PERMEABILITY OF
GRANULAR SUBBASE MATERIALS

Interim Report
for
Project MLR-90-4

September 1991

Project Development Division

Iowa Department of Transportation
Interim Report
for
MLR-90-4

Permeability of
Granular Subbase Materials

by

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Project Development Division
Iowa Department of Transportation
Ames, Iowa 50010

September 1991
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The purpose of this research was to evaluate the materials Iowa uses as a granular subbase and to determine if it provides adequate drainage.

Numerous laboratory and in-situ tests were conducted on the materials currently being used in Iowa. The following conclusions can be made based on the test results:

1. The crushed concrete that is used as a subbase material has a relatively low permeability compared to many other materials used by other states.

2. Further research and tests are needed to find the necessary parameters for crushed concrete to make sure it is providing its optimum drainage and preventing premature damage of the pavement.

3. We have definitely made improvements in drainage in the past few months, but there are many areas that we can improve on that will increase the permeability of this material and insure that the pavement system is safe from premature damage due to water.

The current gradation specification for granular subbase material at the start of this study was:

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9. Key Words
Permeable base
Granular subbase
Drainage
Drainable bases

10. No. of Pages
71
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DISCLAIMER

The contents of this report reflect the views of the author and do not necessarily reflect the official views of the Iowa Department of Transportation. This report does not constitute any standard, specification or regulation.
ACKNOWLEDGEMENT

I would like to personally thank all of the people who made this research possible. The nature of this research and testing involved coordination and cooperation between many different offices and people.

First, I would like to thank my boss, Champ Narotam, for giving me the opportunity to take over this project and having the confidence in me to get the job done. Also, Kumari Bharil did an excellent job of recording all the results of the work she did before I took over the project.

Wayne Strum was extremely helpful and cooperative in fitting in my requests for tests during the busiest part of the year. Cliff Dalbey was very helpful in obtaining all of the necessary equipment needed to run the field tests.

Reilly Construction deserves recognition for their cooperation in making various changes throughout the project. All of the construction people at the various sites I visited are too numerous to mention by name, but were nonetheless instrumental in helping obtain samples and answering questions about the projects.

Bob Steffes was extremely helpful in conducting tests and making the long trips to projects.
A very special thanks goes to Dan Mathis from the Federal Highway Administration for all of his assistance in this research: from answering the numerous questions and supplying technical information to getting the New Jersey Falling Head Permeameter (NJFHP) for our use.

INTRODUCTION

The importance of providing excellent drainage for a pavement system to prevent premature failure has been recognized for many years.

However, recently there have been questions whether or not the material that Iowa uses for a granular subbase material is providing the proper drainage needed to prevent premature breakdown of the road.

There are three very important ideas to keep in mind when discussing permeability.

The first is to recognize that there is not a national value required for permeability and that there are not any long-term studies that supports spending a large amount of money to obtain a very high coefficient of permeability (>2000-5000 ft/day). The "value" that most states have adopted for a target permeability is around 1000 ft/day.
The second is that there is no standard method for measuring the permeability of a granular subbase material in the lab or the field.

The last thing to keep in mind is that the crushed concrete that Iowa uses is very different from the materials many other states use and the properties and behavior of this material are also very different.

These facts are important when discussing permeability because it is difficult to compare permeabilities and properties of materials when different test methods and materials are being used.

PREVIOUS TESTING

Kumari Bharil started this research and conducted many laboratory tests on various materials that Iowa uses for a granular subbase. The lab tests were conducted on a permeameter that was built to ASTM specifications for determining the permeability of materials that had low permeabilities, like soils. The permeability results from those tests and the different gradations are shown in Appendix A, pages 22 and 23.

The results of these tests would indicate that the materials being used in Iowa provide a range of permeabilities that is quite acceptable.
However, there are a few questions regarding the validity of these results. First, the permeameter designed was for low permeable materials like soils, not granular subbase materials. There may have been some other factors that caused the high values for permeability.

The reason for questioning the results are that tests performed by the Federal Highway Administration with a NJFHP indicated that the permeability of the crushed concrete in Iowa is significantly lower than the lab results showed. Also, tests conducted by the FHWA on materials from other states showed that Iowa was on the lower end in permeability.

It is important to keep in mind that permeability is a relative measurement and comparing the permeabilities of different materials and different test methods is not possible. There were no lab tests conducted with materials from other states to compare how Iowa’s material compared to them.

**FIELD TESTS**

After the laboratory test results were analyzed and there was a question with the validity of the results, we decided to conduct in-situ permeability tests to determine how well the material was draining.
Since there was no standard procedure for measuring the in-situ permeability of a granular subbase material, a procedure was developed to obtain a relative idea of the permeability of the material.

This simple procedure consisted of coring out approximately a 4" diameter hole to a depth of 4"-5", filling the hole with 1 liter of water, and timing how long it took to drain from the hole.

We conducted in-situ tests on projects across the state that used crushed concrete and crushed stone for a granular subbase material. The results of these tests are in Appendix B, pages 29-36. The results from the field tests indicate that the virgin crushed stone material is providing adequate drainage, while the crushed concrete is not draining as well as anticipated.

CEDAR COUNTY PROJECT
We had an excellent opportunity to gather information about permeability on a project on I-80 in Cedar County near Tipton.

An agreement was made with the contractor to make changes in the gradation of the granular subbase material and to evaluate the effects on permeability. The letter and details of the project are in Appendix C, pages 38-43.
The agreement called for the contractor to construct the first one mile section of subbase to the regular Iowa specification of 100% passing the 1" sieve and 10%-35% passing the #8 sieve. The second mile section would involve changing the gradation so that 100% was passing the 1.5" sieve and 25% maximum passing the #8 sieve. Tests were to be conducted to determine the effects of this gradation change on permeability.

After the first section was completed, field tests were conducted and showed that the material was draining very poorly, if at all.

Field tests were conducted on the second mile section and showed a slight increase in permeability, but it was still relatively low.

We received a NJFHP from the FHWA, which significantly helped us to compare the permeability of the different materials. The NJFHP provided us with a quick and consistent way to compare the permeability and make a decision about the gradation for the rest of the project. The lab tests also indicated a slight improvement in permeability with the 1.5" material, but it was still in a range that was unacceptable.

There were also some other problems that we ran into on this project that caused the permeability of the material to be low. We noticed that the material seemed to break down quite
significantly at the grade. We conducted gradation tests at the plant and from the field and found that there was a very severe breakdown in the crushed concrete. We attributed the breakdown to handling and over-compacting of the material. The differences in gradation are shown on pages 13-14.

There was also a severe problem with stockpile segregation. The segregation was noticeable just by looking at the stockpile. The results of field tests on pages 28-36 show how much the permeability varied in the same area due to segregation.

In an attempt to prevent breakdown of material and increase permeability, we called for a maximum number of 4 compaction passes with a steel-drummed roller.

Another problem encountered on this project was that the contractor was picking up the old existing subbase material in the removal of the pavement for crushing. This old material was very poor in quality and added fines to the subbase which reduced the permeability.

We made another change in the gradation that should improve the permeability. The change calls for a maximum of 20% passing the #8 sieve. This material is being produced and used on the project. Gradation results of this new material are on page 68. The reports show that the % passing the #8 sieve is
around 17-20%. This new gradation is being produced by bleeding off about 12% of the fine material after crushing.

This project will be able to provide us with valuable information over time because of the various materials that were used.

**CHANGES TO CORRECT PROBLEMS**

We have taken steps to improve the permeability of the crushed concrete that is being used as a granular subbase. The gradation specification for crushed concrete has been changed and will go into effect for the November 1991 letting of contracts. The new specification will have 100% passing the 1.5" sieve and a maximum of 20% passing the #8 sieve. This change in gradation will remove some of the fines and open up the material to allow it to drain better.

From the results of the NJFHP, a relation between density and permeability was developed. The graph and results are on pages 15, 16 and 18. These results clearly show that the crushed concrete will provide adequate drainage if the density remains below 115 pounds per cubic feet (pcf).

In order to increase permeability we are looking at changing the compaction requirements and density of the material. The Construction Office is monitoring changes in the number of passes on the Cedar County project and trying to determine a minimum number of passes that will provide adequate stability.
The problem encountered with stockpile segregation is being corrected by monitoring the gradation from the belt before the stockpile and after it leaves the stockpile to insure there isn’t any significant differences in gradation.

The construction inspectors are closely monitoring the removal of the existing pavement to make sure the contractor is not picking up the old existing subbase material that would lower the permeability.

RECOMMENDATIONS

Although we have made changes that improve the permeability of the crushed concrete, there is still some additional work that needs to be done. The following are my recommendations for the rest of this research:

1. Determine the compaction requirements that keep the subbase stable and at a density that provides good permeability.

2. Conduct lab tests with the NJFHP and the ASTM device and see how the results compare for similar materials. Hopefully, tests will show a correlation between the two methods and field tests. The NJFHP is a quick and easy device to determine permeability and if it can be proven that it provides valid results and a correlation with the ASTM device, we should look into buying or making these
permeameters and making them available to the districts to use to evaluate the permeability of the materials being used on various projects.

3. We should try an asphalt-cement treated or portland-cement treated stabilized subbase test section in the near future to get some experience with this type of procedure and to see how this section performs compared to a non-stabilized section over the years with traffic.

4. Iowa needs to work with other states that are also working on permeability research to exchange ideas and information. At the very least, this will help to avoid repeating research that has already been done. Also, the states need to work with the FWHA to establish a standard method for permeability testing for both the lab and field. As it stands now, different states use different methods, so any comparison in permeability values is not really possible.

5. We should try to obtain the FHWA in-situ permeameter to conduct tests next summer. This may help to develop a quick procedure to determine the in-situ permeability of material.

6. We have obtained samples of aggregate that exhibit a plasticity index (PI) greater than 5. Tests should be done to see the effects of PI on permeability.
7. The crushed concrete sets up and becomes very hard after being in place. Cores should be taken down through the subbase and tested to see if the hardened crushed concrete still drains after it sets up.

**SUMMARY**

There has been many recent changes to improve the permeability of the material used as a granular subbase. We are on the right track for improving the pavement system and need to keep making improvements. Additional tests are needed to finish this research project. Most of the testing should be completed this winter and some additional test conducted next summer.
TABLE TITLES

1. Gradations From I-80 Cedar County - 1" Crushed Concrete
2. Gradations From I-80 Cedar County - 1.5" Crushed Concrete
3. New Jersey Falling Head Permeameter (NJFHP) Results
4. New Jersey Falling Head Permeameter Results 1.5" Crushed Concrete-Scalped, Cedar County, I-80
TABLE 1
GRADATIONS FROM 1–80 CEDAR COUNTY
1" CRUSHED CONCRETE

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FIGURE CAPTIONS

1. Permeability Results
FIGURE 1

Permeability Results

BLUE = 1.5" MATERIAL NON-SCALPED

RED = 1.5" MATERIAL SCALPED (STOCKPILE)
APPENDICES
APPENDIX A

Lab Permeability Results and Gradations
PERMEABILITY AND GRADATIONS

<table>
<thead>
<tr>
<th>SIEVE #</th>
<th>SCOTT (LC) 7000-7720</th>
<th>POWESHEIK 770-1170</th>
<th>DUBUQUE 8490-18760</th>
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WEBSTER (23) 9000-26000 | BUENA VISTA >40000 | WORTH 550-2750 | SCOTT (NW) 340-650 | CASS 380-2100

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23-
PERMEABILITY AND GRADATIONS
CRUSHED STONE

COUNTY AND PERMEABILITY
- DUBLIN 8400-18750
- LYON (33) 22000-26000
- WEBSTER (23) 6000-26000
- WEBSTER (31) 8470-10330

% PASSING

SIEVE SIZE

26
PERMEABILITY AND GRADATIONS
GRAVEL

COUNTY AND PERMEABILITY

- POWESHEIK 770-1170
- BUENA-VISTA 40000
- LYON (25) 200-275

% PASSING

SIEVE SIZE

#200 #100 #500 #300 #50 #16 #4 3/8" 1/2" 3/4" 1"
Appendix B

In-situ Test Results
IN-SITU PERMEABILITY RESULTS

DATE TESTED: JULY 2, 1991
PROJECT: I-80
TYPE OF SUBBASE MATERIAL: CRUSHED CONCRETE
LOCATION: POTTAWATAMIE

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AVERAGE K 41

*** HOLE DID NOT DRAIN
**IN-SITU PERMEABILITY RESULTS**

**DATE TESTED:** JULY 2, 1991  
**PROJECT:** I-80  
**TYPE OF SUBBASE MATERIAL:** CRUSHED CONCRETE  
**LOCATION:** CASS CO

<table>
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**AVERAGE K** 70

*** HOLE DID NOT DRAIN
IN-SITU PERMEABILITY RESULTS

DATE TESTED: JULY 3, 1991
PROJECT: I-520
TYPE OF SUBBASE MATERIAL: CRUSHED STONE
LOCATION: HARDIN CO.

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<td><strong>AVERAGE K</strong></td>
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*** HOLE DID NOT DRAIN
IN-SITU PERMEABILITY RESULTS

DATE TESTED: JULY 10, 1991
PROJECT: I-80
TYPE OF SUBBASE MATERIAL: CRUSHED CONCRETE
LOCATION: POWESHEIK CO.

<table>
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<th>PERMEABILITY (K FT/DAY)</th>
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<tbody>
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<td>1</td>
<td>38 ***</td>
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<tr>
<td>2</td>
<td>58 ***</td>
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AVERAGE K 126

*** HOLE DID NOT DRAIN
IN-SITU PERMEABILITY RESULTS

DATE TESTED: JULY 17, 1991
PROJECT: I-380 (BRIDGE APPROACHES)
TYPE OF SUBBASE MATERIAL: CRUSHED STONE
LOCATION: JOHNSON CO.

<table>
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AVERAGE K 1004

*** HOLE DID NOT DRAIN
## In-Situ Permeability Results

**Date Tested:** Aug 1, 1991  
**Project:** I-80  
**Type of Subbase Material:** Crushed Concrete 1” Material  
**Location:** Cedar Co.

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</thead>
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<tr>
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<td>105</td>
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Average K: 89

*** Hole did not drain
**IN-SITU PERMEABILITY RESULTS**

DATE TESTED: AUGUST 8, 1991  
PROJECT: I-80  
TYPE OF SUBBASE MATERIAL: 1.5" CRUSHED CONCRETE (4 PASSES)  
LOCATION: CEDAR

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AVERAGE K 20

*** HOLE DID NOT DRAIN
IN-SITU PERMEABILITY RESULTS

DATE TESTED: AUG 13, 1991
PROJECT: I-80
TYPE OF SUBBASE MATERIAL: CRUSHED CONCRTE 1.5" MATERIAL
LOCATION: CEDAR CO.

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AVERAGE K 390

*** HOLE DID NOT DRAIN

NOTE:
THERE WAS SEVERE OBVIOUS SEGREGATION
PERMEABILITY MUCH LOWER
Appendix C

I-80 in Cedar County Project
Granular Subbase Recommendations

The Iowa Limestone Producers and Reilly Construction Company have proposed a trial gradation change to allow 100% passing the 1¼ inch sieve for granular subbase produced from recycled concrete. They made this proposal based on project experience concerns indicating that increased crushing efforts cause considerable variability in the amount of material passing the number 8 sieve. This problem results in considerable wastage on some projects and usually results in a finished product which runs very near the upper allowed limit for all sieve sizes. We have found that increased break down occurs in these same problem aggregates during compaction. This combination of factors produces unacceptable drainability.

For this reason I recommend that we allow a mutual benefit, one mile long, trial section on the upcoming Cedar I-80 inlay project. Agreed upon changes are as follow:

1. Gradation: 100% passing the 1¼" sieve
   10 to 25% passing the #8 sieve
   0-15% passing the #50 sieve
   0-6% passing the #200 sieve

2. Reilly would produce the first mile of production at the current specification limits. The second mile (about one weeks run) would then be produced with the above controls under a mutual benefit agreement.

3. The Materials department would do increased control testing including gradation tests from the finished grade and would perform permeability testing on the two test sections.

4. Depending on the results of this trial a decision would be made on which gradation control is used for the remainder of the project. This decision would be based on obtaining improved drainability while maintaining acceptable workability and construction stability.

5. If the decision is made to allow the 1¼" gradation material for the remainder of the project, Reilly Construction would evaluate production savings and consider a price reduction.

Thank you for your assistance in implementing this trial.

KLD:mk

cc: D. A. Anderson
    G. F. Sisson
    D. L. East
    E. T. Cackler
    Roger Boulet, DME, Cedar Rapids
TO OFFICE: District Six Materials

ATTENTION: Roger Boulet

FROM: Bernard C. Brown

OFFICE: Materials Engineer

SUBJECT: Granular Subbase - I-80 Cedar County

As we discussed recently, we are interested in altering the gradation of the granular subbase to enhance the drainability on the above referenced project. Kermit Dirks' July 18, 1991 memo (attached) outlines the plan for an in-place evaluation. I support the plan as does Tom Cackler.

The Central Construction Office will be formally contacting the district to arrange for this test section. The purpose of this memo is to advise you that we should have at least 5 gradation tests on the crushed material going into each of these test sections. If you can get representative samples from the compacted subbase we would like to have 5 gradation tests from each of these sections also.

I'm not sure what the proper way to evaluate permeability should be but at the very least the contractor should be prepared to use a truck to deposit water on each section.

Please keep us advised of the construction schedule so we can be on the scene for the tests.

Please let me know if you have any questions.

BCB:esb

ATTACHMENT

cc: D. A. Anderson
    E. T. Cackler
    K. L. Dirks
TO OFFICE: District No. 6                   DATE: August 9, 1991
ATTENTION: Bruce Kuehl

REF. NO.: Cedar County
IR-80-7(57)265
PCC Inlay

FROM: E. Tom Cackler
OFFICE: Construction

SUBJECT: Granular Subbase

Overcompaction of the granular subbase has resulted in excessive crushing of the crushed concrete. The excess fine particles reduces the drainability of the material.

In order to reduce this crushing, we are proposing several changes in the method of compaction. On a trial basis, we are requesting the following changes be implemented on this project only:

1. The moisture content of the granular material shall be within 2% of the optimum moisture content, as determined by the Central Materials Laboratory.

2. The full thickness of the granular subbase material shall be compacted with four passes of a steel drum roller, operating in the static mode, or a pneumatic-tired roller.

3. No nuclear density testing will be required, although some nuclear testing may be requested later to evaluate the number of roller passes versus compaction.

4. The modified gradation shall continue to be used. The modified gradation was:

   100% passing the 1 1/2" sieve
   10-25% passing the #8 sieve
   0-15% passing the #50 sieve
   0-6% passing the #200 sieve

As per the existing specification, hauling shall not be permitted on the completed granular subbase.

ETC:wik
cc: D. Anderson, M. Burr, R. Boulet, M. Brandl, K. Dirks, J. Lane, D. Mathis, FHWA

Aug 12, 91
B. Brown
V. Marks
F. Niemeyer
C. Richardson
TO OFFICE: District 6
ATTENTION: Bruce Kuehl
FROM: Thomas R. Jacobson
OFFICE: Office of Construction
SUBJECT: Granular Subbase

This letter serves to confirm our telephone conversation this morning and authorize changes in the granular subbase material.

The items to be changed include:

1. The broken concrete pavement is to be passed through a 2" scalper screen prior to crushing. The material passing through the 2" screen is to be wasted.

2. Lower the no. 8 sieve passing requirement to 10-20 percent. The modified gradation will be:

   100 percent passing the no. 1 1/2" sieve
   10-20 percent passing the no. 8 sieve
   0-15 percent passing the no. 50 sieve
   0-6 percent passing the no. 200 sieve

3. The changes will be evaluated after approximately one mile of this material is placed.

TRJ:pc
cc: D. Anderson, M. Burr, R. Boulet, M. Brandl, K. Dirks, J. Lane, D. Mathis, FHWA

CC: B. C. Brown, Marks, Champ, Frank, Jim Gove

8/20/91
Aug 16, 1981

K. Dirks  
T. Jacobson  
J. Groce  
F. Miyogawa  
V. Marks  
K. Boukef, B. Kuch  
D. Mathis  
B. Brown  
T. Castler

This is an update on information from the Color-Co. I-80 project related to crushed concrete granular subbase.

The Davenport RFC Office reports nuclear density results from the road way on 1½" top size material placed with four static roller passes of 101, 2(185) lbs per cubic ft. (See Aug. 19 memo)

Based on the curve F. Miyogawa developed using the N. Jersy permeameter, this indicates permeability in the 500 to 1000 ft per day.
IMPORTANT NOTE

Error Correction

This is to correct an error I made in my note of Aug 16, 1991 about granular subbase road way density. The density from four passes of a static roller should have been 118.5 lbs per cu. ft, instead of 161.2 which I reported. This drops the estimated permeability to something below 50 feet per day.
Appendix D

New Jersey Falling Head Permeameter Procedure
MEMORANDUM

TO: O. Abbott

FROM: V. Mottola

SUBJECT: Laboratory Compaction and Permeability of Non-Stabilized and Bituminous Stabilized Open-Graded Base Course Materials

DATE: 5/27/88

TELEPHONE NO.: 2-5730

As per our discussion at the Interagency Meeting, attached are the methods of tests for open-graded materials which should be included into Section 990 of the NJDOT Standard Specifications. These tests outline the procedure for Laboratory Compaction and Permeability of Non-Stabilized and Bituminous Stabilized Open Graded Base Course Materials. The following have been written in the format followed by Section 990 of the 1983 Standard Specifications.

Method of Tests

Q-1 Compaction of Non-Stabilized Open Graded (NSOG) Base Course Materials

Q-2 Compaction of Bituminous Stabilized Open Graded (BSOG) Base Course Materials

Q-3 Falling Head Permeability Test for Non-Stabilized and Bituminous Stabilized Open Graded Base Course Materials

If you require additional information, please contact me.

Victor E. Mottola

Attachments

cc: J. Croteau
Q-1 COMPACTION OF NON-STABILIZED OPEN-GRADED (NSOG) BASE COURSE MATERIALS

1. **Scope**
   This method of test determines the density of NSOG base course material and outlines the procedure for compaction in preparation for falling head permeability testing.

2. **Apparatus**
   - Modified NSOG compaction equipment as shown in Figures 2 and 3.
   - A Burmister Vibratory Table meeting ASTM D-2049.
   - Four (4) inch diameter permeability molds with #16 sieve screen.
   - 12 lb. lead surcharge.
   - A heavy duty scale capable of weighing samples up to 20 Kg. with an accuracy of ± 1 gram.
   - A steel ruler with 1/100 of an inch gradations.
   - A stopwatch capable of 0.1 second accuracy.

3. **Procedure**
   - Place the 4 inch diameter mold into the recess of the bottom retainer on the Burmister Table. Secure the retainer to the table with threaded rods and wing nuts.
   - Weigh out 3.5 lb. of NSOG material and place the sample loosely into the mold and level the surface. Enter the weight of sample into Figure 6.
   - Place the spacer plate onto the mold and level the surface. Fit the top retainer plate over the threaded rods and cylinder mold.
   - Secure the top retainer with wing nuts.
Q-1 COMPACTION OF NON-STABILIZED OPEN-GRADED (NSOG)

BASE COURSE MATERIALS

1. **Scope**

   This method of test determines the density of NSOG base course material and outlines the procedure for compaction in preparation for falling head permeability testing.

2. **Apparatus**

   Modified NSOG compaction equipment as shown in Figures 2 and 3.
   
   A Burmister Vibratory Table meeting ASTM D-2049.
   
   Four (4) inch diameter permeability molds with #16 sieve screen.
   
   12 lb. lead surcharge.
   
   A heavy duty scale capable of weighing samples up to 20 Kg. with an accuracy of ± 1 gram.
   
   A steel ruler with 1/100 of an inch gradations.
   
   A stopwatch capable of 0.1 second accuracy.

3. **Procedure**

   Place the 4 inch diameter mold into the recess of the bottom retainer on the Burmister Table. Secure the retainer to the table with threaded rods and wing nuts.

   Weigh out 3.5 lb. of NSOG material and place the sample loosely into the mold and level the surface. Enter the weight of sample into Figure 6.

   Place the spacer plate onto the mold and level the surface. Fit the top retainer plate over the threaded rods and cylinder mold.

   Secure the top retainer with wing nuts.
Measure and record (to the nearest .01") the distance from the top of the sample to the top of the cylinder mold.

Lower the 12 lb. surcharge to sit freely onto the spacer plate and begin vibrating the sample for 30 seconds at an amplitude of 50 on the scale described in ASTM D-2049.

Remove the surcharge and measure the compacted height of the sample.

Repeat the procedure for a total of 5 trials.

After completion of each trial, unfasten the cylinder mold with compacted sample from the Burmister Table and place the mold into the modified falling head permeameter for permeability testing (see Method of Test Q-3).

4. Calculations

Measure the compacted density of each NSOG sample as follows:

\[
\text{Density} = \frac{W_{\text{sample}}}{V_{\text{sample}}}
\]

where:

\[w = \text{Weight of compacted sample (lbs.) = 3.5 lbs.}\]

\[V = \text{Height of Sample (in) x (12.56 in}^2) \div 1728\]

5. Report

The densities of five compacted NSOG samples shall be reported on Figure 6, Compaction and Permeability Data Sheet.
Q-3 FALLING HEAD PERMEABILITY TEST FOR NON-STABILIZED AND BITUMINOUS STABILIZED OPEN GRADED BASE COURSE MATERIALS

1. **Scope**

   This method of test describes the procedure determining the permeability of non-stabilized (NSOG) and bituminous stabilized (BSOG) open graded base course materials.

2. **Apparatus**

   Modified falling head permeability apparatus as shown on Figure 6.

   8.5" high x 4" I.D. steel molds with #16 sieve screen soldered to bottom of mold for testing of NSOG materials and without screen mesh for testing of BSOG materials.

   A source of clean water capable of supplying a minimum flow of five to six gallons per minute.

   A stopwatch capable of measuring up to 30 minutes with an accuracy of + 0.1 second.

   A 12" steel ruler with 1/100 inch gradations.

3. **Procedure**

   Place the 4" diameter cylinder mold with compacted NSOG or BSOG sample (see Method of Test Q-1 or Q-2 for compaction procedure) into the bottom support ring of the falling head permeameter. A rubber gasket shall be placed along the bottom edge of the cylinder mold to prevent water leakage.

   Place the rubber stopper at the bottom of the permeameter and close the bottom flap gate.
Q-2 COMPACTION OF BITUMINOUS-STABILIZED OPEN-GRADED (BSOG)
BASE COURSE MATERIAL

1. Scope
This method of test describes the procedure for determining the compacted
density of BSOG base course material in preparation for falling head
permeability testing.

2. Apparatus
Modified BSOG compaction apparatus as described in Figures 4 and 5 and
illustrated in ASTM D-1074.

8.5" high x 4" I.D. steel molds as shown in Figure 5.
A Lancaster mechanical mixer with at least 5 lb. capacity sufficient to
blend an asphalt cement stone mix.
An Instron Universal testing machine or similar device capable of
producing accurate molding pressures up to 2000 psi or 25,000 lbs. total load.
A heating oven capable of heating materials to at least 325°F.
4 inch diameter paper discs.

3. Procedure
Weigh out approximately 5 lbs. of materials for a BSOG mix.
Heat all materials to be blended and the mixing utensils to appropriate
temperatures to assure compaction of the mix in the mold at 250°F as follows:
a. Stone to 325°F
b. Asphalt Cement to 275°F
c. Mixing utensils and bowls to 325°F
If BSOG mix has already been batched (samples taken from field), heat the
mix to 300°F.
Blend and mix 5 lb. of the heated asphalt cement and stone mix in the Lancaster mixer for two minutes or until stone is fully covered by A.C., whichever comes first.

Lightly oil compaction mold and plunger components.

Place half ring supports and mold on bottom plunger.

Insert paper disc into bottom of mold.

Pour 1600 grams (3.5 lbs.) of the heated asphalt cement-stone mix into the 4.0" diameter mold. This is done in three equal lifts. After each lift, the mix is rodded 25 times using a spatula (10 times of the surface of the layer and 15 times around the stone-mold interface.

Place a paper disc on sample and insert the top plunger.

Begin compaction with the Instron Universal testing machine. Compactive pressures should be limited to 600 psi for carbonate rock aggregate, and 1000 psi for aggregates of all other stone types so that excessive pressures do not crush the aggregates.

Compaction should follow procedures outlined in ASTM D-1079.

Remove the cylinder mold and compacted BSOG sample from the Instron machine.

Measure and record the height of the compacted BSOG sample in inches (nearest .01").

Repeat the procedure for a total of 5 trials.

After completion of each trial, calculate the density as outlined below and place the cylinder mold with the compacted sample into the modified falling head permeameter. For permeability testing, see Method of Test Q-3.
4. **Calculations**

Measure the compacted density of each BSOG sample as follows:

\[
\text{Density} = \frac{W_{\text{sample}}}{V_{\text{sample}}}
\]

where:

\[
w = \text{Weight of compacted sample (lbs.)} = 3.5 \text{ lbs.}
\]

\[
V = \frac{\text{Height of Sample (in)} \times (12.56 \text{ in}^2)}{1728}
\]

5. **Report**

The densities of five compacted BSOG samples shall be reported on Figure 6, Compaction and Permeability Data Sheet.
4. **Calculations**

Measure the compacted density of each BSOG sample as follows:

\[
\text{Density} = \frac{W_{\text{sample}}}{V_{\text{sample}}}
\]

where:

\[
w = \text{Weight of compacted sample (lbs.)} = 3.5 \text{ lbs.}
\]

\[
V = \frac{\text{Height of Sample (in)} \times (12.56 \text{ in}^2)}{1728}
\]

5. **Report**

The densities of five compacted BSOG samples shall be reported on Figure 6, Compaction and Permeability Data Sheet.
FIGURE 4-4 BSOG COMPACTION EQUIPMENT ASSEMBLY.

SCALE: 1" = 2"
FIGURE D2 BSOG COMPACITION EQUIPMENT ASSESSORIES.

SCALE: 1" = 3"
FIGURE D2 BSOG COMPACTION EQUIPMENT ACCESSORIES

SCALE: 1" = 3"
Q-3 FALLING HEAD PERMEABILITY TEST FOR NON-STABILIZED AND BITUMINOUS STABILIZED OPEN GRADED BASE COURSE MATERIALS

1. Scope
This method of test describes the procedure determining the permeability of non-stabilized (NSOG) and bituminous stabilized (BSOG) open graded base course materials.

2. Apparatus
Modified falling head permeability apparatus as shown on Figure 6.
8.5" high x 4" I.D. steel molds with #16 sieve screen soldered to bottom of mold for testing of NSOG materials and without screen mesh for testing of BSOG materials.
A source of clean water capable of supplying a minimum flow of five to six gallons per minute.
A stopwatch capable of measuring up to 30 minutes with an accuracy of + 0.1 second.
A 12" steel ruler with 1/100 inch gradations.

3. Procedure
Place the 4" diameter cylinder mold with compacted NSOG or BSOG sample (see Method of Test Q-1 or Q-2 for compaction procedure) into the bottom support ring of the falling head permeameter. A rubber gasket shall be placed along the bottom edge of the cylinder mold to prevent water leakage.
Place the rubber stopper at the bottom of the permeameter and close the bottom flap gate.
Place a rubber gasket at the top edge of the cylinder mold.
Place the upper support ring and plastic standpipe on top of the 4" diameter cylinder mold. Lock the upper support ring to the cylinder mold with the wing nuts.

The permeameter is now assembled and ready for permeability testing.
Place the assembled permeameter near the water source and suitable drain.

With the bottom flapgate closed, fill the plastic standpipe to overflowing with water from the cold water tap.

Once the standpipe is overflowing with water, start the permeability flow test by opening the bottom flapgate to allow water to flow through the sample. Start the watch at the time of opening the flapgate.

When the water level in the plastic standpipe reaches the predetermined mark situated 15.75" below the top of the standpipe, stop the watch.

Record the time in seconds on Figure 6, Compaction and Permeability Data Sheet.
Note the compacted height of the NSOG or BSOG sample (L) in inches.

Repeat the permeability test with additional compacted NSOG or BSOG samples for a total of 5 trials.

4. Calculations
Use Figure 6, Compaction and Permeability Data Sheet to calculate the permeability of the open graded materials.

Calculate the falling head permeability (K) as follows:
where:

\[ K = \frac{L}{T} \left( \ln \left( \frac{h_1}{h_2} \right) \right) \] (7200)

\[ K = \] falling head permeability (ft./day)

\[ L = \] height of compacted NSOG or BSOG sample (in.)

\[ T = \] recorded time for water level to fall 15.75 in. from top of standpipe

\[ h_1 = \] height of assembled permeameter = 30.0 in.

\[ h_2 = \] height from final water mark to bottom of cylinder mold = 14.375 in.

\[ \ln = \] natural logarithm

Repeat the permeability calculation for each of the five trials.

5. Report

The permeabilities of five NSOG or BSOG samples shall be reported on Figure 6, Compaction and Permeability Data Sheet.
where:

\[ K = \frac{L}{T} \ln \left( \frac{h_1}{h_2} \right) \frac{7200}{\pi} \]

- **K** = falling head permeability (ft./day)
- **L** = height of compacted NSOG or BSOG sample (in.)
- **T** = recorded time for water level to fall 15.75 in. from top of standpipe
- **h₁** = height of assembled permeameter = 30.0 in.
- **h₂** = height from final water mark to bottom of cylinder mold = 14.375 in.
- \( \ln \) = natural logarithm

Repeat the permeability calculation for each of the five trials.

5. **Report**

The permeabilities of five NSOG or BSOG samples shall be reported on Figure 6, Compaction and Permeability Data Sheet.
FIGURE D3 MODIFIED BURMISTER EQUIPMENT ASSEMBLY.

SCALE: 1" = 2"

TOP RETAINER
SURCHARGE
MOLD
SPACER PLATE
3/8" ROD (TYP)
DRILL & TAP 3/8" ROD (TYP)
Burmister Table Top
Figure 8-A: Modified Burmister Equipment Assessor Plate SPACER PLATE PLEXIGLAS MOLD SPACER PLATE PLEXIGLAS MOLD SECTION A-A SECTION B-B SECTION C-C TOP RETAINER FOR 4"# MOLD TOP RETAINER FOR 4"# MOLD BOTTOM RETAINER MODIFIED BURMISTER EQUIPMENT ASSESSORIES.
FIGURE 8.4 MODIFIED BURMISTER EQUIPMENT ACCESSORIES.
NEW JERSEY DEPARTMENT OF TRANSPORTATION
DIVISION OF RESEARCH AND DEMONSTRATION

COMPACT AND PERMEABILITY DATA SHEET
COMPACT OF NSOG / BSOG MATERIAL (circle one)

NJDOT SPECIFICATION:  SPEC. PERMEABILITY:

PROJECT:  SECTION:  COUNTY:

MATERIAL:  STONE SIZE:  SOURCE:  QUARRY:

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<th>d2 (inch)</th>
<th>L = 8.5 - (d1 + d2)</th>
<th>Sample Weight W (lb)</th>
<th>Sample Volume V = 12.6L (cu in)</th>
<th>Density W × 1728 (pcf)</th>
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<th>h2 = 14.75 - d2</th>
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<th>T (sec)</th>
<th>ln(h1)</th>
<th>ln(h2)</th>
<th>h1</th>
<th>K × T ln(h2)</th>
<th>L × (1/205)</th>
<th>Density (ft/day)</th>
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<th>0.5</th>
<th>No. 4</th>
<th>No. 8</th>
<th>No. 16</th>
<th>No. 50</th>
<th>P.I.</th>
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PERMEABILITY OF O.G. MATERIALS

GRADATION OF O.G. MATERIALS
Q-2 COMPACTION OF BITUMINOUS-STABILIZED OPEN-GRADED (BSOG) BASE COURSE MATERIAL

1. **Scope**

   This method of test describes the procedure for determining the compacted density of BSOG base course material in preparation for falling head permeability testing.

2. **Apparatus**

   Modified BSOG compaction apparatus as described in Figures 4 and 5 and illustrated in ASTM D-1074.

   8.5" high x 4" I.D. steel molds as shown in Figure 5.

   A Lancaster mechanical mixer with at least 5 lb. capacity sufficient to blend an asphalt cement stone mix.

   An Instron Universal testing machine or similar device capable of producing accurate molding pressures up to 2000 psi or 25,000 lbs. total load.

   A heating oven capable of heating materials to at least 325°F.

   4 inch diameter paper discs.

3. **Procedure**

   Weigh out approximately 5 lbs. of materials for a BSOG mix.

   Heat all materials to be blended and the mixing utensils to appropriate temperatures to assure compaction of the mix in the mold at 250°F as follows:

   a. Stone to 325°F

   b. Asphalt Cement to 275°F

   c. Mixing utensils and bowls to 325°F

   If BSOG mix has already been batched (samples taken from field), heat the mix to 300°F.
Appendix E

MLR-90-4 Reports and Updates
PROJECT NO.: MLR-90-4 (REVISED)  DATE: June 29, 1991

PROJECT TITLE: Permeability of Granular Subbase Materials

PRINCIPAL INVESTIGATOR: Frank Miyagawa

PURPOSE: To determine if adequate drainage is being provided by granular subbase materials.

OBJECTIVE: To determine a range of gradations and P.I.'s that will provide adequate permeability for drainage and to determine the in-place permeability of the subbase to compare with laboratory results.

PROCEDURE: This research will consist of two phases.

PHASE I-a: -test all granular base materials used in 1990 construction projects and determine gradations, permeability, plasticity index, and density. --COMPLETE

PHASE I-b: -gather samples of granular base materials from producers that exhibit a plasticity index from approximately 3-6 and determine the permeability.

PHASE II-a: -evaluate the results from I-a and select various gradations to be altered and view the effects of the alterations on permeability.

PHASE II-b: -measure the in-situ permeability from ongoing projects.

- determine the in-place density, P.I., and gradations and compare with lab results.

RESPONSIBILITIES: The Aggregate and Soils section will conduct all lab tests. Frank Miyagawa will perform all the in-situ tests and prepare the final report.

CC: B. Brown
    O.J. Lane
    V. Marks
    C. Narotam
    K. Dirks
    W. Strum
ATTN: Bernie Brown

FROM: Frank Miyagawa

SUBJECT: Summary of I-80 in Cedar Co. project

The following is a brief summary of the work that has been completed on the I-80 project in Cedar County regarding the permeability of granular subbase materials:

SECTION #1
The first mile section of subbase material was the standard 1" top size crushed concrete meeting gradation specification #4121. In-situ and lab permeability tests were conducted and showed that the material did not drain as well as it should have. Gradation tests revealed that there was a significant breakdown of the material from the stockpile to the grade. This first section has been paved over.

SECTION #2
The second section of material was the 1.5" top size material with a change in the maximum percent passing the #8 sieve from 35% to 25%. In-situ and lab permeability tests were also conducted on this material. There was a slight improvement in permeability compared to the 1" material, but the permeability was still relatively low. Gradation reports also showed a significant breakdown of material as with the 1" material.

SECTION #3
The third section of subbase involved a change in construction procedures. A maximum number of 4 passes with a steel-drum roller operating in the static mode or a pneumatic-tired roller was specified. Gradation tests are being conducted to determine if the new procedure decreases the amount of breakdown.

SECTION #4
The fourth section of material was produced with special care in making sure that the old base material from the existing pavement was not disturbed when the pavement was removed. This resulted in a material that kept the % passing the #8 sieve around 20-23%.

SECTION #5
The fifth section of crushed concrete is starting to be produced. This material will have a target of 17% passing the #8 sieve. This will be achieved by scalping the material through a 2" screen to remove some of the fines.
FUTURE PLANS

The following activities are planned for the rest of the project:

1. Conduct in-situ and lab permeability tests on the new material.

2. Run gradation tests on the new material to determine if the change in construction procedures decreases breakdown.

3. Obtain samples to run abrasion tests on the crushed concrete.

cc: O.J. Lane
C. Narotam
V. Marks
J. Grove
K. Dirks
R. Boulet
D. Mathis, FHWA
ATTN: Bernie Brown

FROM: Frank Miyagawa

SUBJECT: Permeability Update

Bob Steffes and I traveled to the I-80 project in Cedar County on Aug 28 to obtain samples from the scalped crushed concrete and to conduct in-situ permeability tests.

As of Aug 28, the contractor was producing the new scalped crushed concrete at the plant, but it had not been used yet at the grade. The samples we obtained at the plant were from the belt, so the samples should be representative. In-situ permeability tests were performed on the 1.5" material that was produced without scalping and that was running around 20-25% passing the #8 sieve.

The in-situ test results were slightly better for the material that had the number of compaction passes limited to four. There were still some areas that took over 35 minutes to drain. However, most of the holes did drain. This would indicate that there is some improvement due to the new construction changes.

Laboratory permeability tests were conducted on the stockpile-scalped material. Attached are the results of those tests and a graph comparing the theoretical curves for the scalped vs. non-scalped material. There is significant improvement in permeability at lower densities for the scalped material, but it is clear that as the density approaches 115-120 pcf that there is little difference between the two materials. The in-place-scalped material would most likely have a lower permeability at the grade due to material breakdown. Laboratory tests are being conducted to evaluate the breakdown effects of the new construction procedures.

There was one interesting difference between the two materials. The scalped material was not as dense as the non-scalped material with the same compaction energy. For the standard proctor, the maximum density achieved in the New Jersey Falling Head Permeameter was 123 pcf, with two other samples only at 112 pcf. The maximum density achieved on the first material for a standard proctor was 129 pcf, with most running around 120 pcf. Although the accuracy of determining densities with the permeameter is subject to question, the two materials were compacted under similar conditions and this difference in characteristics is something that should be looked into further.

There seems to be some improvement in permeability with the new procedures and material. However, it is obvious that the density has a great impact on the permeability of this material regardless of gradation. A possible solution would be to look at specifying a maximum density for the crushed concrete. Other
states that use crushed concrete do have maximum densities that run around 110-115 pcf and provide adequate stability. The permeability of the crushed concrete in Iowa at 110-115 pcf seems to be in a range that would provide adequate drainage with very little increase in cost. Additional tests would be needed to determine if a density of 110-115 pcf would provide adequate stability with the material Iowa is using.

I am planning on conducting in-situ tests as soon as the new material has been placed. Lab tests with in-place samples will also be conducted to see how the results compare with the plant samples.

cc: O. J. Lane
    V. Marks
    C. Narotam
    K. Dirks
    T. Cackler
    R. Boulet
    D. Mathis, FHWA
ATTN: Bernie Brown

FROM: Frank Miyagawa

SUBJECT: Summary of I-80 in Cedar Co. project

The following is a brief summary of the work that has been completed on the I-80 project in Cedar County regarding the permeability of granular subbase materials:

SECTION #1
The first mile section of subbase material was the standard 1" top size crushed concrete meeting gradation specification #4121. In-situ and lab permeability tests were conducted and showed that the material did not drain as well as it should have. Gradation tests revealed that there was a significant breakdown of the material from the stockpile to the grade. This first section has been paved over.

SECTION #2
The second section of material was the 1.5" top size material with a change in the maximum percent passing the #8 sieve from 35% to 25%. In-situ and lab permeability tests were also conducted on this material. There was a slight improvement in permeability compared to the 1" material, but the permeability was still relatively low. Gradation reports also showed a significant breakdown of material as with the 1" material. This section has also been paved over.

SECTION #3
The third section of subbase involved a change in construction procedures. A maximum number of 4 passes with a steel-drum roller operating in the static mode or a pneumatic-tired roller was specified. This section has been paved.

SECTION #4
The fourth section of material was produced with special care in making sure that the old base material from the existing pavement was not disturbed when the pavement was removed and with the change in compaction as section #3. This resulted in a material that kept the % passing the #8 sieve around 20-23%. In place gradation tests showed that the amount of breakdown with this new construction procedure was much less than before. The percent passing the #8 was 25.7 on the sample we obtained.

SECTION #5
The fifth section of crushed concrete is being produced and placed. Gradation tests show that the % passing the #8 is about 17-18% and the % passing the #200 is around 2-4.5%. In-situ tests need to be run and samples need to be obtained. This low amount of fines is being achieved by bleeding off about 12% of the fines after crushing. This is different from the original idea of scalping off material passing a 2" sieve before crushing. The contractor believed scalping over a 2" sieve would result in
about 35% waste as opposed to the 12% now from bleeding off fines.

Abrasion tests were conducted on the 1.5" scalped material from the stockpile. The crushed concrete had an abrasion number of 39 and 41. This would indicate that this material is not as bad as we first believed as far as abrasion is concerned.

FUTURE PLANS

An interim report will be done in the next week with my recommendations for the rest of this research project.

cc: O.J. Lane
    C. Narotam
    V. Marks
    J. Grove
    K. Dirks
    R. Boulet
    D. Mathis, FHWA
Appendix F

Iowa DOT and Production Gradations
IOWA DOT CENTRAL LABORATORY GRADATIONS

Percent Passing

<table>
<thead>
<tr>
<th>Sample Description</th>
<th>1½&quot;</th>
<th>1&quot;</th>
<th>3/4&quot;</th>
<th>1/2&quot;</th>
<th>3/8&quot;</th>
<th>#4</th>
<th>#8</th>
<th>#16</th>
<th>#30</th>
<th>#50</th>
<th>#100</th>
<th>#200</th>
</tr>
</thead>
<tbody>
<tr>
<td>1½&quot; Stockpile</td>
<td>100</td>
<td>88</td>
<td>72</td>
<td>54</td>
<td>43</td>
<td>29</td>
<td>22</td>
<td>17</td>
<td>13</td>
<td>9.2</td>
<td>6.9</td>
<td>5.5</td>
</tr>
<tr>
<td>1½&quot; Stockpile - Scalped</td>
<td>100</td>
<td>83</td>
<td>67</td>
<td>53</td>
<td>43</td>
<td>26</td>
<td>17</td>
<td>12</td>
<td>8.7</td>
<td>6.2</td>
<td>4.9</td>
<td>4.0</td>
</tr>
<tr>
<td>1½&quot; Stockpile - Scalped</td>
<td>100</td>
<td>79</td>
<td>64</td>
<td>55</td>
<td>43</td>
<td>27</td>
<td>18</td>
<td>12</td>
<td>8.2</td>
<td>4.8</td>
<td>3.1</td>
<td>2.1</td>
</tr>
<tr>
<td>1½&quot; In-Place #1</td>
<td>100</td>
<td>96</td>
<td>90</td>
<td>83</td>
<td>76</td>
<td>64</td>
<td>48</td>
<td>36</td>
<td>27</td>
<td>18</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>1½&quot; In-Place #2</td>
<td>100</td>
<td>94</td>
<td>88</td>
<td>77</td>
<td>65</td>
<td>47</td>
<td>36</td>
<td>27</td>
<td>21</td>
<td>14</td>
<td>10</td>
<td>8.2</td>
</tr>
<tr>
<td>1½&quot; In-Place - 4 passes only</td>
<td>98</td>
<td>94</td>
<td>77</td>
<td>62</td>
<td>51</td>
<td>35</td>
<td>26</td>
<td>19</td>
<td>14</td>
<td>9.0</td>
<td>6.5</td>
<td>4.5</td>
</tr>
<tr>
<td>1½&quot; Trough</td>
<td>100</td>
<td>94</td>
<td>82</td>
<td>71</td>
<td>59</td>
<td>41</td>
<td>30</td>
<td>23</td>
<td>17</td>
<td>12</td>
<td>9.0</td>
<td>7.0</td>
</tr>
<tr>
<td>1&quot; Stockpile</td>
<td>100</td>
<td>100</td>
<td>84</td>
<td>70</td>
<td>56</td>
<td>37</td>
<td>26</td>
<td>19</td>
<td>13</td>
<td>8.0</td>
<td>5.3</td>
<td>4.0</td>
</tr>
<tr>
<td>1&quot; In-Place</td>
<td>100</td>
<td>100</td>
<td>87</td>
<td>69</td>
<td>52</td>
<td>35</td>
<td>25</td>
<td>18</td>
<td>13</td>
<td>8.2</td>
<td>5.6</td>
<td>4.2</td>
</tr>
<tr>
<td>1&quot; Trough</td>
<td>100</td>
<td>100</td>
<td>94</td>
<td>83</td>
<td>72</td>
<td>50</td>
<td>35</td>
<td>26</td>
<td>18</td>
<td>11</td>
<td>8.0</td>
<td>5.9</td>
</tr>
</tbody>
</table>

| 1½" Specification       | 100 |      |      |      |      |     |     |     |     |     |      |      |
| 1" Specification        | 100 |      |      |      |      |     |     |     |     |     |      |      |

| Specification           | 10-25 | 0-15 | 0-6  |
| Specification           | 10-35 |      |      |
Iowa Department of Transportation

CERTIFIED GRADATION TEST REPORT

RECYCLED CR. CONC. FROM JUST W. OF THE CEDAR RIVER, EASTERLY TO APPROX. 1/2 MILE EAST OF THE SCOTT COUNTY

<table>
<thead>
<tr>
<th>Source Name</th>
<th>Material</th>
<th>Class</th>
<th>Gradation No.</th>
<th>Beds</th>
</tr>
</thead>
<tbody>
<tr>
<td>LINE ON I-80</td>
<td>Granular Subbase, 1&quot;</td>
<td></td>
<td>12</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Material Producer</th>
<th>Destination</th>
<th>Jobsite</th>
<th>Sampled At</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reilly Const.</td>
<td></td>
<td></td>
<td>Recycle Plant and off of Grade</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date Sampled</th>
<th>Sample Identification</th>
<th>Sampled By</th>
<th>Tested By</th>
<th>Sieve Analysis</th>
<th>Percent Passing</th>
<th>Other Test Results</th>
<th>Comp. Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/30</td>
<td>Lamantia, Wood, McCull</td>
<td>Abbott</td>
<td>Abbott</td>
<td>100 90 79 68 47 34 25 17</td>
<td>9.3 5.4 3.4</td>
<td>Plant</td>
<td></td>
</tr>
<tr>
<td>7/31</td>
<td>DIJL-121 &quot; Lowder</td>
<td>100 91 79 65 45 34 24 16</td>
<td>8.5 4.9 3.1</td>
<td>Plant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/31</td>
<td>DIJL-122 &quot; Lowder</td>
<td>100 94 81 66 46 35 27 19</td>
<td>12 8.4 6.2</td>
<td>Grade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8/01</td>
<td>DIJL-93 &quot; McCull</td>
<td>Abbott</td>
<td>Abbott</td>
<td>100 99 91 81 70 50 36 27 18</td>
<td>9.6 5.7 3.7</td>
<td>Plant</td>
<td></td>
</tr>
<tr>
<td>8/01</td>
<td>DIJL-94 &quot; Abbott</td>
<td>100 89 80 71 52 39 30 22 13</td>
<td>8.9 6.6</td>
<td>Grade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8/02</td>
<td>DIJL-95 &quot; Abbott</td>
<td>100 87 73 61 43 31 23 15 7.5</td>
<td>4.0 2.2</td>
<td>Plant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8/02</td>
<td>DIJL-28 &quot; Wood</td>
<td>100 89 79 67 47 34 26 19 12</td>
<td>8.5 6.4</td>
<td>Grade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8/02</td>
<td>DIJL-27 &quot; Wood</td>
<td>100 88 73 61 41 30 22 15 8.0</td>
<td>4.8 3.2</td>
<td>Plant</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note to County and Resident Engineers—If County or Project Number is incorrect, please notify Inspector and Area Office Promptly. Corrected Reports will be issued.

*AGREED by the contractor/producer

Reporting By: Harold E. McCullough
Representing: IDOT

<table>
<thead>
<tr>
<th>Date</th>
<th>Material Type</th>
<th>Source Location</th>
<th>Sec.</th>
<th>Twp.</th>
<th>Range</th>
<th>County</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/08/91</td>
<td>APPROX. 1/2 MILE EAST OF THE SCOTT COUNTY</td>
<td>Cedar County</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CERTIFICATION NUMBER

TOTAL PREVIOUSLY CERTIFIED ____________ Tons
TOTAL CERTIFIED TO DATE ____________ Tons
ESTIMATED QUANTITY ____________ Tons

Comments
Form 621276-2-69

**CERTIFIED GRADATION TEST REPORT**

**County** Cedar  
**Project** IR-80-7(57)265-12-1  
**Contractor** Fred Carlson Co.  
**Contract No.** 33011  
**Design**  
**Date** 8/08/91  
**Report No.** D1ML-189-15

**RECYCLED CR. CONC. FROM JUST W. OF THE CEDAR RIVER, EASTERLY TO APPROX. 1/2 MILE EAST OF THE SCOTT COUNTY**

**Source Name** LINE ON I-80  
**T-203A No.**  
**Source Location**  
**Sec.**  
**Twp.**  
**Range**  
**County**  
**Material** Granular Subbase, 1"  
**Class**  
**Gradation No.**  
**Beds**

**Material Producer** Reilly Const.  
**Destination**  
**Jobsite**  
**Sampled At** Recycle Plant and off of Grade

<table>
<thead>
<tr>
<th>Date Sampled</th>
<th>Sample Identification</th>
<th>Sampled By</th>
<th>Tested By</th>
<th>Sieve Analysis</th>
<th>Percent Passing</th>
<th>Other Test Results</th>
<th>Comp. Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/05</td>
<td>D1AW-29</td>
<td>Abbott</td>
<td>Wood</td>
<td>Max. 100</td>
<td>35</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Min. 10</td>
<td>0</td>
<td>0</td>
<td></td>
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<tr>
<td>8/06</td>
<td>D1RA-97</td>
<td>Garrity</td>
<td>Abbott</td>
<td>100 99 94 84 71 50 37 28 21 13 9.4 7.2</td>
<td>Grade</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note to County and Resident Engineers**—If County or Project Number is incorrect, please notify Inspector and Ames Office Promptly. Corrected Reports will be issued.

**Comments**

**ESTIMATED QUANTITY** ___________ Tons  
**TOTAL PREVIOUSLY CERTIFIED** ___________ Tons  
**TOTAL CERTIFIED TO DATE** ___________ Tons  
**CERTIFICATION NUMBER**

**Reported By**  
**Representing** IDOT

*AGREED by the contractor/producer*
## Daily Certified Gradation Test Report

### Identification of Samples

<table>
<thead>
<tr>
<th>Lab No.</th>
<th>IDENTIFICATION OF SAMPLES</th>
<th>Sieve Analysis</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>688-91</td>
<td>7/26/91</td>
<td>100 84 67 54 36 26 20 14 8.2 5.1 3.5</td>
<td>1500 ton</td>
</tr>
<tr>
<td>689</td>
<td>7/29</td>
<td>100 92 89 74 62 44 33 26 19 12 7.7 5.2 3.3</td>
<td>1500 ton</td>
</tr>
<tr>
<td>690</td>
<td>7/19</td>
<td>100 89 78 66 46 33 25 19 13 8.9 5.1 3.3</td>
<td>1500 ton</td>
</tr>
<tr>
<td>691</td>
<td>7/30</td>
<td>100 87 75 62 42 30 22 16 9.9 6.5 4.4</td>
<td>1500 ton</td>
</tr>
<tr>
<td>692</td>
<td>7/31</td>
<td>100 89 74 60 40 29 21 14 8.4 5.1 3.3</td>
<td>1500 ton</td>
</tr>
<tr>
<td>693</td>
<td>8/1</td>
<td>100 87 77 62 44 31 22 15 8.7 50.3</td>
<td>1500 ton</td>
</tr>
<tr>
<td>694</td>
<td>8/2</td>
<td>100 86 70 58 40 27 19 13 7.4 46.3</td>
<td>1500 ton</td>
</tr>
</tbody>
</table>

Note to County and Resident Engineers—If County or Project Number is incorrect, please notify Inspector and Ames Office Promptly. Corrected Reports will be issued. (Check One)

### Estimation of Quantity

- **Cu. Yd.**
- **Tons**

<table>
<thead>
<tr>
<th>ESTIMATED QUANTITY</th>
<th>10,500</th>
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</thead>
</table>

### Certification Number

- **1352**

Sampled and Tested By

**Susan S. Foltzhaus**

Representing

**Killy Construction Co., Inc.**