FINAL REPORT

FOR

PROJECT HR-1021

HIGH RANGE WATER REDUCER IN PORTLAND CEMENT CONCRETE MADE WITH D-CRACKING SUSCEPTIBLE COARSE AGGREGATE

BY

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TABLE OF CONTENTS

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INTRODUCTION

Crushed limestones and gravels are the predominate materials used for the production of coarse aggregate for concrete in Iowa. The choice is generally dictated by geographic location. In many areas of the State, crushed limestone is all that is economically available.

The quality of crushed limestone is governed by Iowa Standard Specification 4115. For years this section has limited the abrasion loss to a maximum of 50% and the 16 cycle water alcohol freeze and thaw to a maximum of 6% for crushed limestone. This criteria is quite effective in identifying most aggregates that would contribute to low quality portland cement concrete (pcc). Unfortunately, these tests do not identify aggregate that is susceptible to "D-cracking" deterioration, a serious problem in Iowa that shortens a pavement's effective life. D-cracking is used in reference to deterioration where many fine cracks develop parallel to cracks, joints or free edges of pavement slabs. There is general agreement that the type of D-cracking occuring in Iowa is primarily related to freeze-thaw failure originating in the coarse aggregate particles. Iowa's D-cracking is generally associated entirely with the failure of limestone or dolomite particles. Even when river gravel aggregates exhibit D-cracking, a petrographic analysis has identified the limestone fraction as the cause of the deterioration. Freeze and thaw testing of concrete beams by ASTM C666 procedure B (previously ASTM C291) after a 90 day moist cure, has been used to identify D-cracking susceptible (Class 1) crushed limestone. Durable (Class 2) aggregate must exhibit a durability factor of at least 80.

PROBLEM STATEMENT

There is a large area of southwest Iowa where there is no durable high quality coarse aggregate for pcc economically available. With the energy shortage and rapid increase in transportation costs, it becomes more costly to ship in high durability aggregate from other locations. There is, therefore, an increased emphasis on identifying procedures or treatments that would allow the use of lower quality aggregate while providing satisfactory performance and longevity. In general, laboratory investigation has shown that a lowering of the water-cement (W/C) ratio results in an increase in the resultant durability factor. Recently, the use of high range water reducers (HRWR) has become quite common and they are readily available from admixture companies. The use of a HRWR at a significantly lower W/C ratio will yield desired workability.

OBJECTIVE

The objective of this research was to determine if the use of a HRWR (resulting in a lower W/C ratio) with a D-cracking susceptible crushed limestone coarse aggregate would yield significant improvement in the durability.

MATERIALS

Type I cement is specified for all concrete pavement in Iowa. For laboratory work, a blend (AC8-179) of Type I cement from seven different producers is used.

A common fine aggregate for concrete, for laboratory work, is a natural sand from the Hallett Construction, Christensen pit at Ames (Sp.Gr. = 2.68). A typical gradation is:

Sieve Analysis

Sieve No.	% Passing
3/8"	100
No. 4	98
No. 8	88
No. 16	71
No. 30	44
No. 50	11
No. 100	0.9
No. 200	0.2

This research was initiated to investigate D-cracking susceptible crushed limestone coarse aggregate. The crushed limestone selected is from the Schildberg Construction Quarry at

Crescent in Pottawattamie County which historically has exhibited D-cracking deterioration in as few as 7 years. The test results for the aggregate used in this research (AAC9-62) are given in Appendix A. The gradation was:

Sieve No.	% Passing
1 1/2"	100
1"	99
3/4"	73
1/2"	39
3/8"	15
No. 4	1.0
No. 8	0.8

The air entraining admixture was a vinsol resin produced by Carter Waters as Ad Aire.

There are two types of HRWR readily available today. One HRWR of each type was selected for use in the research. Melment is a modified polycondensation product of melamine and formaldehyde. The Mighty 150 admixture is a solution of sulfoaryl alkylene product.

MIX PROPORTION

The intended application, if successful, was primarily for secondary pcc pavement which is normally Class B concrete. A

B-3 mix proportion was selected with the volumes and batch weights as:

B-3 Mix Proportions

	Absolute Volumes	Weight (lbs) per cubic yard
Cement	0.090539	479
Water	0.152017	256
Air	0.06	-
Fine Agg.	0.313850	1417
Coarse Agg.	0.383594	1713

TEST PROCEDURE

The coarse aggregate was soaked for 24 hours and dried to a saturated surface dry condition for mixing. Mixing was accomplished in a 1 3/4 cu.ft. Lancaster rotating paddle mixer. Six mixes were to be used in the research. Air content has a definite influence on the laboratory durability factor so the air entraining agent was adjusted to yield two air contents (approximately 6 & 8 1/2 %). These air contents were used with no HRWR, Melment and Mighty 150.

Nine 4 1/2" x 9" cylinders and three 4" x 4" x 18" beams were made for each of the six mixes. Two mixes were remade as the desired air was not achieved on one and low strengths were obtained on another. Three cylinders were used for compressive strength testing at 7, 14 and 28 days.

The beams were cured in 100% humidity moist room prior to freezing in air, thawing in water testing. There were eight freeze-thaw cycles per day (ASTM C-666 procedure B). The change in soundness is based on change in length and fundamental frequency (Figure 1).

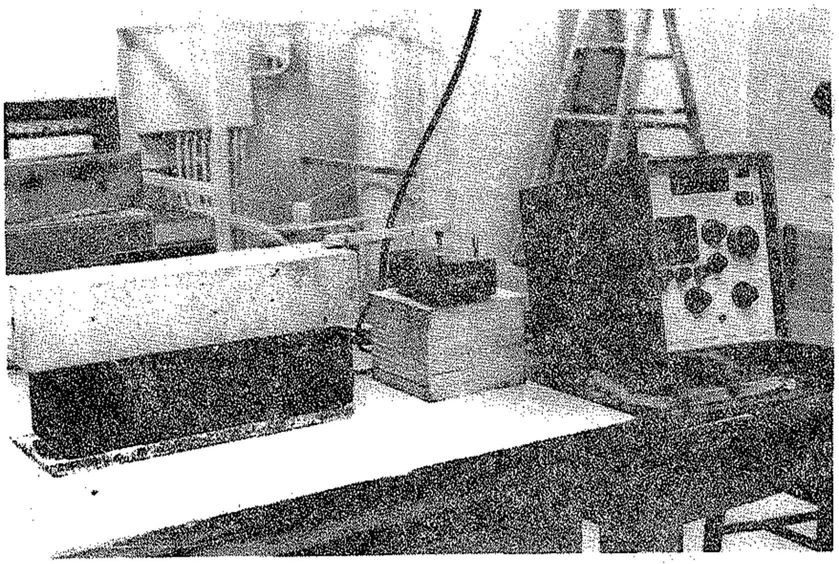

Figure 1: Apparatus for determining fundamental frequency

DISCUSSION OF RESULTS

The test results are summarized in Appendix B. The first mixes with Melment resulted in higher W/C ratios than intended. There are some variations in compressive strengths that do not relate well to the W/C ratios and air contents.

The mixes without HRWR resulted in durability factors of 31 at 8.0% air and 28 at 5.9% air. The highest durability factor of any mix using a HRWR was 32. In general, the durability factors of the HRWR mixes were lower than the mixes without HRWR. Pictures of every set of beams are taken for permanent record of physical condition (Figure 2). A sawed slice (Figure 3) is used to examine the cracking of individual coarse aggregate particles.

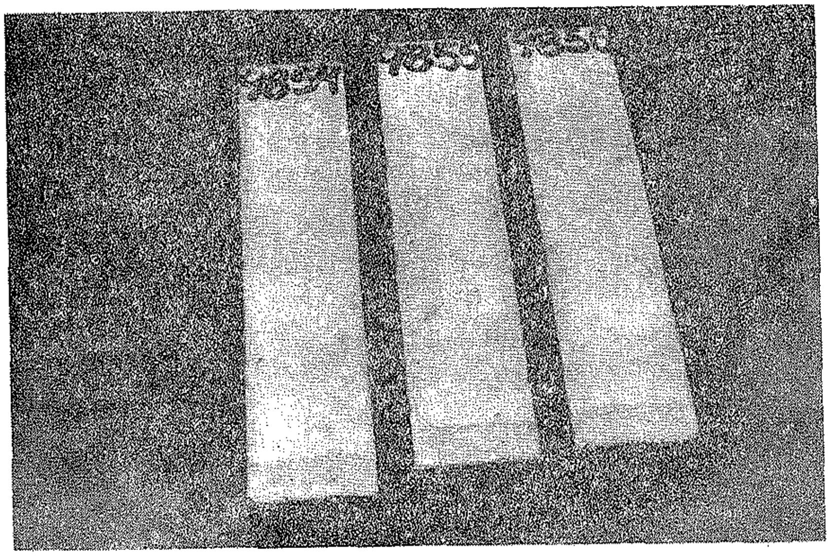

Figure 2: Freeze and thaw beams after testing

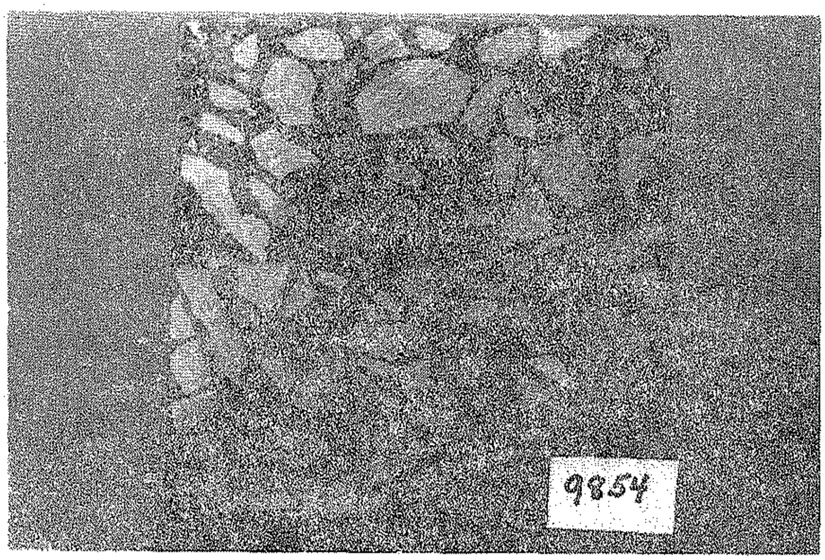

Figure 3: Sawed slice exhibiting cracks in aggregate particles.

CONCLUSIONS

It is evident from this research that:

1. HRWR did not significantly improve the durability factor of concrete made with D-cracking susceptible aggregate.

2. HRWR is not an effective treatment for use of low quality aggregate in pcc pavement.

ACKNOWLEDGEMENT

The time and effort of George Calvert, Jerry Bergren, Bernard Brown and Sam Moussalli in planning the research is appreciated.

Thanks also to the cement, concrete and aggregate sections of the Office of Materials who conducted the research under the direction of Sam Moussalli.

Appendix A

IOWA DEPARTMENT OF TRANSPORTATION
OFFICE OF MATERIALS
TEST REPORT- - MISCELLANEOUS MATERIALS
LAB LOCATION AMES

MATERIAL CRUSHED STONE LAB NO. AAC9-62

INTENDED USE CONCRETE RESEARCH

COUNTY POTTAWATTAMIE PROJ NO.

DESIGN CONTRACT NO.

PRODUCER SCHILDBERG CONSTR. CONTRACTOR

SOURCE CRESCENT QR. 34/35 76-44 POTTAWATTAMIE CO.

UNIT OF MATERIAL 15 BAGS TO BE USED FOR "D" CRACKING RESEARCH PROJECT

SAMPLED BY GARY SCHOENROCK SENDERS' NO.

DATE SAMPLED 4-10-79 REC'D 4-11-79 REPORTED 4-17-79

% PSG. #8 AFTER 16 CYCLES, F&T, WATER-ALC. SOL.	2
% WEAR, LA ABRASION, GRADING B	25
SPECIFIC GRAVITY (S.S.D.)	2.628
% ABSORPTION (S.S.D.)	1.90

COPIES:
CRUSHED STONE
V. R. SNYDER
SAM MOUSSALLI
GEOLOGY

DISPOSITION:

SIGNED: BERNARD C. BROWN
TESTING ENGINEER

TEST RESULTS SUMMARY

Specimen No.	High Range Water Reducer	W/C Ratio	Slump Inches	Air %	Strength PSI 7	14	28	Durability Factor
9833 to 9844	None	0.534	2.0"	8.0	2940	3520	3960	31
9845 to 9856	None	0.534	1 3/4	5.9	4020	4630	5110	28
9857 to 9869	Melment	0.469	2 1/4	6.4	3440	3980	4380	32
9870 to 9881	Melment	0.469	2.0	8.0	3520	3900	4380	27
9906 to 9917	Melment	0.350	3 1/2	5.8	4110	4500	5260	9.3
9918 to 9929	Melment	0.350	2 3/4	9.0	5180	6080	7040	25
9882 to 9893	Mighty 150	0.334	1 3/4	8.75	4940	5260	5800	16
9894 to 9905	Mighty 150	0.338	2.0	5.75	4480	5200	5660	21