IOWA STATE HIGHWAY COMMISSION

MATERIALS DEPARTMENT
SPECIAL INVESTIGATIONS SECTION

FINAL REPORT OF R-255

AN INVESTIGATION OF PORTLAND CEMENT CONCRETE UTILIZING 70% CLASS V AGGREGATE AND 30% CALCAREOUS COARSE AGGREGATE

JULY 20, 1973

IOWA STATE HIGHWAY COMMISSION
Materials Department

AMES LABORATORY

AN INVESTIGATION OF PORTLAND CEMENT CONCRETE UTILIZING 70% CLASS V AGGREGATE AND 30% CALCAREOUS COARSE AGGREGATE

R-255

July 20, 1973

Materials Laboratory

By

Terry Legvold

TABLE OF CONTENTS

1.0 INTRODUCTION

The main sources of coarse aggregate for secondary slip form paving in Southwest Iowa exhibit undesirable "D" cracking. "D" cracking is a discoloration of the concrete caused by fine, hairline cracks. These cracks are caused by the freezing and thawing of moisture inside the coarse aggregate. The cracks are often hour glass shaped, are parallel to each other, and occur along saw joints.

The B-4, a typical secondary mix, utilizes 50% fine aggregate and 50% coarse aggregate. It has been proposed that a concrete mix with less coarse aggregate and more fine aggregate might impede this type of deterioration. The Nebraska Standard 47B Mix, a 70% fine aggregate, and 30% coarse aggregate mix, as used by Nebraska Department of Roads produces concrete with ultimate strengths in excess of 4500 psi but because of the higher cost of cement (it is a six bag per cubic yard mix) is not competitive with our present secondary mixes.

The sands of Southwest Iowa generally have poorer mortar strengths than the average Iowa Sand. Class V Aggregate also found in Southwest Iowa has a coarser sand fraction, therefore it has a better mortar strength, but exhibits and acidic reaction and therefore must be used with limestone. This illustrates the need to find a mix for use in Southwest Iowa that possesses adequate strength and satisfactory durability at a low cost.

2.0 PURPOSE

The purpose of this study is to determine a concrete mix with an acceptable cement content which will produce physical properties similar to that of our present secondary paving mixes.

3.0 MATERIALS

One of the materials used was Class V Aggregate for concrete meeting the requirements of Section 4117 of the Standard Specifications. Class V Aggregate tested under two separate lab numbers, AAS2-8 and AAS3-8, was used. These aggregates had the following properties:

SIEVE ANALYSIS

Sieve No.	% Passing	
	AAS2-8	AAS3-8
1/2"	100	100
3/8"	99	99
#4	88	90
#8	62	69
#16	46	47
#30	31	28
#50	15	9.1
#100	2.8	1.3
#200	0.4	0.5
Mortar Strength	2.18	1.99
Specific Gravity	2.618	2.618

The fine aggregate (Standard Specification 4110) used was sand from Shenandoah, Iowa, (AAS3-15). This aggregate had the following properties:

SIEVE ANALYSIS

Sieve No.	% Passing
1/2"	100
#4	98
#8	90
#16	78
#30	52
#50	14
#100	1.3
#200	0.7

Mortar Strength - 1.53 Specific Gravity - 2.639

One of the coarse aggregates used was limestone from Hopper Brother's Quarry at Weeping Water, Nebraska. Aggregate tested under different lab numbers (AAC2-1 and AAC3-7) was used. The aggregate had the following properties:

GILSON SIEVE ANALYSIS

Sieve No.	% Passing	
	AAC2-1	AAC3-7
1"	100	100
3/4"	83	91
1/2"	52	63
3/8"	23	32
#4	0	0
Specific Gravity	2.693	2.70

The other coarse aggregate used was limestone from Schildberg's Cresent Quarry which met the grading limits of AASHO-57. This aggregate was also tested under two different lab numbers (AAC2-4 and AAC2-20). The following are the properties for these aggregates:

GILSON SIEVE ANALYSIS

Sieve No.	% Passing	
	AAC2-4	AAC2-20
1"	100	100
3/4"	81	81
1/2"	52	52
3/8"	20	20
#4	0	0
Specific Gravity	2.640	2.640

A blend of Type I Cement (ACO-149 or AC2-95) from seven different producers (R-11 Blend) was used.

The air entraining agent used was Ad-Aire (ACA9-24) produced by Carter-Waters of Kansas City, Missouri.

EXPERIMENTAL CONCRETE MIXES

CEMENT		AIR	CLASS V		COARSE AGG.		WATER	
Sacks	Abs. Vol.	Abs. Vol.	Cu. Ft.	Abs. Ft.	Cu. Ft.	Abs. Vol.	Cu. Ft.	Abs. Vol.
6	0.107	0.06	12.60	0.466	5.4	0.200	4.5	0.167
5.5	0.098	0.06	13.18	0.488	5.66	0.209	3.9	0.145
5.0	0.089	0.06	13.63	0.505	5.85	0.218	3.5	0.128
4.5	0.080	0.06	14.01	0.518	6.01	0.222	3.2	0.120

BATCH WEIGHTS

CEMENT Lbs.	AIR %	CLASS V Lbs.	COARSE AGG. Lbs.	WATER Lbs.
564	6	2060	*889.6 **909.8	281
517	6	2155	*932.4 **953.6	243
470	6	2228	*963.7 **966.2	218
423	6	2290	*990.1 **1012.1	200

* Schieldberg's Quarry ** Hopper's Quarry

4.0 LABORATORY PROCEDURE

The concrete mixes tested had limits of 2±1/2 on slump and 6±1% on air content. The cement contents of the experimental mixes were disigned at 4.5, 5.0, 5.5 and 6.0 bags per cubic yard. These experimental mixes had approximately 70% Class V Aggregate and 30% Crushed Limestone. The amount of air entraining agent was adjusted to yield the desired air for each mix.

The standard mixing procedure was:

1. Proportion sand and cement
2. Mix for one minute
3. Proportion coarse aggregate
4. Mix for one minute
5. Add water and air entraining agent while mixing for three minutes and adjusting the slump to 2±1/2 inches.

For this study the B-4, a typical secondary paving mix, was used as the control.

Two B-4 mixes were made with each coarse aggregate. One of these mixes used the portion of the Class V material passing the #4 screen as the fine aggregate while the other mix used the Shenandoah Sand as the fine aggregate. There were two mixes, one with Hopper's and one with Schildberg's coarse aggregate, made using each experimental mix porportion.

Three 6" x 12" cylinders were made from each of the above concrete mixes. After curing for 28 days in the moist room a compressive strength test was made on each set of cylinders.

Three 4" x 4" x 18" beams were made from each mix also. After curing for 90 days in the moist room, durability tests utilizing freezing in air and thawing in water were conducted. The ASTM C-666 Procedure B Method was used except that eighteen inch beams were used instead of the specified 14-16 inch beams and they were not weighed.

There were four mixes where the air content was over the specified limit. These results were discarded and these tests were rerun.

5.0 INTERPRETATION OF RESULTS

The results of the freeze-thaw tests and the 28 day compressive strength tests are shown in Table I. The B-4 mixes using Hopper's and Schildberg's aggregate with Shenandoah sand did not have durability tests made because the durability results were evident from the previous results. Table II shows the results of the mixes where the air content was out of the specifications. Since the air content was out of the specifications these results are considered invalid and will not be discussed further.

The 4.5 sack/yard^3 experimental mix with Hopper's coarse aggregate was remixed but cylinders were not made due to insufficient material.

A definite relationship is shown in Figure 1 and Figure 2 when compressive strengths are plotted against cement factors. As expected the compressive strength increases as the cement factor increases. The figures also show that the B-4 mixes using the Class V sand have higher compressive strengths (4825 psi with Schildberg's and 4800 psi with Hopper's aggregate) than the B-4 mixes using the Shenandoah Sand (3975 psi with Schildberg's and 4105 psi with Hopper's aggregate). This is because the Class V sand has a mortar strength of about 2.00 as compared to a mortar strength of 1.53 for the Shenandoah Sand.

To obtain compressive strengths from the experimental mixes that compare favorably with the compressive strengths of the B-4 mixes using Class V sand you have to go to mixes with a higher cement factor, 6.30 sack/yard^3 with Hopper's coarse aggregate to 6.80 sacks/yard^3 with Schildberg's coarse aggregate. These higher cement factors would yield a mix that would not be competitive with our present secondary mixes.

An experimental mix with a much lower cement factor was found to have compressive strengths similar to those of the B-4 mixes made with the Shenandoah Sand. These cement factors were 4.82 sacks/yard^3 in mixes using Schildberg's coarse aggregate and 4.79 sacks/yard^3 in mixes using Hopper's coarse aggregate. This indicates that the experimental mixes with cement factors of about 4.8 sacks/yard^3 should yield strengths similar to those of the B-4 mixes using Southwest Iowa sands.

There is no definite trend apparent in the durability factors of the experimental mixes. The durability factors ranged from 30 to 52 in the mixes using Schildberg's coarse aggregate and 67 to 88 in the mixes using Hopper's coarse aggregate. Schildberg's coarse aggregate has always been known to have lower durability factors, and the experimental mixes didn't seem to alter this tendancy as the beams made with Schildberg's aggregate have lower durability factors again. The difference in the durability factors of the two coarse aggregates and the fact that there was no trend apparent in the durability factor of the experimental mixes indicates that durability factor depends primarily on the coarse aggregate and much less on the cement factor, even at these lower fractions of coarse aggregate.

6.0 SUMMARY

In summary the following is evident:

1. The B-4 mixes made with the Shenandoah Sand have lower compressive strengths than the B-4 mixes made with the -4 fraction of the Class V material.
2. The experimental mixes with a 4.79 to a 4.82 sack/yard^3 cement factor have compressive strengths similar to the compressive strengths of the B-4 mix using the Shenandoah Sand with graphs showing that a 4.8 sack/yard^3 mix would have properties equivalent to the properties of the B-4 mix.
3. In this study the durability factor generally is not dependent on the cement factor.

Table I

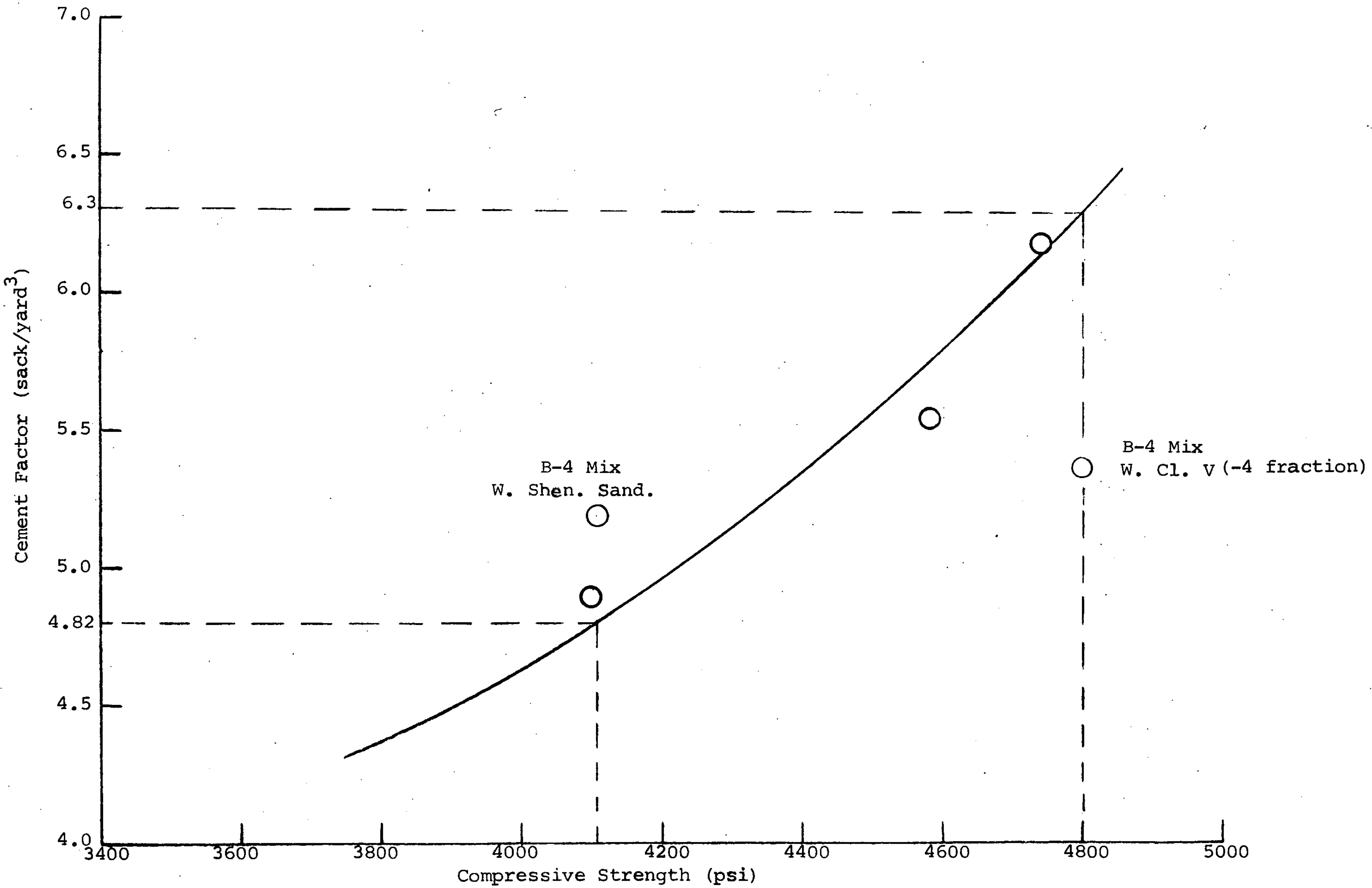
Mix	Cement Factor	Air Content	Slump In.	Cyl. Nos.	Strength 28 day PSI	Beam No.	D.F.	Growth	Cycles	Coarse Aggregate
B-4 with Class V Sand	5.44	5.3	2.0	5390-2	4825	273	47	.165	293	Schildberg Crescent
B-4 with Shenandoah Sand	5.23	5.9	1.75	5699-5701	3975					" "
70% Cl. V 30% Cr. L.	4.47	6.2	1.5	5387-9	3660	272	52	.184	293	" "
"	4.91	6.0	1.75	5384-86	4090	271	35	.263	293	" "
"	5.49	6.1	1.5	5411-13	4305	280	30	.228	195	" "
"	6.13	6.3	1.75	5408-10	4585	279	36	.206	219	" "
B-4 with Class V Sand	5.38	5.6	2.0	5693-95	4800					Hopper Weeping Water
B-4 with Shenandoah Sand	5.20	6.4	2.0	5696-98	4105					" " "
70% Cl. V 30% Cr. L.	4.36	5.7	1.75			281	88	.047	300	" " "
"	4.89	6.5	2.0	5399-5401	4100	276	67	.131	300	" " "
"	5.53	5.6	1.5	5396-98	4585	275	76	.124	300	" " "
"	6.17	6.2	2.25	5383-95	4745	274	84	.085	300	" " "

Table II

Mix	Cement Factor	Air Content	Slump In.	Cyl. Nos.	Strength 28 Day PSI	Beam No.	D.F.	Growth	Cycles	Coarse Aggregate
70% Cl. V 30% Cr. L.	5.41	7.7	3.0	5381-83	4035	270	50	.253	293	Schildberg Crescent
"	6.03	7.7	4.0	5378-80	4005	269	40	.339	293	" "
B-4 with Class V Sand	5.33	7.2	2.5	5405-07	4605	278	82	.069	300	Hopper Weeping Water
70% Cl. V 30% Cr. L.	4.31	7.2	2.0	5402-04	3700	277	77	.076	300	" " "

Cement Factor v.s. Compressive Strength
Mixes with Hopper's aggregate

Figure 1



Cement Factor v.s. Compressive Strength
Mixes with Schildberg's Aggregate

Figure 2