# STUDY OF LIME VS. NO LIME IN COLD IN-PLACE RECYCLED ASPHALT CONCRETE PAVEMENTS

**Final Report**

by

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and

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Oregon Department of Transportation

September 1991

Technical Report Documentation Page

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16. Abstract


The resilient characteristics of cold in-place recycled asphalt concrete with and without lime were examined. Six core samples were obtained from a site two months after construction; six months later, six additional core samples were obtained from the site. The samples were tested in the laboratory for resilient modulus.

Conclusions of this study include:

1. The resilient modulus of the recycled mix with lime increased substantially in the early stage, as compared to the recycled mix without lime.
2. The resilient modulus value of the recycled mix with lime after freeze-thaw conditioning was much higher than the recycled mix without lime.
3. Eight months after construction, the resilient modulus of the unconditioned recycled mix with lime was similar to that of the unconditioned recycled mix without lime.

Recommendations of this study include:

1. Further evaluate the potential benefit of adding lime to the recycled mix and investigate the effects of adding different percentages of lime to the recycled mix.
2. Evaluate the effects of adding quick lime compared to hydrated lime to the recycled mix.
3. Appropriate mix design criteria, construction procedures, and field control guidelines should be developed if adding lime to the recycled mix.


| | | | |
|---|---|---|---|
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## ACKNOWLEDGEMENTS

The authors appreciate the cooperation of Tony George (Materials Unit, Oregon State Highway Division) and his staff for conducting the tests in the laboratory. In addition, the authors are grateful for Tony George, Dale Allen (Oregon State Highway Division), and Dave Rogge (Oregon State University) for their review of this report. Furthermore, the authors thank Stephanie Swetland and Jo Anne Robison for typing this report.

## DISCLAIMER

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# STUDY OF LIME VS. NO LIME IN COLD IN-PLACE RECYCLED ASPHALT CONCRETE PAVEMENTS

## 1.0 INTRODUCTION

In the summer of 1990, a six-mile section of pavement on the Central Oregon Highway, as part of the Arnold Cave - Horse Ridge Section project, was recycled using the cold in-place process. The eastbound (EB) lane of this project had lime added to the recycled mix while the westbound (WB) lane was recycled without the use of lime.

To investigate the possible benefits of adding lime to the cold in-place recycled (CIR) mix, Region 4 and the Research Unit of the Oregon State Highway Division (OSHD) conducted a mini-study on the recycled mix with and without lime. The focus of this study was on the resilient characteristics of the recycled mix with and without lime.

This report documents the initial findings from the laboratory tests on limited core samples.

## 2.0 PROJECT DESCRIPTION

### 2.1 Pavement Condition

This section of pavement was constructed in the mid-1970's. The existing pavement condition (1990) was poor with an average of 3/4" rutting and severe fatigue cracking in all four wheelpaths (Appendix A).

### 2.2 Traffic Condition

This section of highway received an average daily traffic (ADT) of 1,000, of which 23% was truck traffic, based on the 1988 traffic data assembled by the Pavements Unit of the OSHD.

## 3.0 PROJECT EVALUATION

### 3.1 Core Samples

A total of twelve core samples were obtained and tested in the laboratory for resilient modulus. Six of the twelve cores were obtained approximately two months after construction while another six cores were obtained approximately eight months after construction. For each batch of six samples, three had lime and three had no lime.

### 3.2 Lime Used

Two percent of quick lime was added to the recycled mix.

### 3.3 Recycle Agent

For this study, pavement cores with a 0.4% CMS-2S recycle agent were evaluated.

### 3.4 Resilient Modulus Tests

The core samples were tested for resilient modulus in accordance with the ASTM D4123 procedure. For each sample, the resilient modulus before and after freeze-thaw conditioning was measured. Then, the Index of Retained Modulus (IRM) was calculated. Table 1 summarizes the test results on cores that were obtained two months after construction. Table 2 presents a summary of test results on cores that were obtained eight months after construction. The test results are also plotted in Figure 1. Detailed test results are included in Appendix B.

Table 1. Summary of Test Results on Cores Obtained
Two Months after Construction

| Sample I.D. | Location | Lift (Top, in) | Resilient Modulus (psi) | | IRM (%) |
|---|---|---|---|---|---|
| | | | Unconditioned | F-T Conditioned | |
| a) Without Lime | | | | | |
| 1 | MP 16.77 WB | -- | 73,293 | 33,024 | 45 |
| 2 | MP 16.77 WB | -- | 63,049 | 26,258 | 42 |
| 3 | MP 16.77 WB | -- | 57,740 | 20,041 | 35 |
| Average | | | 64,694 | 26,441 | 41 |
| b) With Lime | | | | | |
| 4 | MP 17.50 EB | -- | 159,096 | 90,521 | 57 |
| 5 | MP 17.50 EB | -- | 149,816 | 86,154 | 58 |
| 6 | MP 17.50 EB | -- | 158,125 | 91,942 | 58 |
| Average | | | 155,679 | 89,539 | 58 |

Note: At the time of testing, the mix had 0.4% CMS-2S and 1.3% water.

Table 2. Summary of Test Results on Cores Obtained
Eight Months after Construction

| Sample I.D. | Location | Lift (Top, in) | Resilient Modulus (psi) | | IRM (%) |
|---|---|---|---|---|---|
| | | | Unconditioned | F-T Conditioned | |
| a) Without Lime | | | | | |
| 1 | MP 16.75 WB | 2.0 | 206,750 | 19,570 | 9 |
| 2 | MP 16.75 WB | 2.3 | 235,420 | 27,420 | 12 |
| 3 | MP 16.75 WB | 2.2 | 221,380 | 27,720 | 13 |
| Average | | | 221,183 | 24,903 | 11 |
| b) With Lime | | | | | |
| 4 | MP 17.50 EB | 1.7 | 187,000 | 110,110 | 54 |
| 5 | MP 17.50 EB | 1.9 | 180,350 | 110,520 | 61 |
| 6 | MP 17.50 EB | 1.6 | 222,640 | 118,620 | 53 |
| Average | | | 196,663 | 113,083 | 56 |

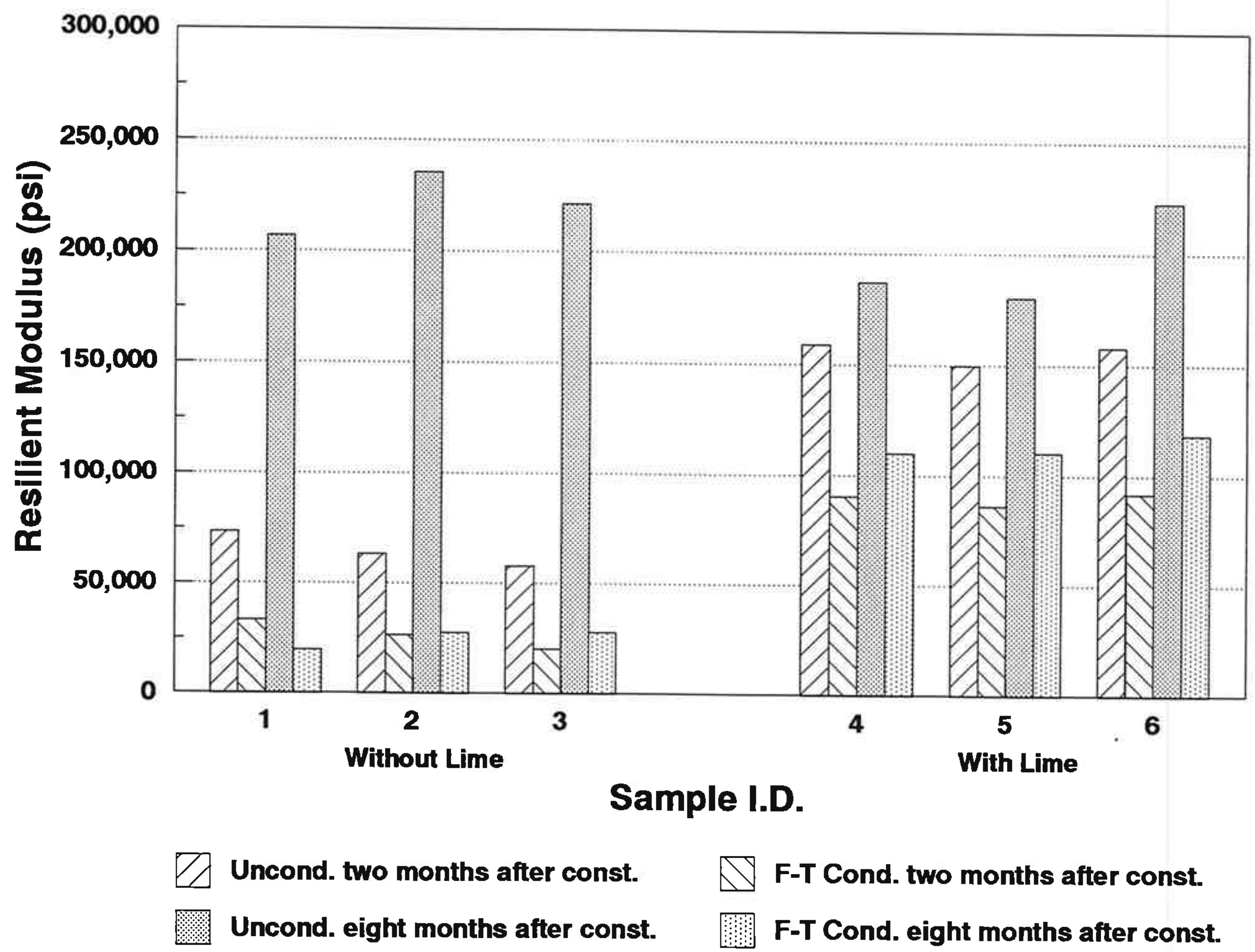


Figure 1 Resilient Modulus Test Results

## 3.5 Discussion of Test Results

Laboratory tests were conducted on recycled mix cores obtained two months after construction and the following is a discussion of the results. Laboratory test results on unconditioned core samples indicate that the resilient modulus of recycled mix with lime was approximately 140% greater than the resilient modulus of recycled mix without lime. Laboratory test results on freeze-thaw conditioned core samples indicated that the resilient modulus of the recycled mix with lime is also significantly higher than that of the recycled mix without lime. These characteristics may indicate that adding lime to the recycled mix may accelerate curing time and strength build-up.

Laboratory tests were also conducted on recycled mix cores obtained eight months after construction and the following is a discussion of the results. Laboratory test results on unconditioned core samples indicated that the resilient modulus for both mixes increased significantly with time, but the average resilient modulus value of the recycled mix with lime is similar to or slightly lower than that of the recycled mix without lime. This may indicate that the resilient modulus for both mixes would be the same after a period of time. However, laboratory test results on the freeze-thaw conditioned core samples indicated that the resilient modulus of the recycled mix with lime is significantly higher than that of the recycled mix without lime. This characteristic may indicate that adding lime to the recycled mix may improve its resistance to freeze-thaw damage.

## 4.0 CONCLUSIONS AND RECOMMENDATIONS

### 4.1 Conclusions

1. For recycled mix core samples obtained two months after construction, the resilient modulus of the recycled mix with lime had a substantially higher resilient modulus compared to the recycled mix without lime. This may indicate that the added lime accelerated curing time and strength gain.
2. For recycled mix core samples obtained two and eight months after construction, the resilient modulus values of the recycled mix with lime after freeze-thaw conditioning were much higher than those of the recycled mix without lime. This may indicate that the recycled mix with lime have improved resistance to freeze-thaw damage compared to the recycled mix without lime.
3. For unconditioned recycled mix core samples obtained eight months after construction, the resilient moduli of both mixes are significantly higher than those two months after construction. However, eight months after construction, the average resilient modulus for each mix is similar. This may indicate the recycled mix with lime may not continue to increase its strength with time.

### 4.2 Recommendations

1. Further evaluate the potential benefits of adding lime to the recycled mix and investigate the effects of adding different quantities of lime to the recycled mix.
2. Evaluate the effects of adding quick lime compared to hydrated lime to the recycled mix.
3. Appropriate mix design criteria, construction procedures, and field control guidelines should be developed if adding lime to the recycled mix.

# APPENDIX A

## Correspondences

Oregon Department of Transportation
HIGHWAY DIVISION

# LABORATORY RECORD

| | |
|---|---|
| LABORATORY NO. | 10143 |
| PROJECT | Arnold Ice Caves - Horse Ridge |
| DATA SHEET NO. | A-30162 |
| HIGHWAY | Central OR |
| COUNTY | Deschutes |
| EXP. ACCT. SUB JOB | M009-4402-000-119 |
| CONTRACTOR | |
| F.A. PROJECT NO. | None |
| BID ITEM NO. | |
| PROJECT MANAGER | Dale Allen |
| AGY.—ORG. UNIT | 02-4000 |
| DATE RECEIVED | 5-15-91 |
| DATE REPORTED | 8-19-91 |
| SUBMITTED BY | Ron Shartner |
| AGY.-ORG. UNIT | 02-4061 |
| TEST NO. | 3-315B |
| VAR | |
| LAB CHARGE | $249.00 |
| SOURCE OF MATERIAL | M.P. 17.5 EB |
| QUANTITY REPRESENTED | |
| SAMPLED AT | M.P. 17.5 EB |
| SAMPLED BY | R. Shartner |
| TO BE USED | Pavement Evaluation |
| DATE SAMPLED | 5-13-91 |

| Core No. | #1 | #2 | #3 |
|---|---|---|---|
| Location | MP 17.5 EB | MP 17.5 EB | MP 17.5 EB |
| Lift | Top 1.7" | Top 1.9" | Top 1.6" |
| Unconditioned Mr | 187,000 | 180,350 | 222,640 |
| Freeze-Thaw conditioned Mr | 100,110 | 110,520 | 118,620 |
| Index of Retained Mr | 54% | 61% | 53% |

RECEIVED
AUG 19 1991
RESEARCH UNIT

DISTRIBUTION
X Files
X Project Manager — REG 4 - RON SHARTNER
Contractor
Region Engineer
X Region Assurance Specialist — 4
Region Geologist
Materials - Portland
Materials - Eugene
X RESEARCH
X BIT MIX
X BILLQUINN

NOTE: Material represented by this sample ~~does, does not comply with specifications.~~ For information only.

W. J. Quinn
Engineer of Materials

734-3069 (5-88)

STATE OF OREGON

INTEROFFICE MEMO

TO: Tony George
Roadway Materials Engineer

DATE: November 8, 1990

NOTED
Tony George

FROM: Dale D. Allen
Region Engineer

Neil
Dick AD FYI

SUBJECT: US 20
CIR Lime Study

This is to confirm our discussion on the scope of the above study and provide a little background data.

Purpose of Study: Does the addition of 2% lime improve the quality of CIR mixes and accelerate the strength development (curing). If the answer is positive to both questions, then we would consider greater use of lime in CIR projects in 1991.

Section Tested: This section of US 20 (MP 13.3-17.5) was an excellent old FLH project built in the mid-1970's (1975/76), Arnold Ice Caves-Horse Ridge Section. Rutting to one inch (3/4 average) and continuous fatigue cracking in all four wheel paths was the mode of failure.

Lime Used: 2% of quick lime was placed in EB lane for the entire 4 miles. (MP 13.33-17.51)

No Lime: No lime was used when the single-unit recycle unit turned around (at Horse Ridge) and headed west. Therefore, the WB lane has no lime.

Recycle Agents Used:

EB (2% Lime) - MP 13.3-14.8 used 0.7 to 0.9% HFE 200 w/lime
MP 14.8-16.8 used 0.6% HFE 200 w/lime
MP 15.8-17.5 used 0.4% CMS-2S w/lime

WB (No lime) - MP 14.1-15.5 used 0.2 to 0.3% CMS-2S
MP 15.5-16.73 used 0.4% CMS-2S
MP 17.5-17.4 used 0.5% CMS-2S

Core Location: To obtain similar sections, the cores with lime were cut in the EB lane at MP 17.51. (0.4% CMS-2S) The WB lane (w/o lime) had cores cut at MP 16.73 (0.4% CMS-2S). Three four-inch cores cut at both locations.

25-1387

Observation of Cores: (November 8, 1990) - On this date, I observed the above 6 cores and the 3 cores cut in the lime section look excellent and did not break at the contact point. (At 2-inch depth) These will be sent to Salem today.

On the other hand, the cores broke when being cut in the sections w/o lime and after trimming would be less than 1½ inches. I asked Ron Shartner to re-core and try to obtain 3 full-depth cores which you can trim to 2 inches.

The above observation clearly indicates some degree of improvement using lime. It appears the lime is accelerating the cure and strength gain.

Lab Samples: You should have lab samples requested by Dick Nelson this Spring, which provide the properties of the pavement before CIR. He sent in millings at MP 13, 14, 15, 16, 17, and 18.

DA:mr

Bill Quiros

# Oregon

August 20, 1991

| | | | | | |
|---|---|---|---|---|---|
| CMR | BQ | MUE | | CON | |
| ASM | | RME | | CSS | |
| AA | | SME | | MRD | |
| RUE | | FIS | | PET | |
| OSC | | AGG | | PHY | |
| TSC | | BIT | | SOI | |
| TTC | | CHE | | | |
| TAA File Return to | BQ | | | | |

DEPARTMENT OF TRANSPORTATION

Highway Division
Region 4

FILE CODE:

Dr. David Rogge
Construction-Engineering Project Mgmt.
Dept. of Civil Engineering
Oregon State University
Corvallis, OR 97331

RE: CIR Cores - US 20
Lab No's 10143-44

Attached are the Lab results of the cores on the cold recycle project in which one lane had lime and one lane did not.

I have requested the Materials and Research Section to provide an analysis.

It appears to me that the following conclusions can be drawn from this limited data.

**Unconditioned $M_R$:** The mixture, with and without lime, after 9 months has essentially the same modulus values, 190-200,000. This compares well with previous OSU Research.

**Resistance to freeze-thaw:** There is a significant and substantial improvement in the ability of the mixture with lime to resist freeze-thaw. $M_R$ without lime after freeze/thaw was only 20-27,000. $M_R$ with lime increased to 100-118,000. Likewise, this resulted in an increase Index of Retained $M_R$ from 10% to 55%.

**Conclusion:** It appears that the use of lime at a rate of ±1.5% can produce the following results.

1. Accellerates the curing time and strength build-up. Field observations support this lab finding. Further research is needed to define the curing curve rate. In areas where CIR is performed in late fall or where the CIR will be covered with an overlay in two or three weeks after recycling, this use of lime would seem to be warranted.

2. Lime does not appear to significantly change the strength after one year. Visual examination of cores, however, indicate that the CIR with lime appears to have fewer voids and is more dense. In the long term, you would expect this mixture to have better qualities.



P.O. Box 5309
Bend, OR 97708
FAX (503) 388-6231

3. Lime significantly improves CIR to resist freeze-thaw damage. This is important for several reasons. First, we know that CIR without seals will crack in areas of frequent freeze-thaw. If lime is used, it allows (if necessary) to carry a CIR job through the first winter with a sand seal. The fact that the Highway 20 CIR has not shown freeze-thaw damage seems to support the laboratory results.

I have requested Bill Quinn to follow up with additional research on the I-84 CIR project.

A question I have is whether we could not get equal or better results by introducing the lime as a slurry in front of the mill. This would seem to provide more uniform mixing and control. Also, would slacked vs. quick lime work equally as well without the steam problem? How much lime to use? Very limited data indicates that about 1½% is optimum, but we should do some research on 1%, 1.5%, 2%.

Bill Quinn advised he would meet with Region 4 and develop strategy for additional research.

Dale D. Allen, P.E.
Region Engineer

DA:mr

encl

cc: Gary Hicks
Bill Quinn
Dick Nelson

# APPENDIX B

## Laboratory Test Results

The Oregon Department of Transportation
HIGHWAY DIVISION

# LABORATORY RECORD

| | |
|---|---|
| LABORATORY NO. | 9013575 |
| DATA SHEET NO. | A-30155 |
| PROJECT | ARNOLD ICE CAVE - HORSE RIDGE |
| HIGHWAY | Central Oregon |
| COUNTY | Descutes |
| EXP. ACCT. SUB JOB, ACTIVITY | M009 4402 000 119 |
| CONTRACTOR | - |
| FA PROJECT NO. | None |
| BID ITEM NO. | |
| PROJECT MANAGER | Dale Allen |
| AGY. - ORG. UNIT | 02-4000 |
| DATE RECEIVED | 11-30-90 |
| DATE REPORTED | DEC 24 1990 |
| SUBMITTED BY | RonShartner |
| AGY. - ORG. UNIT | 02-4061 |
| TEST NO. | 3X 302D; 3X 315C |
| VAR. | |
| LAB CHARGE | $57.00; $324.00 |
| SOURCE OF MATERIAL | M.P. 16.77 WB 9' |
| QUANTITY REPRESENTED | |
| SAMPLED AT | MP 16.77 WB 9' |
| SAMPLED BY | R Shartner |
| TO BE USED | Pavement Evaluation |
| DATE SAMPLED | 11-29-90 |

| Core # | 1 | 2 | 3 | |
|---|---|---|---|---|
| Location | MP 16.77 | MP 16.77 | MP 16.77 | |
| Lift | top | top | top | |
| Unconditioned $M_r$ | 73,293 | 63,049 | 57,740 | |
| Freeze - Thaw conditioned $M_r$ | 33,024 | 26,258 | 20,041 | |
| Index of Retained $M_r$ | 45.1 | 41.6 | 34.7 | |

NOTE: At time of mixing the mix had 0.4% CMS-2S and 1.3% H2O. No lime was added. Samples when tested after freeze-thaw were too soft to obtain the proper average microinches of total diametral deformation as specified in OSHD TM 315-90.

The unconditioned $M_R$ is significantly lower than for the cores at M.P. 17.5 EB. The data indicates a difference in the properties of the lime treated vs. non-lime treated pavement, although a direct comparison of the stripping test results is not possible due to the NOTE above. AB

NOTED
Tony George

~~MATERIAL REPRESENTED BY THIS SAMPLE DOES, DOES NOT COMPLY WITH SPECIFICATIONS.~~ AB

X FILES
X RAS-4
X DALE ALLEN
X BIT. MIX

W. J. Quinn
ENGINEER OF MATERIALS

FIELD USE ONLY

| FIELD INSP. NUMBER | BID ITEM NO. | QUANTITY ACCEPTED | TOTAL TO DATE | QUANTITY REJECTED (EXPLAIN) |
|---|---|---|---|---|
| MATERIAL REPRESENTED BY LAB REPORT ABOVE RECEIVED ON JOB, VERIFIED BY | | | INSPECTED BY | DATE |
| ☐ SAMPLE NO. ☐ HT/LOT NO./ROLL NO. ☐ SPEC. NO. MARK ☐ OTHER (EXPLAIN BELOW) | | | | |
| REMARKS | | | | |

The Oregon Department of Transportation
HIGHWAY DIVISION

# LABORATORY RECORD

| | |
|---|---|
| LABORATORY NO. | 9013344 |
| DATA SHEET NO. | A-30154 |
| PROJECT | ARNOLD ICE CAVE - HORSE RIDGE |
| HIGHWAY | Central Oregon |
| COUNTY | Deschutes |
| EXP. ACCT. SUB JOB. ACTIVITY | M0094402-000-119 |
| CONTRACTOR | |
| FA PROJECT NO. | None |
| BID ITEM NO. | |
| PROJECT MANAGER | Dale Allen |
| AGY. - ORG. UNIT | 02-4000 |
| DATE RECEIVED | 11-9-90 |
| DATE REPORTED | DEC 24 1990 |
| SUBMITTED BY | Ron Shartner |
| AGY. - ORG. UNIT | 02-4061 |
| TEST NO. | 3X 302D |
| VAR. | |
| LAB CHARGE | \$57.00 |
| SOURCE OF MATERIAL | M.P. 17.5 EB 4.5' |
| QUANTITY REPRESENTED | 3X 315C |
| LAB CHARGE | \$324.00 |
| SAMPLED AT | M.P. 17.5 EB 4.5' |
| SAMPLED BY | R Shartner |
| TO BE USED | Pavement Evaluation |
| DATE SAMPLED | 10-31-90 |

| Core # | 1 | 2 | 3 |
|---|---|---|---|
| Location | MP 17.5 EB | MP 17.5 EB | MP 17.5 EB |
| Lift | top | top | top |
| Unconditioned $M_r$ | 159,096 | 149,816 | 158,125 |
| Freeze - Thaw conditioned $M_r$ | 90,521 | 86,154 | 91,942 |
| Index of Retained $M_r$ | 56.9 | 57.5 | 58.1 |

NOTE: At time of mixing the mix had 0.4% CMS-2S and 1.3% H2O. Lime was added.

NOTED
Tony George

~~MATERIAL REPRESENTED BY THIS SAMPLE DOES, DOES NOT COMPLY WITH SPECIFICATIONS.~~ AR

X FILES
X RAS-4
X DALE ALLEN
X BIT. MIX

W. J. Quinn
ENGINEER OF MATERIALS

FIELD USE ONLY

| FIELD INSP. NUMBER | BID ITEM NO. | QUANTITY ACCEPTED | TOTAL TO DATE | QUANTITY REJECTED (EXPLAIN) |
|---|---|---|---|---|
| | | | | |

MATERIAL REPRESENTED BY LAB REPORT ABOVE RECEIVED ON JOB. VERIFIED BY

☐ SAMPLE NO. ☐ HT/LOT NO. /ROLL NO. ☐ SPEC. NO. MARK ☐ OTHER (EXPLAIN BELOW)

INSPECTED BY DATE

REMARKS

734-3069 (3-90)

Oregon Department of Transportation
HIGHWAY DIVISION

# LABORATORY RECORD

| | |
|---|---|
| LABORATORY NO. | 10144 |
| DATA SHEET NO. | A-30163 |
| PROJECT | Arnold Ice Caves - Horse Ridge |
| HIGHWAY | Central OR. |
| COUNTY | Deschutes |
| EXP. ACCT. SUB JOB | M 009-4402-000-119 |
| CONTRACTOR | |
| F.A. PROJECT NO. | None |
| BID ITEM NO. | |
| PROJECT MANAGER | Dale Allen |
| AGY.—ORG. UNIT | 02-4000 |
| DATE RECEIVED | 5-15-91 |
| DATE REPORTED | 8-14-91 |
| SUBMITTED BY | Ron Shartner |
| AGY.-ORG. UNIT | 02-4061 |
| TEST NO. | 3-315B |
| VAR | |
| LAB CHARGE | $249.00 |
| SOURCE OF MATERIAL | M.P. 16.75 WB |
| QUANTITY REPRESENTED | |
| SAMPLED AT | M.P. 16.75 WB |
| SAMPLED BY | R. Shartner |
| TO BE USED | Pavement Evaluation |
| DATE SAMPLED | 5-13-91 |

| Core No. | 1 | 2 | 3 |
|---|---|---|---|
| Location | M.P. 16.75 WB | M.P. 16.75 WB | M.P. 16.75 WB |
| Lift | Top 2.0" | Top 2.3" | Top 2.2" |
| Unconditioned Mr | 206,750 | 235,420 | 221,380 |
| Freeze - Thaw conditioned Mr | 19,570 | 27,420 | 27,720 |
| Index of Retained Mr | 9% | 12% | 13% |

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DISTRIBUTION
X Files
X Project Manager — REG 4 - RON SHARTNER
Contractor
Region Engineer
X Region Assurance Specialist — 4
Region Geologist
Materials - Portland
Materials - Eugene
X RESEARCH
X BIT MIX
X BILL QUINN

NOTE: Material represented by this ~~sample does, does not comply with specifications.~~ for information only.

W. J. Quinn
Engineer of Materials

734-3069 (5-86)