the results of testing the mix design samples and the field core samples.

9) Klein - South - This roadway mix design was performed August 5, 1987 with a good moderately absorptive aggregate with an absorption of 1.51%. Hydrated lime was added to increase the Marshall stability and the immersion compression retained strength, but this also influenced adhesion, volume swell and other mixture properties. As designed, the adhesion was 85%, the volume swell was 1.4%, the fracture was 83% and the VMA was 14.4%.

The Marshall stabilities were 1880 pounds and the immersion compression was 81% retained strength. The mix design Modified Lottman testing indicated 11.9 years of service before failure and the Root-Tunnicliff test data indicated 10.8 years. Both tests yielded 79% retained strength of mix design samples tested. Cores taken two years later tested for Modified Lottman indicated 27 years of service and Root-Tunnicliff testing indicated 9.7 years. Retained strengths of cores were 110% for Modified Lottman testing and 76% for Root-Tunnicliff testing. One of the procedures is not generating the correct prediction. The density of a field core was less than the density of the mix compacted in the lab, 2.363 for the mix design; compared to 2.316 for the field core. The increase of pavement life projected from the second Modified Lottman testing is opposite to what the lesser density of plant mix would produce.

10) Miles City - NW - This mix design was performed April 24, 1987 with a good aggregate that had 1.78% absorption. No additive was required. The adhesion was 75%, the immersion compression retained strength was 88.5% and the volume swell of the -10M was 1.8%. Fracture was 89% and the VMA was 15.6%. Marshall stabilities were 2000 pounds. The Lottman was 79% and the Root-Tunnicliff was 94%. The cores now show 70% adhesion. The predicted life of the mix design was 16 years for the Lottman test and 21 years for the Root-Tunnicliff test. The field core predictions from cores taken two years later are 9-10 years for either test. The Modified Lottman and Root-Tunnicliff retained strengths are somewhat less, 67% and 74% respectively. The density of a field sample with a

density of 2.317 is somewhat less than the density determined during the mix design of 2.340. This rather minor difference in densities is not believed to be a significant factor in the predicted moisture damage susceptibility of these mixtures.

Conclusions and Summary of Group Review

For this project, we determined immersion compression, Modified Lottman, Root-Tunnicliff and visual stripping of 10 bituminous mixtures at the mix design stage. Two years later we took cores from the roadway and tested them for Root-Tunnicliff, Modified Lottman and visual stripping. We attempted to determine which test data taken initially at the mix design stage was most consistent with the same type of data determined by testing field cores later. After this was done, we did not have enough uniformity of predicted core condition and actual core condition to conclusively prove or refute that the test procedures evaluated could be interpreted to predict plant mix moisture damage susceptibility.

There are contradictions as to what may be expected of the pavement in service with each type of data immersion compression, Lottman and Root-Tunnicliff. Some plant mix that immersion compression data indicated will provide a useful service life was noticeably stripped within the two years between the placement of the section and when the cores were taken. Testing of pavement cores from some other projects indicated that the pavement section would exceed the service life predicted after fabricating and testing laboratory specimens during the mix design. This uncertainty will require additional investigation of the test procedures.

Inconsistent Moisture Susceptibility Factors

We reviewed the test data for other factors that could be introducing an influence on the moisture damage susceptibility. The factor we reviewed first was compaction. It is generally accepted that low compaction of a bituminous pavement leaves voids that provide pathways for free moisture and accelerates moisture damage. The density of plant mix for the mix design was compared to the average density of the in-place plant mix. This data is tabled in the back of this report, but no correlation was found. The asphalt cement (AC) content of the mix design was also compared to the % AC extracted from core samples from each project. A comparison was made to determine how the change in % AC corresponded to the change in moisture damage susceptibility of the bituminous mixtures. This data is included in a table in the appendix, but a correlation was not made.

The gradings of the bituminous mixtures are also tabled in this report. We compared the grading used for the mix design to the grading actually extracted from the cores and determined the differences for each of the gradation sieve sizes. The differences, in most instances, were within one standard deviation. An exception was the group 7 aggregate which had 3.4% less -200M than the mix design. This apparently does not correlate with the predictions of life cycle, no gradation - longevity correlations were made.

All of the information used to assess pavement life cycle is included in the tables in the appendix. When a review of tabled data did not show us recognizable correlations of data and apparent plant mix performance, we tried graphing the various data sets. Comparisions were made of Modified Lottman test data developed during the mix design to Modified Lottman field data from cores two years later, and Root-Tunnicliff mix design and field data in the same sequence. The graphs identify the inconsistency of the data and the lack of a pattern characteristic of a consistent relationship between the properties of the bituminous mixture and the moisture susceptibility.

Graph Set Discussion

These graphs are discussed in detail here.

1) The first set of graphs, a mix design and field data comparison, seriously disturb the idea that mix design laboratory testing can be used to predict the service life of a pavement. If the pavement life predictions were all right, the test data determined with the mix design samples would show a pavement life expectancy of two years more than the field cores. This did not occur and cores often had half or less of the life expectancy of the mix design samples. If the test methods are capable of isolating plant mix

weakness, there is a major weakness of plant mix produced by the field production for many of the mixtures studied. However, there are also occasional projects where the plant mix produced in the field is significantly better than initially predicted by the mix design. There is an alternative interpretation to the first set of graphs. If the actual environment is more severe than the factor used in the mixture fatigue life calculation, the deterioration would occur faster than predicted. This would fit the two known data points of several of the sample groups. The validity of this theory will only be proven if the roadways fail in less time than the design life in the order of the pavement life predictions that were made.

The second set of graphs, Mix Design Lottman compared to Mix Design Root-Tunnicliff, is a reasonable match on five of the projects and the data is totally at odds on the other five projects. On three of the projects where the data is not in agreement, Modified Lottman based predictions are for a longer pavement life than predictions based on Root-Tunnicliff testing. This is not what was expected. It was anticipated that the Modified Lottman test would be more severe than the Root-Tunnicliff test because the Modified Lottman conditioning process has a freeze-thaw cycle and the Root-Tunnicliff conditioning process does not. Since it is more severe and other factors were held constant for the calculations, the wet fatigue performance life predicted using Root-Tunnicliff was expected to be longer than wet fatigue performance using Modified Lottman testing. In actual testing, the longer wet fatigue lives were predicted by the Modified Lottman testing on seven of the test groups on the mix design. This reversed with the field cores; the Root-Tunnicliff test data did indicate a longer wet fatigue life than the Modified Lottman testing did on these samples.

The third set of graphs displayed the differences between pavement life projections using Lottman data for mix design samples and field cores taken two years later. They also display the differences between pavement life projections using Root-Tunnicliff test data for mix design samples and field cores. The graphs show the improbability that Modified Lottman or Root-Tunnicliff testing of mix design samples will compare to the same test from a field core two years later. There is no way of knowing, except to wait for the pavement life cycle to end, what testing yields results that will anticipate pavement performance.

RECOMMENDATIONS

This study was intended to validate the application of Modified Lottman testing and/or Root-Tunnicliff as acceptable methods for determining the moisture damage susceptibility of bituminous mixtures. Quantifying that determination by predicting the pavement service life was tested using an ACMODAS computer program.

We were unable to verify the validity of pavement life projections by establishing how long the pavement will provide a specified level of service before repair or rehabilitation is required. This question will be finally answered by the service life of the projects evaluated. Only when the test projects have reached their terminal life will we finally be able to determine if the pavement life cycle prediction was correct and which test procedure is the most applicable to environments in Montana. A two-year program is too short to establish the accuracy of life cycle projections for bituminous pavements.

The coring evaluation and pavement monitoring of the condition of the test groups must be continued until the pavements fail.

A data deficiency occurred when cores were not obtained immediately after the pavement was placed. We have no means of assessing how much of the difference between mix design tested samples and field cores was a result of environment and how much was differences in the bituminous mixture as it was designed and after it was placed. Future analysis of projects should require cores immediately to complement the testing performed on the laboratory samples.

Future Plans

We have started and will continue to perform Modified Lottman testing on mix designs submitted and most proposed surfacing aggregates. We are finding frequent instances where the Modified Lottman test ratios are lower than the immersion compression ratios for the same bituminous mixtures. If the pavement performance corresponds to this lower test data (failure from moisture damage susceptibility), we may implement Modified Lottman testing as a routine procedure in our mix design program.

Modified Lottman testing used with the ACMODAS program would also permit the development of regional and geographical factors to express the severity of the environment when designing mixes. The more wet/dry cycles or freeze-thaw cycles that a pavement is to be exposed to the more effort could be directed to minimizing the moisture damage susceptibility of the bituminous mixture. If pavement service life from moisture susceptibility could be calculated, design decisions could be made based on expected service and cost/benefit ratios of additives or special asphalts. The concept would be to design for the conditions and the service life. This would be more economical as we would not pay for the minimization of moisture damage susceptibility of bituminous mixtures unless it was necessary.

PAVEMENT LIFE PROJECTIONS

ni	Group No.	IC Ratio%	Mix Design Lottman	Field Cores Lottman	Mix Design -vs- -Field- Comparison +/- yrs.	Mix Design Root-Tunnicliff	Field Cores Root-Tunnicliff	M Co
ey Lake	1	67.8	18.6 yrs	5.4 yrs	+13.2 yrs	17.4 yrs	6.6 yrs	+1
outh Section	2	67.9	16.2 yrs	7.7 yrs	+8.5 yrs	14.2 yrs	9.8 yrs	
na - West	3	75.8	12.9 yrs	12.1 yrs	+0.8 yrs	20.1 yrs	6.6 yrs	+1
- E. & W.	4	78.8	37.4 yrs	6.6 yrs	+30.8 yrs	19.8 yrs	8.0 yrs	+1
ua - North	5	77.3	26.7 yrs	9.8 yrs	+16.9 yrs	11.1 yrs	25.8 yrs	-
ger - Fromberg	6	64.0	14.4 yrs	8.9 yrs	+5.5 yrs	8.9 yrs	39.1 yrs	-
e Forks - N.	7	97.0	5.2 yrs	6.0 yrs	-0.8 yrs	14.4 yrs	7.6 yrs	
Sandy RR pass	8	83.3	20.0 yrs	9.4 yrs	+10.6 yrs	9.4 yrs	7.3 yrs	
n - South	9	86.3	11.9 yrs	27.3 yrs	-15.4 yrs	10.8 yrs	9.7 yrs	
s City - N.W.	10	88.5	16.4 yrs	8.9 yrs	+7.5 yrs	21.2 yrs	9.7 yrs	+

DATA TABULATION

Mix Identity	Stripping (Retained)	Lottman (psi) Dry	Lottman (psi) Wet	Root Tunnicliff (psi) Dry	Root Tunnicliff (psi) Wet	MR (psi) Lottman Dry	MR (psi) Lottman Wet	MR Lottman Dry	MR Lottman Wet
GROUP 1									
Seeley Lake - Inez		110.2	72.5	116.4	94.7	$6.75\times10^{+5}$	$3.47\times10^{+5}$	$6.75\times10^{+5}$	$5.23\times10^{+5}$
RTF 83-1(4)15 (MD)	80%	65.8%		81.4					
Seeley Lake - Inez		103.9	38.8	116.8	56.5	$4.24\times10^{+5}$	$3.36\times10^{+5}$	$5.27\times10^{+5}$	$4.08\times10^{+5}$
RTF 83-1(4)15 (core)	60%	37.3		48.4					
Differences		+6.3	+33.7	-0.4	+38.2				
(gain or loss)	+20%	+28.5		+33.0		+2.51 x	-0.11	$-1.24\times10^{+5}$	$-1.15\times10^{+5}$
GROUP 2									
Ulm-South		106.1	83.7	88.0	70.4	$4.71\times10^{+5}$	$3.60\times10^{+5}$	$4.71\times10^{+5}$	$4.08\times10^{+5}$
RS 330-1(7)0 (MD)	80%	78.9		80.0					
Ulm-South		105.4	56.7	91.2	61.9	$3.42\times10^{+5}$	$2.78\times10^{+5}$	$3.88\times10^{+5}$	$3.45\times10^{+5}$
RS 330-1(7)0 (core)	70%	53.8		67.9					
Differences		+0.7	+27.0	-3.2	+8.5				
(gain or loss)	+10%	+25.1			+1.21	$+1.29\times10^{+5}$	$0.82\times10^{+5}$	$+0.83\times10^{+5}$	$+0.63\times10^{+5}$
GROUP 3									
Helena-West (MD)		110.7	64.2	92.6	51.2	$5.00\times10^{+5}$	$4.06\times10^{+5}$	$5.00\times10^{+5}$	$3.05\times10^{+5}$
RTF-BRF 8-2(15)34	80%	58.0		55.3					
Helena-West (core)		99.1	48.4	107.1	52.0	$4.76\times10^{+5}$	$1.93\times10^{+5}$	$5.12\times10^{+5}$	$3.57\times10^{+5}$
RTF-BRF 8-2(15)34	40%	48.8		48.6					
Difference		+11.6	+15.8	-14.5	-0.8				
(gain or loss)	+40%	+9.2		+6.7		$+0.24\times10^{+5}$	$+2.13\times10^{+5}$	$-0.12\times10^{+5}$	$-0.52\times10^{+5}$
GROUP 4									
Kila - E & W (MD)		97.3	77.1	100.2	73.0	$5.84\times10^{+5}$	$2.99\times10^{+5}$	$5.84\times10^{+5}$	$3.30\times10^{+5}$
F-BRF-HES 1-2(37)99	85%	79.2		72.9					
Kila - E & W (core)		129.3	73.8	121.5	79.0	$5.14\times10^{+5}$	$5.31\times10^{+5}$	$6.39\times10^{+5}$	$5.84\times10^{+5}$
F-BRF-HES 1-2(37)99	75%	57.1		65.0					
Difference		-32.0	+3.3	-21.3	-6.0				
(gain or loss)	+10%	+22.1		+7.9		$+0.70\times10^{-5}$	-2.32×10^{-5}	-0.55×10^{-5}	-2.54×10^{-5}
GROUP 5									
Nashua - North		93.6	76.6	80.8	40.9	$3.67\times10^{+5}$	$1.70\times10^{+5}$	$3.67\times10^{+5}$	$1.85\times10^{+5}$
RS 438-1(4)0 (MD)	70%	81.8		50.6					
Nashua - North		109.0	73.7	65.3	71.6	$2.35\times10^{+5}$	$2.30\times10^{+5}$	$2.99\times10^{+5}$	$2.94\times10^{+5}$
RS 438-1(4)0 (core)	30%	67.6		109.6					
Difference		-15.4	+2.9	+15.5	-30.9				
(gain or loss)	+40%	+14.2		-59.0		$+1.32\times10^{-5}$	-0.60×10^{-5}	$+0.68\times10^{-5}$	-1.09×10^{-5}

DATA TABULATION (Part 2 of 2)

Mix Identity	Stripping (Retained)	Lottman (psi) Dry	Lottman (psi) Wet	Root Tunnicliff (psi) Dry	Root Tunnicliff (psi) Wet	MR (psi) Lottman Dry	MR (psi) Lottman Wet	MR Lottman Dry	MR Lottman Wet
GROUP 6									
Bridger-Fromberg		126.3	96.3	115.7	77.9	$6.38\times10^{+5}$	$4.85\times10^{+5}$	$6.38\times10^{+5}$	$5.66\times10^{+5}$
F-BRF 4-1(5)26 (MD)	85%	76.2		67.3					
Bridger-Fromberg		133.0	106.2	130.7	107.0	$6.05\times10^{+5}$	$6.86\times10^{+5}$	$5.33\times10^{+5}$	$9.33\times10^{+5}$
F-BRF 4-1(5)26 (core)	80%	78.7		81.9					
Difference		-6.7	-9.9	-15.0	-29.1				
(gain or loss)	+5%	-2.5		-14.6		$+0.33\times10^{+5}$	$-2.01\times10^{+5}$	$+1.05\times10^{+5}$	$-3.67\times10^{+5}$
GROUP 7									
Three Forks - N		97.1	63.2	102.8	69.1	$3.69\times10^{+5}$	$2.27\times10^{+5}$	$3.69\times10^{+5}$	$2.28\times10^{+5}$
F-HES 8-4(11)99 (MD)	75%	65.1		67.2					
Three Forks - N		131.5	74.9	92.1	55.0	$4.54\times10^{+5}$	$5.60\times10^{+5}$	$4.09\times10^{+5}$	$3.80\times10^{+5}$
F-HES 8-4(11)99 (core)	40%	57.0		59.7					
Difference		-34.4	11.7	+10.7	+14.1				
(gain or loss)	+35%	+8.1		+7.5		$-0.85\times10^{+5}$	$-3.33\times10^{+5}$	$-0.40\times10^{+5}$	$-1.52\times10^{+5}$
GROUP 8									
Big Sandy - RR		118.0	94.8	109.1	67.4	$7.46\times10^{+5}$	$5.15\times10^{+5}$	$7.46\times10^{+5}$	$5.44\times10^{+5}$
Overpass (MD)		80.3		61.8					
RRS 10-2(14)71	85%								
Big Sandy - RR		128.3	93.1	129.6	93.3	$7.44\times10^{+5}$	$6.82\times10^{+5}$	$5.40\times10^{+5}$	$6.88\times10^{+5}$
Overpass (core)		72.6		72.0					
RRS 10-2(14)71	50%								
Difference		-10.3	+1.7	-20.5	-25.9				
(gain or loss)	+35%	+7.7		-8.2		$+.02\times10^{+5}$	$-1.67\times10^{+5}$	$+2.06\times10^{+5}$	$-1.44\times10^{+5}$
GROUP 9									
Klein - South (MD)		128.5	102.1	113.3	89.5	$4.33\times10^{+5}$	$4.17\times10^{+5}$	$4.33\times10^{+5}$	$4.44\times10^{+5}$
F-HES 16-2(3)29	85%	79.5		79.0					
Klein - South (core)		105.0	116.0	127.4	97.2	$4.72\times10^{+5}$	$4.78\times10^{+5}$	$6.16\times10^{+5}$	$6.13\times10^{+5}$
F-HES 16-2(3)29	80%	110.5		76.3					
Difference		+23.5	15.9	14.4	-7.7				
(gain or loss)	+5%	+31.0		+2.7		$+0.39\times10^{+5}$	$-0.61\times10^{+5}$	$-1.83\times10^{+5}$	$-1.69\times10^{+5}$
GROUP 10									
Miles City - NW		95.5	75.3	99.3	93.5	$2.32\times10^{+5}$	$1.78\times10^{+5}$	$2.32\times10^{+5}$	$1.76\times10^{+5}$
F-HES 18-1(2)1 (MD)	75%	78.8		94.2					
Miles City - NW		124.4	63.6	131.2	96.9	$4.52\times10^{+5}$	$4.21\times10^{+5}$	$2.93\times10^{+5}$	$3.23\times10^{+5}$
F-HES 18-1(2)1 (core)	70%	67.2		73.9					
Difference		-28.9	-8.3	-31.9	-3.4				
(gain or loss)	+5%	+11.6		+20.3		$-2.2\times10^{+5}$	$2.43\times10^{+5}$	$0.6\times10^{+5}$	$-1.57\times10^{+5}$

DENSITY OF BITUMINOUS MIXTURES

Mix Identity	Mix Design % AC	Mix Design Rice Gravity	Mix Design Density	Field Cores % AC	Field Cores Rice Gravity	Field Cores Density
GROUP 1						
Seeley Lake - Inez RTF 83-1(4)15	5.9	2.390	2.306	6.3	2.383	2.243
GROUP 2						
Ulm - South RS 330-1(7)0	6.2	2.424	2.341	5.9	2.459	2.357
GROUP 3						
Helena - West RTF-BRF 8-2(15)34	6.3	2.406	2.320	6.3	2.421	2.306
GROUP 4						
Kila - West F-BRF-HES 1-2(37)99	5.6	2.438	2.377	5.8	2.424	2.365
GROUP 5						
Nashua - North RS 438-1(4)0	6.1	2.413	2.330	5.9	2.418	2.368
GROUP 6						
Bridger - Fromberg F-BRF 4-1(5)26	5.7	2.462	2.378	5.6	2.452	2.357
GROUP 7						
Three Forks - North F-HES 8-4(11)99	5.6	2.446	2.363	5.3	2.433	2.383
GROUP 8						
Big Sandy RRS 10-2(14)71	5.75	2.425	2.338	6.0	2.409	2.309
GROUP 9						
Klein - South F-HES 16-2(3)29	5.6	2.450	2.363	5.4	2.456	2.316
GROUP 10						
Miles City - NW F-HES 18-1(2)1	6.5	2.380	2.294	6.2	2.385	2.306

GRADINGS OF BITUMINOUS MIXTURES

Mix Identity		3/4"	1/2"	3/8"	4M	10M	40M	200M
GROUP 1								
Seeley Lake - Inez	M.D.	100	89	76	56	36	16	8.0
RTF 83-1(4)15	Cores	100	91	81	59	36	16	7.5
	Diff.	0	-2	-5	-3	0	0	+0.5
GROUP 2								
Ulm - South	M.D.	100	90	75	53	34	18	6.0
RS 330-1(7)0	Cores	100	93	73	51	35	20	5.7
	Diff.	0	-3	+2	+2	-1	+2	+0.3
GROUP 3								
Helena - West	M.D.	100	90	78	55	40	16	6.0
RTF-BRF 8-2(15)34	Cores	100	95	85	64	43	18	6.7
	Diff.	0	-5	-7	-11	-3	-2	-0.7
GROUP 4								
Kila - West	M.D.	100	86	75	53	36	16	8.0
F-BRF-HES 1-2(37)99	Cores	100	92	79	55	39	17	9.9
	Diff.	0	-6	-4	-2	-3	-1	-1.9
GROUP 5								
Nashua - North	M.D.	100	92	77	52	36	21	5.0
RS 438-1(4)0	Cores	100	92	77	54	36	21	4.7
	Diff.	0	0	0	-2	0	0	+0.3
GROUP 6								
Bridger - Fromberg	M.D.	100	90	77	53	39	18	6.0
F-BRF 4-1(5)26	Cores	100	94	80	57	41	20	5.3
	Diff.	0	-4	-3	-4	-3	-2	+0.7
GROUP 7								
Three Forks - North	M.D.	100	86	75	53	37	18	6.5
F-HES 8-4(11)99	Cores	100	82	67	47	32	18	3.1
	Diff.	0	-4	+B	+6	+5	0	+3.4
GROUP 8								
Big Sandy	M.D.	100	90	78	53	38	18	7.0
RRS 10-2(14)71	Cores	100	98	-8	53	38	20	6.4
	Diff.	0	-8	-2	0	D	-2	+0.6
GROUP 9								
Klein - South	M.D.	100	90	75	53	37	18	6.0
F-HES 16-2(3)29	Cores	100	93	79	56	39	22	5.6
	Diff.	0	-3	-4	-3	-2	-4	+0.4
GROUP 10								
Miles City - NW.	M.D.	100	90	77	56	34	17	6.0
F-HES 18-1(2)1	Cores	100	9D	76	56	38	21	4.1
	Diff.	0	0	+1	0	-4	-4	+1.9

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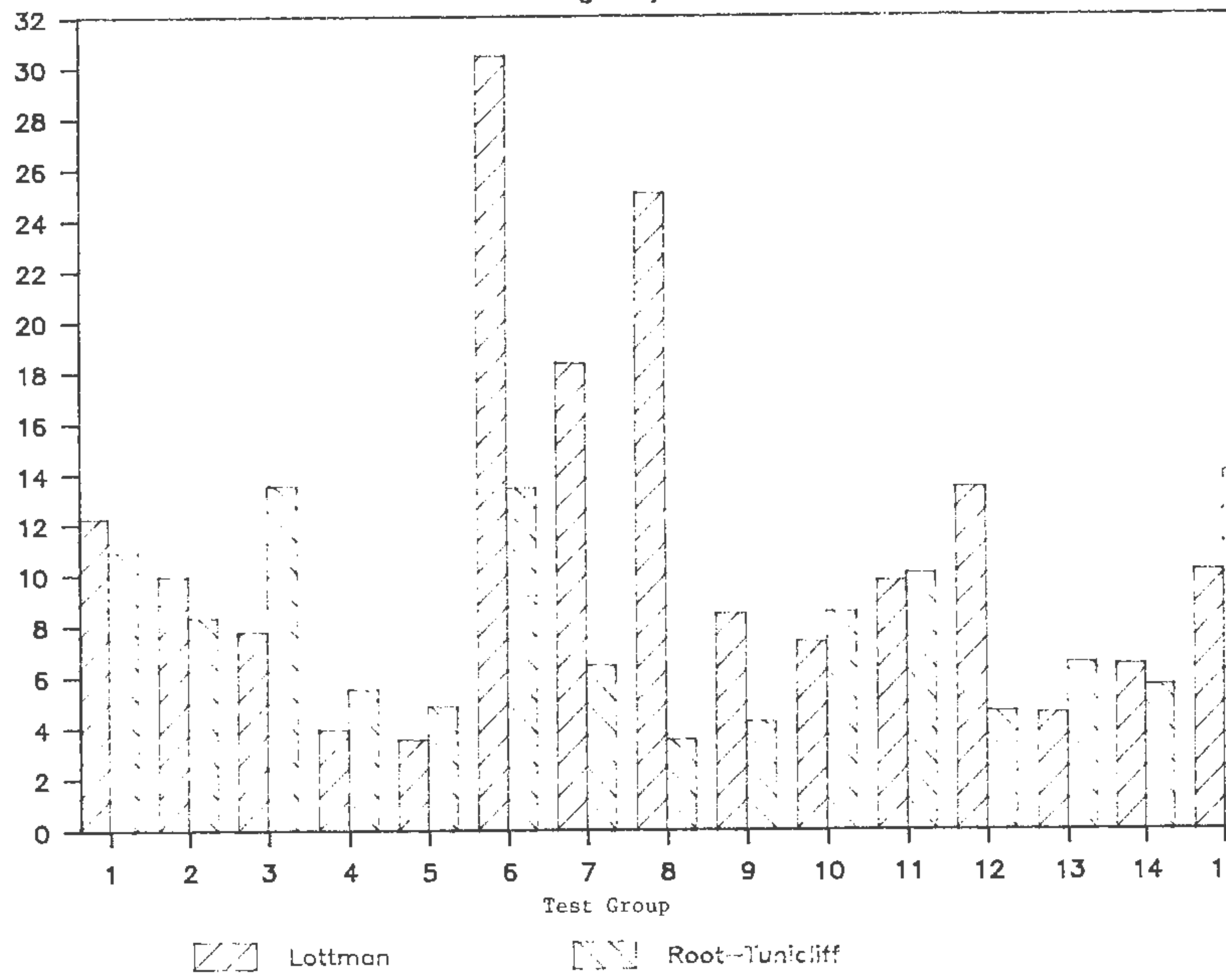
APPENDIX*

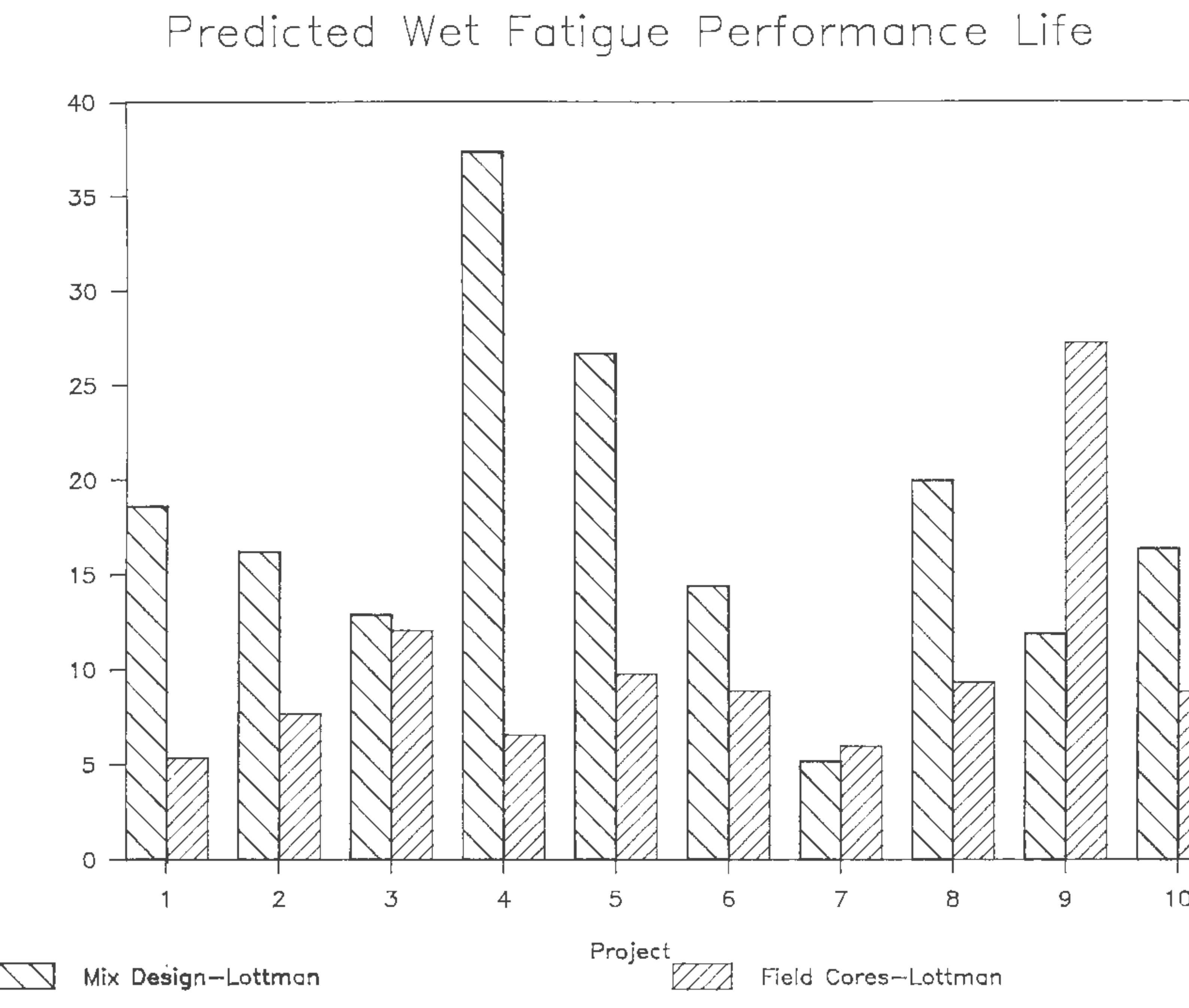
DATA BASE

*See TABLE OF CONTENTS for Detailed Listing

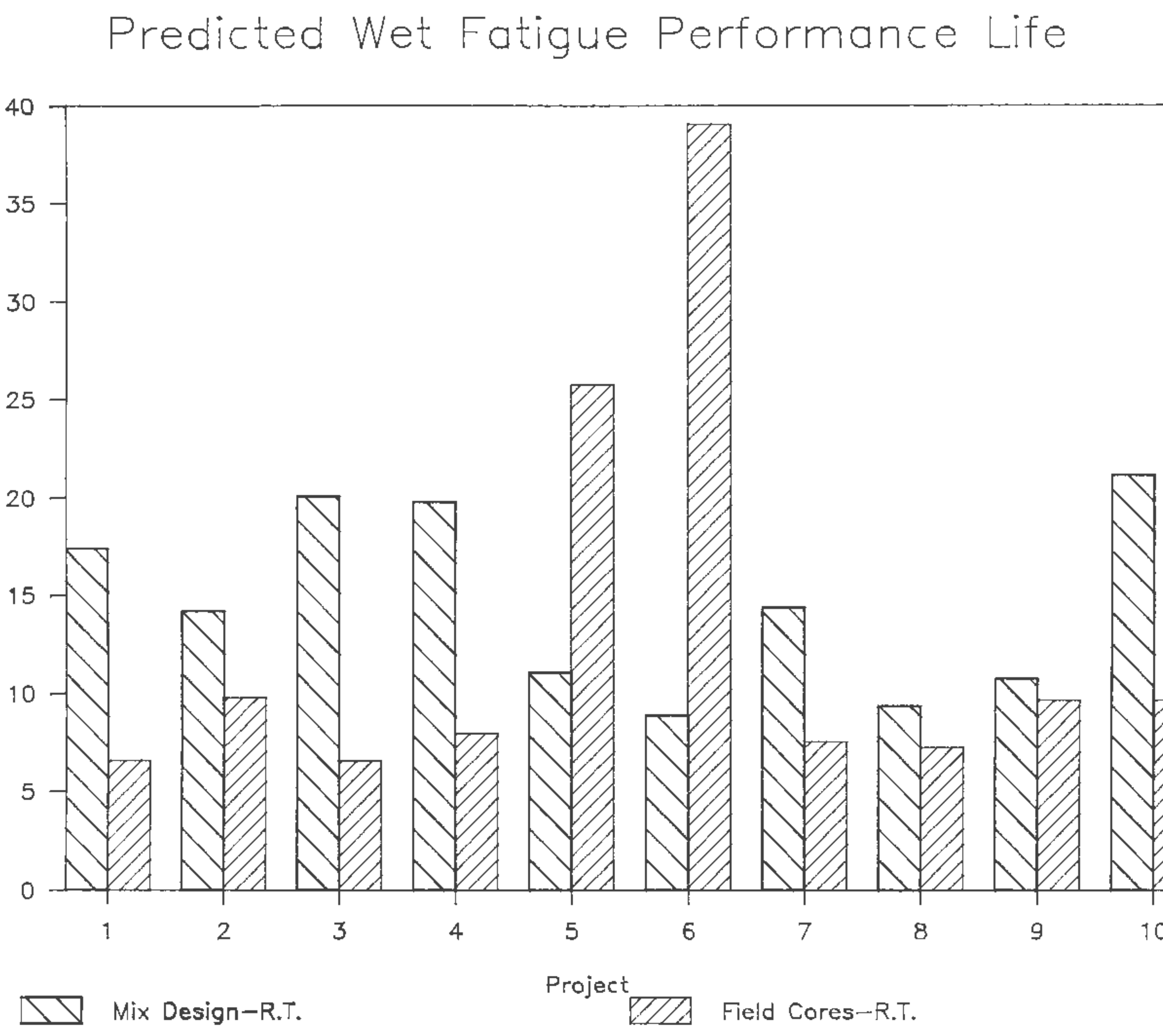
Predicted Cohesive Life

(years)

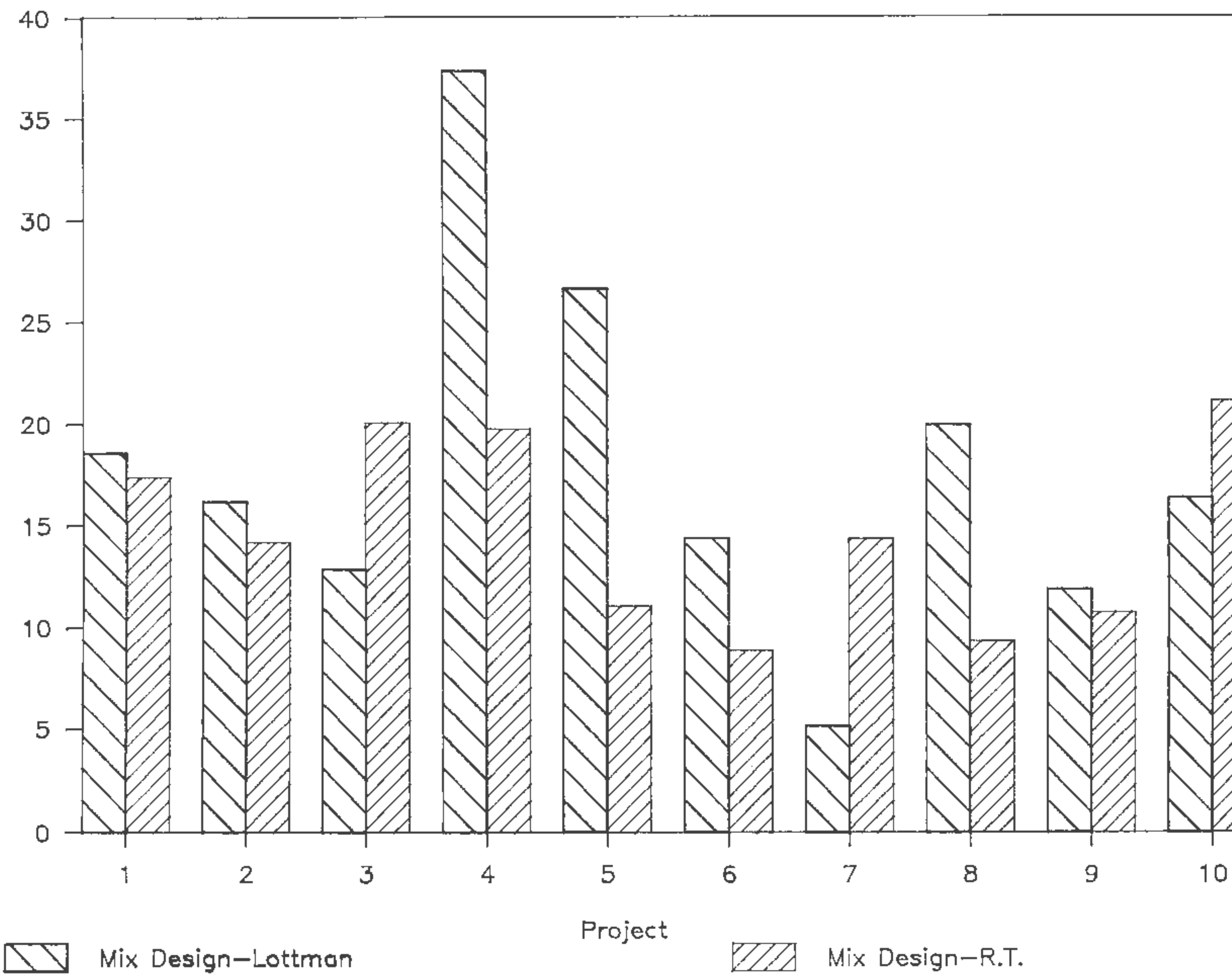


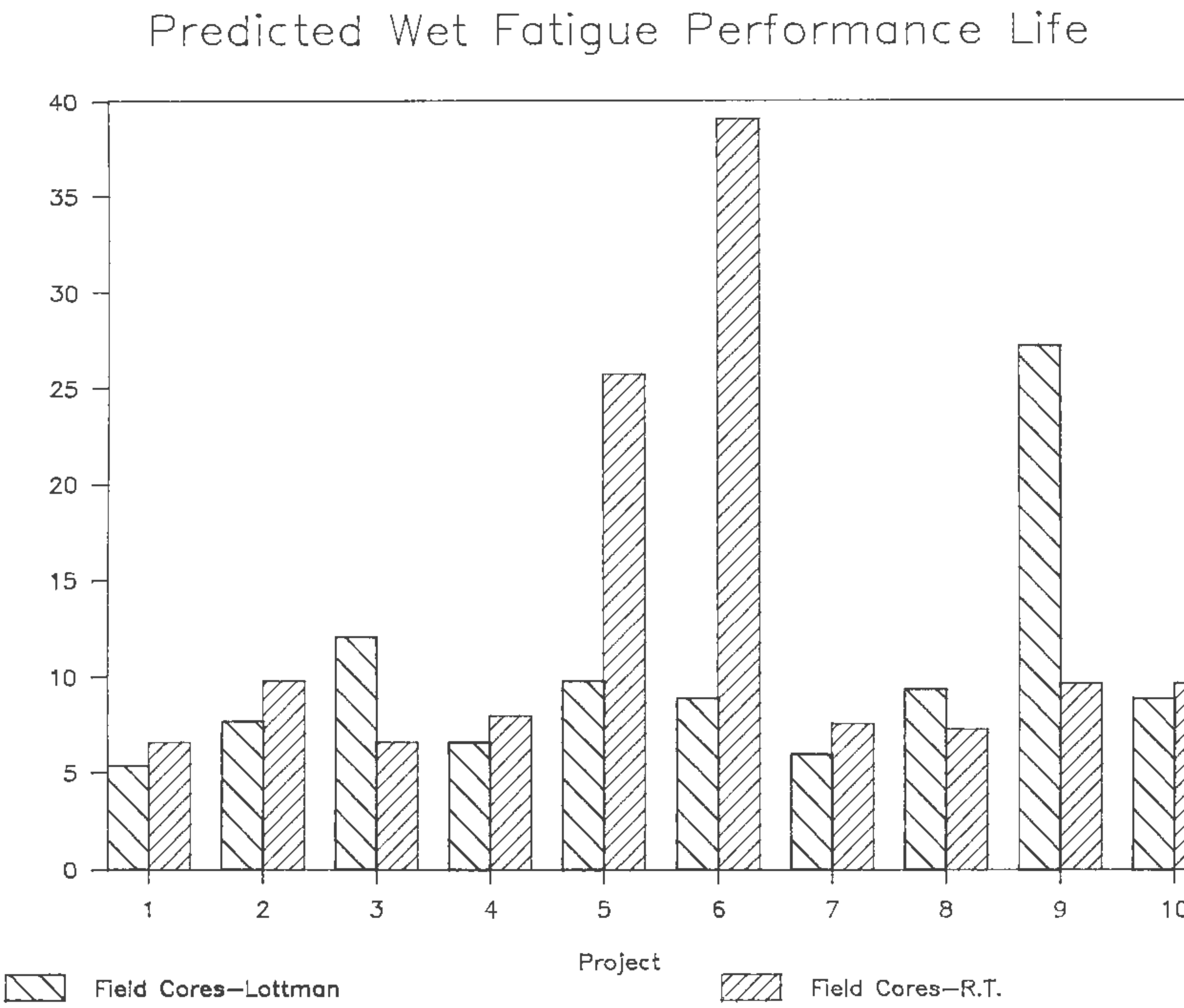


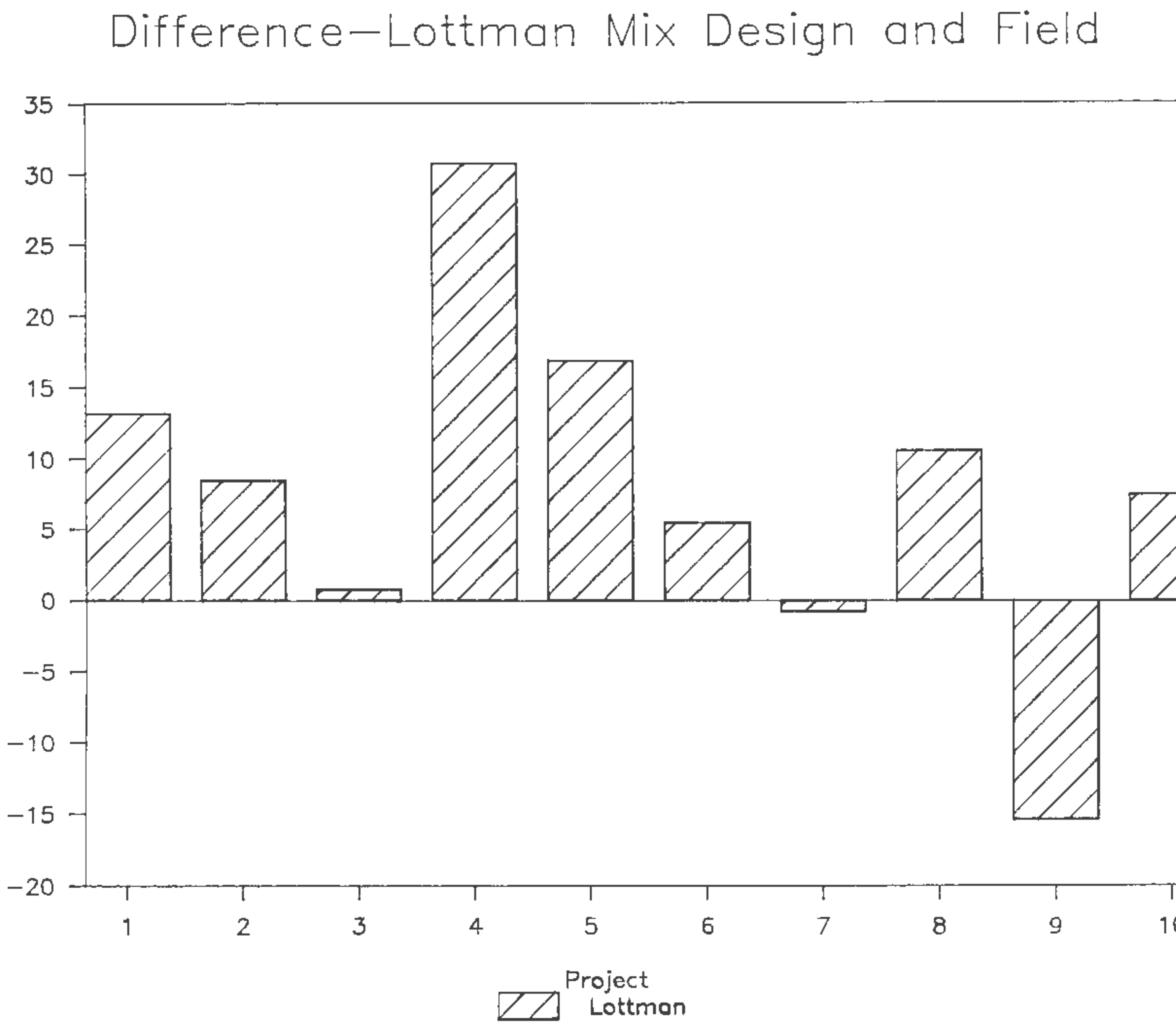
Predicted Wet Fatigue Performance Life
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
Project
Mix Design—Lottman
Field Cores—Lottman


Predicted Wet Fatigue Performance Life
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
Project
Mix Design—R.T.
Field Cores—R.T.

Predicted Wet Fatigue Performance Life

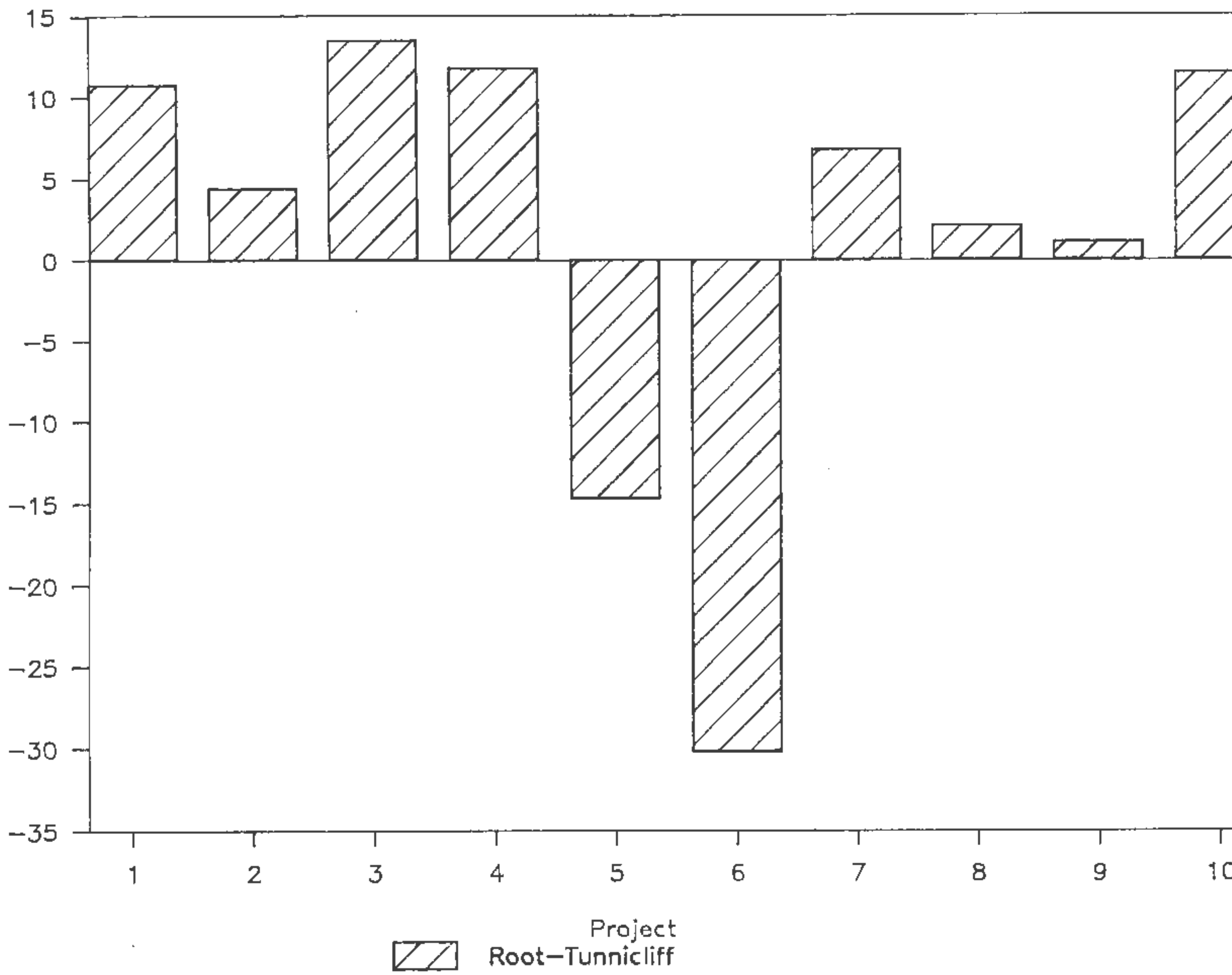



Predicted Wet Fatigue Performance Life
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
Project
Field Cores—Lottman
Field Cores—R.T.



Difference—Lottman Mix Design and Field
35
30
25
20
15
10
5
0
−5
−10
−15
−20
1
2
3
4
5
6
7
8
9
10
Project
Lottman

Difference R.T. Mix Design and Field



Lab. Form No. 606
(Rev. 1/20/87)

0:214/MT-306/11

STATE OF MONTANA
DEPARTMENT OF HIGHWAY
Material Bureau

3/4" PLANT MIX SURFACING, GRADE 3
PLANT MIX BASE, GRADE
ROAD MIX SURFACING, GRADE

Lab. No. 614601 Sample No. 1 (10 sks) Project No. TRF 33-1(4)15
Termini Seeley Lake-Inez Lake
Date Sampled 9/2/87 Date Received 9/4/87
Sampled by Childers Title ES I Address Missoula
Submitted by Smola Title MLT II Address
Area Source Represented by Lab. No 611573-8 & 611537-9 Sample taken at
Owner John Cahoon Address Seeley Lake, Mont

TEST RESULTS ON AGGREGATE

	% Passing As Received	% Passing As Tested
1-½"		
1"		
3/4"	100	100
1/2"	89	89
3/8"	76	76
4M	56	56
10M	36	36
40M	15	16
80M		
200M	7.4	8.0

LL NP PL NP PI NP Dust Ratio Fracture 80
Wear 28 % Degradation Sand Equiv. 46
** Absorption Cs 2.12 % Fine 2.24 % Blend 2.19
Bulk Dry Sp. Gr. of Agg. Fine 2.528 Coarse 2.558

VOLUME SWELL RESULTS

1.5 % 1.4 % 2.1
No. Treat. HARD; 1.5% Hyd. Lime HARD; 1.5% Fly Ash HARD
1.5% Cement %

1984 ADT 750
2007 ADT 1500
18K 114

Recommended: 5.9 % 85/100 A/C; — % NONE

TEST RESULTS ON TRIAL BITUMINOUS MIXES
Marshall Results

Refinery CONOCO

Mineral Filler %	Type	% Asphalt	Rice Gravity	Density (Gm/cc)	% Voids	Lb. Stability	Flow	Appearance
	NONE	5.0	2.403	2.274	5.4	1850	10	NORMAL
		5.5	2.396	2.289	4.5	1782	10	
		5.9	2.390	2.306	3.5	1875	10	INTERPOLATED
		6.0	2.389	2.310	3.3	1898	10	NORMAL
1.5	HYD. LIME	5.0	2.403	2.270	5.5	2000	12	
		5.5	2.396	2.285	4.6	1950	11	
		6.0	2.389	2.314	3.1	2038	13	
1.5	FLY ASH	5.0	2.403	2.309	3.9	2091	12	
		5.5	2.396	2.314	3.4	1811	11	
		6.0	2.389	2.328	2.6	2128	14	

IMMERSION COMPRESSION RESULTS

Mineral Filler %	Type	Percent Asphalt	Dry Break psi	Wet Break psi	Retained Strength
--	NONE	5.9	305.6	207.0	67.8 %
1.5%	FLY ASH	5.9	321.6	103.5	32.2 %
1.5%	HYD.LIME	5.4	346.2	239.6	69.3 %
					%
					%

ADHESION RESULTS

%	Adhesive Agent	Adhesion
--	NONE	80 %
1.5%	FLY ASH	80 %
1.5%	HYD.LIME	85 %
		%
		%

~~Admin. Maint. Div.~~
2 District Engineer MISSOULA
1 Dist. Mat. Supr. MISSOULA
Area Lab —
1 Chief Const. Bureau
1 Chief Materials Bureau
1 Surfacing Design Sect.
2 Bit. Mix Design Sect.
1 FHWA
1 Materials Bureau File

** NOTE: VMA of this Mix Design 14.0
Absorption: 0-1.2 low, 1.2-2.0 moderate, 2.0 and above high

This aggregate has HIGH absorption.
REMARKS:

CHECKED DATE 9/11/87 NAME MFL

Chief, Materials Bureau
Dated

Lab. Form No. 606
(Rev. 1/20/87)

STATE OF MONTANA
DEPARTMENT OF HIGHWAY
Material Bureau

3/4" PLANT MIX SURFACING, GRADE B
PLANT MIX BASE, GRADE
ROAD MIX SURFACING, GRADE

Lab. No. 614107 Sample No. 1 Project No. RS 330-1(7)0
Termini Ulm-South (North Section)
Date Sampled Date Received 7/26/87
Sampled by Title Address
Submitted by J. Powell Title DMS Address Gt. Falls
Area Source Represented by Lab. No. 611964-76 Sample taken at
Owner Stanley Bros/Mont. Power Address Ulm/Butte, MT.

TEST RESULTS ON AGGREGATE

Sieve	% Passing As Received	% Passing As Tested
1-¼"		
1"		
3/4"	100	100
1/2"	92	90
3/8"	75	75
4M	50	53
10M	36	34
40M	20	18
80M		
200M	5.5	6.0

LL NP PL NP PI NP Dust Ratio Fracture 78
Wear 20 % Degradation Sand Equiv. 55
** Absorption Cs 1.54 % Fine 1.64 % Blend 1.59

Bulk Dry Sp. Gr. of Agg. Fine 2.626 Coarse 2.619

VOLUME SWELL RESULTS

No. Treat. HARD 2.8 %; 1.5% Hyd. Lime HARD 2.0 %; 1.5% Fly Ash HARD 2.9
1.5% Cement %

1979 ADT 110
1999 ADT 180
18K 6.9

Recommended: 6.2 % 85/100 A/C; — % NONE

TEST RESULTS ON TRIAL BITUMINOUS MIXES Refinery EXXON
Marshall Results

Mineral Filler %	Type	% Asphalt	Rice Gravity	Density (Gm/cc)	% Voids	Lb. Stability	Flow	Appearance
	NONE	5.5	2.449	2.318	5.3	1950	9	NORMAL
		6.0	2.431	2.330	4.2	1859	10	
		6.2	2.424	2.341	3.4	1932	10	INTERPOLATED
		6.5	2.414	2.357	2.4	2041	11	SLIGHTLY RICH
1.5	HYD. LIME	5.0	2.467	2.328	5.6	1988	11	NORMAL
		5.5	2.449	2.344	4.3	2003	12	
		6.0	2.431	2.363	2.8	2084	11	SLIGHTLY RICH
1.5	FLY ASH	5.5	2.449	2.358	3.7	2158	11	NORMAL
		6.0	2.431	2.379	2.1	1989	13	
		6.5	2.414	2.364	2.1	2063	12	SLIGHTLY RICH

IMMERSION COMPRESSION RESULTS

Mineral Filler %	Type	Percent Asphalt	Dry Break psi	Wet Break psi	Retained Strength
--	NONE	6.2	238.0	161.6	67.9 %
1.5%	FLY ASH	5.8	245.2	207.8	84.8 %
1.5%	HYD.LIME	5.8	271.4	228.4	84.2 %
					%
					%

ADHESION RESULTS

%	Adhesive Agent	Adhesion
--	NONE	80 %
1.5%	FLY ASH	85 %
1.5%	HYD.LIME	85 %
		%
		%

~~Admin. Mgmt. Div.~~
2 District Engineer GREAT FALLS
1 Dist. Mat. Supr. GREAT FALLS
Area Lab —
Chief Const. Bureau
1 Chief Materials Bureau
1 Surfacing Design Sect.
2 Bit. Mix Design Sect.
1 FHWA
1 Materials Bureau File

** NOTE: VMA of this Mix Design 15.0
Absorption: 0-1.2 low, 1.2-2.0 moderate, 2.0 and above high

This aggregate has MODERATE absorption.
REMARKS:
Discussed with John Maykuth by BJB

[signature]
Chief, Materials Bureau
Dated 9/1/87

	DATE	NAME
CHECKED	9/2/17	mpL

STATE OF MONTANA
DEPARTMENT OF HIGHWAY
Material Bureau

3/4" PLANT MIX SURFACING, GRADE B
PLANT MIX BASE, GRADE
ROAD MIX SURFACING, GRADE

Lab. No. 617440 Sample No. Project No. RTF BRF 8-2(15)34
Termini Helena-West(West Section)
Date Sampled 11/30/87 Date Received 12/4/87
Sampled by Sprague/Alley Title MSII & LT Address Butte
Submitted by Yarnall Title DMS Address Butte
Area Source Represented by Lab. No. 613857-65 Sample taken at
Owner 3/4" PMS Gr B Mix Design Address

TEST RESULTS ON AGGREGATE

	% Passing As Received	% Passing As Tested
1-½"		
1"		
3/4"		100
1/2"		90
3/8"		78
4M		55
10M		40
40M		16
80M		
200M		6.0

LL NP PL NP PI NP Dust Ratio Fracture 72 %
Wear 32 % Degradation Sand Equiv. 38
** Absorption Cs 1.45 % Fine 1.57 % Blend 1.51 %

Bulk Dry Sp. Gr. of Agg. Fine 2.588 Coarse 2.599

VOLUME SWELL RESULTS

No. Treat. 6.8 % FIRM; 1.5% Hyd. Lime 5.4 % FIRM; 1.5% Fly Ash 6.4 % FIRM %
1.5% Cement %

1986 ADT 3302
2006 ADT 6200
18K 266

Recommended: 6.3* % 85/100 A/C; 1.4 % HYD. LIME
% HL and % ASPHALT BASED ON TOTAL WEIGHT

TEST RESULTS ON TRIAL BITUMINOUS MIXES Refinery CONOCO
Marshall Results

Mineral Filler %	Mineral Filler Type	% Asphalt	Rice Gravity	Density (Gm/cc)	% Voids	Lb. Stability	Flow	Appearance
—	NONE	6.0	2.418	2.312	4.3	2078	11	NORMAL
		6.5	2.398	2.302	4.0	1608	10	SLIGHTLY RICH
		7.0	2.378	2.308	3.0	1827	10	
1.5	HYD. LIME	5.5	2.437	2.286	6.2	1725	11	NORMAL
		6.0	2.418	2.312	4.3	2078	11	
		6.3	2.406	2.320	3.6	2159	12	INTERPOLATED
		6.5	2.398	2.326	3.0	2213	12	SLIGHTLY RICH
1.5	FLY ASH	6.0	2.418	2.310	4.4	1900	11	NORMAL
		6.5	2.398	2.331	2.8	1950	11	SLIGHTLY RICH
		7.0	2.378	2.339	1.7	2260	12	

IMMERSION COMPRESSION RESULTS

Mineral Filler %	Mineral Filler Type	Percent Asphalt	Dry Break psi	Wet Break psi	Retained Strength
--	NONE	6.75	230.8	158.4	68.6 %
1.5%	FLY ASH	6.3	251.5	164.7	65.5 %
1.5%	HYD.LIME	6.3	269.8	204.5	75.8 %
					%
					%

ADHESION RESULTS

%	Adhesive Agent	Adhesion
--	NONE	70 %
1.5%	FLY ASH	75 %
1.5%	HYD.LIME	80 %
		%
		%

~~Admin. Maintenance Div.~~
2 District Engineer Butte
1 Dist. Mat. Supr. Butte
Area Lab —
1 Chief Const. Bureau
1 Chief Materials Bureau
1 Surfacing Design Sect.

* NOTE: % ASPHALT IS BASED ON TOTAL WEIGHT
** NOTE: VMA of this Mix Design 16.2%
Absorption: 0-1.2 low, 1.2-2.0 moderate, 2.0 and above high

This aggregate has MODERATE absorption.
REMARKS:

0:214/MT-306/I1

Lab. Form No. 606
(Rev. 1/20/87)

STATE OF MONTANA
DEPARTMENT OF HIGHWAY
Material Bureau

3/4" PLANT MIX SURFACING, GRADE B
PLANT MIX BASE, GRADE
ROAD MIX SURFACING, GRADE

Lab. No. 616530 Sample No. Project No. F SRF HES 1-2(37)9 / RTF SRF HES 1-2(35

Termini Kila E&W & Marion West

Date Sampled 10/21/87 Date Received 10/22/87

Sampled by R. French Title ALMS Address Kalispell

Submitted by " Title " Address "

Area Source Represented by Lab. No. 580038-47 Sample taken at

Owner David Klehm Address Kalispell, Mont.

TEST RESULTS ON AGGREGATE

	% Passing As Received	% Passing As Tested
1-½"		
1"		
3/4"	100	100
1/2"	84	86
3/8"	64	75
4M	41	53
10M	31	36
40M	12	16
80M		
200M	6.8	8.0

LL NP PL NP PI NP Dust Ratio ____ Fracture 70
Wear 24 % Degradation ____ Sand Equiv. 46
** Absorption Cs 1.95 % Fine 1.45 % Blend 1.65

Bulk Dry Sp. Gr. of Agg. Fine 2.630 Coarse 2.594

VOLUME SWELL RESULTS

3.2 % No. Treat. HARD; 2.9 % 1.5% Hyd. Lime HARD; 3.7 % 1.5% Fly Ash FIRM
% 1.5% Cement ____ %

1990 ADT 1400
2010 ADT 2100
18K 103

Recommended: 5.6 % 85/100 A/C; 1.5 % HYDRATED LIME

TEST RESULTS ON TRIAL BITUMINOUS MIXES Refinery MRC
Marshall Results

Mineral Filler %	Mineral Filler Type	% Asphalt	Rice Gravity	Density (Gm/cc)	% Voids	Lb. Stability	Flow	Appearance
	NONE	5.0	2.455	2.374	3.3	2266	11	NORMAL
		5.5	2.441	2.398	1.8	2235	12	
		6.0	2.427	2.399	1.2	2003	14	SLIGHTLY RIC
1.5	HYD. LIME	5.0	2.455	2.362	3.8	2392	11	NORMAL
		5.5	2.441	2.372	2.8	2431	14	
		5.6	2.438	2.377	2.5	2397	14	INTERPOLATE
		6.0	2.427	2.395	1.3	2262	17	NORMAL
1.5	FLY ASH	5.0	2.455	2.387	2.8	2184	12	
		5.5	2.441	2.405	1.5	2093	12	
		6.0	2.427	2.404	0.9	1703	16	

IMMERSION COMPRESSION RESULTS

Mineral Filler %	Filler Type	Percent Asphalt	Dry Break psi	Wet Break psi	Retained Strength
--	NONE	5.0	291.3	172.7	59.3 %
1.5%	FLY ASH	5.2	264.2	196.6	74.4 %
1.5%	HYD.LIME	5.2	290.5	225.2	77.5 %
1.5%	HYD. LIME	5.6	337.4	265.8	78.8 %
--	NONE	5.25	297.6	151.2	50.8 %

ADHESION RESULTS

%	Adhesive Agent	Adhesion
--	NONE	75
1.5%	FLY ASH	80
1.5%	HYD.LIME	85

~~Admin. Maintenance Div.~~
2 District Engineer Missoula
1 Dist. Mat. Supr. Missoula
1 Area Lab Kalispell
1 Chief Const. Bureau
1 Chief Materials Bureau
1 Surfacing Design Sect.
2 Bit. Mix Design Sect.
1 FHWA
1 Materials Bureau File
1 HILDE CONSTRUCTION CO

	DATE	NAME
CHECKED	11/2/87	MFL

** NOTE: VMA of this Mix Design 13.8 %
Absorption: 0-1.2 low, 1.2-2.0 moderate, 2.0 and above high

This aggregate has MODERATE absorption.
REMARKS: Discussed with John Haylruth by B at an earlier date.

[signature]
Chief, Materials Bureau
Dated

Lab. Form No. 606
(Rev. 1/20/87)

0:214/MT-306/11

STATE OF MONTANA
DEPARTMENT OF HIGHWAY
Material Bureau

3/4" PLANT MIX SURFACING, GRADE B
____ PLANT MIX BASE, GRADE ____
____ ROAD MIX SURFACING, GRADE ____

Lab. No. 609836 Sample No. ____ Project No. RS 438-1(4)0
Termini Nashua-North
Date Sampled 6/4/87 Date Received JUN 11 1987
Sampled by Cahill Title DMS Address Glendive
Submitted by " Title " Address "
Area Source Represented by Lab. No. 593720-26 Sample taken at ____
Owner William Lauckner Address Nashua

TEST RESULTS ON AGGREGATE

	% Passing As Received	% Passing As Tested
1-½"		
1"		
3/4"	100	100
1/2"	92	92
3/8"	76	77
4M	50	52
10M	34	36
40M	23	21
80M		
200M	4.3	5.0

LL NP PL NP PI NP Dust Ratio ____ Fracture 86
Wear 16 % Degradation ____ Sand Equiv. 53
** Absorption Cs 0.81 % Fine 1.39 % Blend 1.03

Bulk Dry Sp. Gr. of Agg. Fine 2.592 Coarse 2.596

VOLUME SWELL RESULTS

4.2 % No. Treat. FIRM; 2.7 % 1.5% Hyd. Lime HARD; 3.6 % 1.5% Fly Ash FIRM
____ % 1.5% Cement ____ %

1988 ADT 220
2008 ADT 320
18K 5.8

Recommended: 6.1 % 120/150 A/C; ____ % NONE

TEST RESULTS ON TRIAL BITUMINOUS MIXES
Marshall Results

Refinery EXXON

Mineral Filler %	Type	% Asphalt	Rice Gravity	Density (Gm/cc)	% Voids	Lb. Stability	Flow	Appearance
	NONE	5.5	2.431	2.316	4.7	1275	7	SLIGHTLY RICH
		6.0	2.416	2.327	3.7	1251	7	/
		6.5	2.401	2.342	2.5	1363	10	RICH
		6.1	2.413	2.330	3.4	1273	8	INTERPOLATED
1.5	HYD. LIME	5.0	2.446	2.323	5.0	1300	8	NORMAL
		5.5	2.431	2.341	3.7	1388	8	/
		6.0	2.416	2.356	2.5	1425	10	SLIGHTLY RICH
1.5	FLY ASH	5.0	2.446	2.314	5.4	1075	7	NORMAL
		5.5	2.431	2.340	3.7	1272	8	/
		6.0	2.416	2.346	2.9	1238	9	SLIGHTLY RICH

IMMERSION COMPRESSION RESULTS

Mineral Filler %	Type	Percent Asphalt	Dry Break psi	Wet Break psi	Retained Strength
--	NONE	6.25	147.2	113.8	77.3 %
1.5%	FLY ASH	5.6	166.3	144.8	87.1 %
1.5%	HYD.LIME	5.6	195.8	165.5	84.5 %
					%
					%

ADHESION RESULTS

%	Adhesive Agent	Adhesion
--	NONE	70
1.5%	FLY ASH	75
1.5%	HYD.LIME	80

2 District Engineer GLENDIVE
1 Dist. Mat. Supr. GLENDIVE
1 Area Lab WOLF POINT
1 Chief Const. Bureau
1 Chief Materials Bureau
1 Surfacing Design Sect.
2 Bit. Mix Design Sect.
1 FHWA
1 Materials Bureau File

** NOTE: VMA of this Mix Design 15.3
Absorption: 0-1.2 low, 1.2-2.0 moderate,
2.0 and above high

This aggregate has LOW absorption.
REMARKS:
Discussed with John [illegible] 6-19-87

CHECKED DATE 6/19/87 NAME [illegible]

Chief, Materials Bureau
Dated [illegible]

Lab. Form No. 606
(Rev. 1/20/87)

STATE OF MONTANA
DEPARTMENT OF HIGHWAY
Material Bureau

3/4" PLANT MIX SURFACING, GRADE B
PLANT MIX BASE, GRADE
ROAD MIX SURFACING, GRADE

Lab. No. 613076 Sample No. 2 Project No. F BRF 4-1(5)26
Termini Bridger-Fromberg
Date Sampled 7/31/87 Date Received 8-4-87
Sampled by Neumiller Title DMS Address Billings
Submitted by " Title " Address "
Area Source Represented by Lab. No. 606811-12 Sample taken at
Owner U.S.A.(Farmers Home Admin.) Address Red Lodge, Mont.

TEST RESULTS ON AGGREGATE

	% Passing As Received	% Passing As Tested
1-½"		
1"		
3/4"	100	100
1/2"	91	90
3/8"	77	77
4M	53	53
10M	39	39
40M	19	18
80M		
200M	4.6	6.0

LL NP PL NP PI NP Dust Ratio Fracture 24
Wear 80 % Degradation Sand Equiv. 59
** Absorption Cs 1.61 % Fine 1.30 % Blend 1.43

Bulk Dry Sp. Gr. of Agg. Fine 2.599 Coarse 2.641

VOLUME SWELL RESULTS

No. Treat. 3.0 % HARD; 1.5% Hyd. Lime 2.2 % HARD; 1.5% Fly Ash 2.5 % HARD
1.5% Cement %

1987 ADT 2370
2007 ADT 3150
18K 260

Recommended: 5.7 % 85/100 A/C; 1.5 % Hydrated Lim

TEST RESULTS ON TRIAL BITUMINOUS MIXES Refinery Conoco
Marshall Results

Mineral Filler %	Type	% Asphalt	Rice Gravity	Density (Gm/cc)	% Voids	Lb. Stability	Flow	Appearance
	NONE	5.5	2.469	2.357	4.5	1625	9	NORMAL
		6.0	2.451	2.363	3.6	1638	9	
		6.5	2.433	2.366	2.8	1716	8	SLIGHTLY RI
1.5	HYD. LIME	5.0	2.487	2.350	5.5	1924	9	NORMAL
		5.5	2.469	2.372	3.9	1846	10	
		5.7	2.462	2.378	3.4	1960	10	INTERPOLATE
		6.0	2.451	2.388	2.6	2132	10	SLIGHTLY RIC
1.5	FLY ASH	5.0	2.487	2.346	5.7	1391	8	NORMAL
		5.5	2.469	2.361	4.4	1354	9	
		6.0	2.451	2.379	2.9	1820	10	SLIGHTLY RI

IMMERSION COMPRESSION RESULTS

Mineral Filler %	Type	Percent Asphalt	Dry Break psi	Wet Break psi	Retained Strength
--	NONE	6.0	270.6	112.2	41.5 %
1.5%	FLY ASH	5.7	344.6	178.3	51.7 %
1.5%	HYD.LIME	5.7	320.7	205.3	64.0 %
					%
					%

ADHESION RESULTS

%	Adhesive Agent	Adhesic
--	NONE	70
1.5%	FLY ASH	75
1.5%	HYD.LIME	85

2 District Engineer Billings
1 Dist. Mat. Supr. Billings
Area Lab
1 Chief Const. Bureau
1 Chief Materials Bureau
1 Surfacing Design Sect.
2 Bit. Mix Design Sect.
1 FHWA
1 Materials Bureau File

** NOTE: VMA of this Mix Design 13.9
Absorption: 0-1.2 low, 1.2-2.0 moderate, 2.0 and above high

This aggregate has MODERATE absorption.
REMARKS:
Discussed with John Maykuth by DJD

DATE	NAME
CHECKED 8/27/87	RJB

Chief, Materials Bureau
Dated

Lab. Form No. 606
(Rev. 1/20/87)

STATE OF MONTANA
DEPARTMENT OF HIGHWAY
Material Bureau

3/4" PLANT MIX SURFACING, GRADE B
PLANT MIX BASE, GRADE
ROAD MIX SURFACING, GRADE

Lab. No. 614026 Sample No. 1 Project No. F HES 3-4-11)99
Termini Three Forks-North
Date Sampled 8/20/87 Date Received 8/24/87
Sampled by Yarnall-Deighton Title DMS/MLS II Address Butte/Bozeman
Submitted by Yarnall Title DMS Address Butte
Area Source Represented by Lab. No. 608074-84 Sample taken at
Owner Patricia Woods Estate Address Bozeman, Mont.

TEST RESULTS ON AGGREGATE

	% Passing As Received	% Passing As Tested
1-½"		
1"		
3/4"	100	100
1/2"	82	86
3/8"	70	75
4M	52	53
10M	37	37
40M	21	18
80M		
200M	6.6	6.5

LL NP PL NP PI NP Dust Ratio ____ Fracture 80
Wear 20 % Degradation ____ Sand Equiv. 54
** Absorption Cs 0.79 % Fine 1.16 % Blend 0.95

Bulk Dry Sp. Gr. of Agg. Fine 2.613 Coarse 2.636

VOLUME SWELL RESULTS

3.3 %	2.6 %	3.2
No. Treat. HARD	1.5% Hyd. Lime HARD	1.5% Fly Ash HARD
1.5% Cement ____ %		

1986 ADT 1700
2006 ADT 2900
18K 105

Recommended: 5.6 % 85/100 A/C; – %

TEST RESULTS ON TRIAL BITUMINOUS MIXES
Marshall Results

Refinery EXXON

Mineral Filler %	Type	% Asphalt	Rice Gravity	Density (Gm/cc)	% Voids	Lb. Stability	Flow	Appearance
	None	5.0	2.473	2.346	5.1	2197	9	Normal
		5.5	2.451	2.360	3.7	1768	9	
		6.0	2.429	2.372	2.3	2048	10	
		5.6	2.446	2.363	3.4	1824	10	Interpolated
1.5	Hyd. Lime	5.0	2.473	2.353	4.9	2028	10	Normal
		5.5	2.451	2.381	2.9	1859	10	
		6.0	2.429	2.399	1.2	2015	12	
	Fly Ash	5.0	2.473	2.354	4.8	1963	9	
		5.5	2.451	2.371	3.3	1820	11	
		6.0	2.429	2.388	1.7	1963	11	

IMMERSION COMPRESSION RESULTS

Mineral Filler %	Type	Percent Asphalt	Dry Break psi	Wet Break psi	Retained Strength
--	NONE	5.6	190.2	184.6	97.1 %
1.5%	FLY ASH	5.5	226.1	220.5	97.6 %
1.5%	HYD.LIME	5.4	274.6	259.5	94.6 %
					%
					%

ADHESION RESULTS

%	Adhesive Agent	Adhesio
--	NONE	75
1.5%	FLY ASH	80
1.5%	HYD.LIME	85

~~Administrative Div.~~
2 District Engineer GLENDIVE
1 Dist. Mat. Supr. GLENDIVE
Area Lab –
Chief Const. Bureau
1 Chief Materials Bureau
1 Surfacing Design Sect.
2 Bit. Mix Design Sect.
1 FHWA
1 Materials Bureau File

** NOTE: VMA of this Mix Design 14.8
Absorption: 0-1.2 low, 1.2-2.0 moderate, 2.0 and above high

This aggregate has LOW absorption.

REMARKS:
Discussed with John Maykuth by AJB

Chief, Materials [illegible]
Dated [illegible]

CHECKED DATE 9/22/87 NAME MFL

Lab. Form No. 606
(Rev. 1/20/87)

STATE OF MONTANA
DEPARTMENT OF HIGHWAY
Material Bureau

3/4" PLANT MIX SURFACING, GRADE B
PLANT MIX BASE, GRADE ____
ROAD MIX SURFACING, GRADE ____

Lab. No. 614645 Sample No. ____ Project No. RRS 10-2(14)71
Termini Big Sandy Railroad Overpass-Bypass
Date Sampled 09/03/87 Date Received 9/8/87
Sampled by J Brummer Title ALS II Address Havre
Submitted by L Powell Title DMS Address Gt. Falls
Area Source Represented by Lab. No. 580286-97 Sample taken at ____
Owner George Schlack Address Big Sandy, Mont.

TEST RESULTS ON AGGREGATE

	% Passing As Received	% Passing As Tested
1-½"		
1"		
3/4"	100	100
1/2"	96	90
3/8"	78	78
4M	47	53
10M	35	38
40M	18	18
80M	9	
200M	6.1	7.0

LL NP PL NP PI NP Dust Ratio ____ Fracture 81 %
Wear 27 % Degradation ____ Sand Equiv. 36
** Absorption Cs 1.57 % Fine 1.84 % Blend 1.70

Bulk Dry Sp. Gr. of Agg. Fine 2.580 Coarse 2.585

VOLUME SWELL RESULTS

No. Treat. 6.9 % FIRM; 1.5% Hyd. Lime 5.1 % FIRM; 1.5% Fly Ash 5.3 FIRM
1.5% Cement ____ % ____

1984 ADT 1145
2004 ADT 1600
18K 46.7

Recommended: 5.75 % 85/100 A/C; 1.5 % HYDRATED LIME

TEST RESULTS ON TRIAL BITUMINOUS MIXES Refinery MRC
Marshall Results

Mineral Filler %	Mineral Filler Type	% Asphalt	Rice Gravity	Density (Gm/cc)	% Voids	Lb. Stability	Flow	Appearance
	NONE	5.5	2.434	2.302	5.4	1560	9	NORMAL
		6.0	2.416	2.323	3.8	1976	11	
		6.5	2.398	2.336	2.6	1937	10	SLIGHTLY RICH
1.5	HYD. LIME	5.0	2.452	2.320	5.4	1911	10	NORMAL
		5.5	2.434	2.326	4.4	2015	9	
		5.75	2.425	2.338	3.6	2028	10	INTERPOLATED
		6.0	2.416	2.350	2.7	2041	10	SLIGHTLY RICH
1.5	FLY ASH	5.0	2.452	2.323	5.3	1495	10	NORMAL
		5.5	2.434	2.325	4.5	1573	9	
		6.0	2.416	2.341	3.1	1703	9	

IMMERSION COMPRESSION RESULTS

Mineral Filler %	Mineral Filler Type	Percent Asphalt	Dry Break psi	Wet Break psi	Retained Strength
--	NONE	6.1	218.1	118.6	54.4 %
1.5%	FLY ASH	5.9	233.2	183.9	78.9 %
1.5%	HYD.LIME	5.75	269.8	224.5	83.3 %
					%
					%

ADHESION RESULTS

%	Adhesive Agent	Adhesion
--	NONE	75 %
1.5%	FLY ASH	80 %
1.5%	HYD.LIME	85 %
		%
		%

~~Admin. Maint. Div.~~
2 District Engineer GREAT FALLS
1 Dist. Mat. Supr. GREAT FALLS
1 Area Lab HAVRE
1 Chief Const. Bureau
1 Chief Materials Bureau
1 Surfacing Design Sect.
2 Bit. Mix Design Sect.
1 FHWA
1 Materials Bureau File

** NOTE: VMA of this Mix Design 14.2 %
Absorption: 0-1.2 low, 1.2-2.0 moderate, 2.0 and above high

This aggregate has MODERATE absorption.
REMARKS:
Discussed with John Maykuth by BJB

	DATE	NAME
CHECKED	9/16/87	DFL

Chief, Materials Bureau
Dated ____

Lab. Form No. 606
(Rev. 1/20/87)

0:214/MT-306/11

STATE OF MONTANA
DEPARTMENT OF HIGHWAY
Material Bureau

3/4 PLANT MIX SURFACING, GRADE B
____ PLANT MIX BASE, GRADE ____
____ ROAD MIX SURFACING, GRADE ____

Lab. No. 612289 Sample No. 2 Project No. F-HES 26-2(3)29
Termini Klein-South
Date Sampled 7-27-87 Date Received 7-28-87
Sampled by K Neumiller Title DMS Address Billings
Submitted by " Title " Address "
Area Source Represented by Lab. No. 591479-591489 Sample taken at Stockpile
Owner Bill Michaels Address ____

TEST RESULTS ON AGGREGATE

	% Passing As Received	% Passing As Tested
1-½"		
1"		
3/4"	100	100
1/2"	90	90
3/8"	75	75
4M	51	53
10M	37	37
40M	21	18
80M		
200M	5.2	6.0

LL NP PL NP PI NP Dust Ratio ____ Fracture 83
Wear 19 % Degradation ____ Sand Equiv. 63
** Absorption Cs 1.10 % Fine 1.72 % Blend 1.36

Bulk Dry Sp. Gr. of Agg. Fine 2.592 Coarse 2.639

VOLUME SWELL RESULTS

No. Treat. 2.2 % HARD; 1.5% Hyd. Lime 1.6 % HARD; 1.5% Fly Ash 1.9 HARD
1.5% Cement ____ % ____ % ____

1986 ADT 1560
2006 ADT 2000
18K 110

Recommended: 5.6 % 85/100 A/C; 1.5 % HYDRATED LIME

TEST RESULTS ON TRIAL BITUMINOUS MIXES
Marshall Results

Refinery CENEX

Mineral Filler %	Mineral Filler Type	% Asphalt	Rice Gravity	Density (Gm/cc)	% Voids	Lb. Stability	Flow	Appearance
	NONE	5.5	2.454	2.337	4.8	1788	10	NORMAL
		6.0	2.432	2.347	3.5	1807	11	
		6.5	2.410	2.366	1.8	1872	11	SLIGHTLY RICH
1.5	HYD. LIME	5.5	2.454	2.360	3.8	1888	10	NORMAL
		5.6	2.450	2.363	3.6	1880	10	INTERPOLATED
		6.0	2.432	2.373	2.4	1846	11	NORMAL
		6.5	2.410	2.383	1.1	2132	13	SLIGHTLY RICH
1.5	FLY ASH	5.5	2.454	2.336	5.7	1748	10	NORMAL
		6.0	2.432	2.362	3.7	1861	10	
		6.5	2.410	2.403	0.3	2366	10	SLIGHTLY RICH

IMMERSION COMPRESSION RESULTS

Mineral Filler %	Mineral Filler Type	Percent Asphalt	Dry Break psi	Wet Break psi	Retained Strength
--	NONE	6.0	246.7	159.2	64.5 %
1.5%	FLY ASH	5.6	335.8	211.7	63.0 %
1.5%	HYD.LIME	5.6	327.9	266.6	81.3 %
					%
					%

ADHESION RESULTS

%	Adhesive Agent	Adhesion
--	NONE	80 %
1.5%	FLY ASH	80 %
1.5%	HYD.LIME	85 %
		%
		%

2 District Engineer Billings
1 Dist. Mat. Supr. Billings
Area Lab ——
1 Chief Const. Bureau
1 Chief Materials Bureau
1 Surfacing Design Sect.
2 Bit. Mix Design Sect.
1 FHWA
1 Materials Bureau File

** NOTE: VMA of this Mix Design 14.4
Absorption: 0-1.2 low, 1.2-2.0 moderate, 2.0 and above high

This aggregate has MODERATE absorption.
REMARKS:
Discussed w/John Mykeltis; Bob Thelt
8-5-87

CHECKED DATE 8/5/87 TYPE MFL

Chief, Materials Bureau
Dated

Lab. Form No. 606
(Rev. 1/20/87)

STATE OF MONTANA
DEPARTMENT OF HIGHWAY
Material Bureau

3/4" PLANT MIX SURFACING, GRADE B
PLANT MIX BASE, GRADE
ROAD MIX SURFACING, GRADE

Lab. No. 607974 Sample No. 1 Project No. F BES 18-1(2)1
Termini Miles City-NW
Date Sampled 4/10/87 Date Received APR 14 1987
Sampled by Peaslee Title LT III Address Miles City
Submitted by Jackman Title LS II Address "
Area Source Represented by Lab. No. 606045-53 Sample taken at
Owner Eckart Construction Address Miles City, Mt.

TEST RESULTS ON AGGREGATE

	% Passing As Received	% Passing As Tested
1-½"		
1"		
3/4"	100	100
1/2"	90	90
3/8"	75	77
4M	55	56
10M	33	34
40M	16	17
80M		
200M	4.8	6.0

LL NP PL NP PI NP Dust Ratio ____ Fracture 89 %
Wear 18 % Degradation ____ Sand Equiv. 85
** Absorption Cs 1.54 % Fine 2.02 % Blend 1.78 %

Bulk Dry Sp. Gr. of Agg. Fine 2.543 Coarse 2.563

VOLUME SWELL RESULTS

No. Treat. 2.5 % HARD ; 1.5% Hyd. Lime 1.8 % HARD ; 1.5% Fly Ash 1.4 % HARD
1.5% Cement ____ %

1986 ADT 1091
2006 ADT 1700
18K 46.8

Recommended: 6.5 % AC-10 A/C; NO %

TEST RESULTS ON TRIAL BITUMINOUS MIXES
Marshall Results

Refinery Asphalt Supply

Mineral Filler %	Mineral Filler Type	% Asphalt	Rice Gravity	Density (Gm/cc)	% Voids	Lb. Stability	Flow	Appearance
	NONE	5.5	2.410	2.276	5.6	1824	14	NORMAL
		6.0	2.395	2.293	4.3	1848	16	
		6.5	2.380	2.294	3.6	2002	17	
1.5	HYD. LIME	5.5	2.410	2.277	5.5	1680	17	
		6.0	2.395	2.284	4.6	1716	19	
		6.5	2.380	2.307	3.1	1908	18	
1.5	FLY ASH	6.0	2.395	2.309	3.6	1723	18	
		6.5	2.380	2.302	3.3	1512	16	
		7.0	2.365	2.327	1.6	1776	23	

IMMERSION COMPRESSION RESULTS

Mineral Filler %	Mineral Filler Type	Percent Asphalt	Dry Break psi	Wet Break psi	Retained Strength
--	NONE	6.5	284.1	251.5	88.5 %
1.5%	FLY ASH	6.4	298.4	248.3	83.2 %
1.5%	HYD.LIME	6.4	350.9	349.4	99.6 %
					%
					%

ADHESION RESULTS

%	Adhesive Agent	Adhesion
--	NONE	75 %
1.5%	FLY ASH	80 %
1.5%	HYD.LIME	85 %
		%
		%

2 District Engineer Glendive
1 Dist. Mat. Supr. Glendive
1 Area Lab Miles City
1 Chief Const. Bureau
1 Chief Materials Bureau
1 Surfacing Design Sec.
2 Bit. Mix Design Sect.
1 FHWA
1 Materials Bureau File

** NOTE: VMA of this Mix Design 15.6
Absorption: 0-1.2 low, 1.2-2.0 moderate, 2.0 and above high

This aggregate has MODERATE absorption.
REMARKS:
Discussed with John Maykuth 5/5/87 BJB

	DATE	NAME
CHECKED	4/24/87	MEE

Chief, Materials Bureau
Dated 5/5/87