DEPARTMENT OF TRANSPORTATION

DIVISION OF HIGHWAYS

OFFICE OF MATERIALS

Geology Section

Research Project R-258
Final Report

DURABILITY OF CONCRETE AS AFFECTED BY VARIATIONS IN AIR AND W/C RATIO

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Author:
Wendell Dubberke
Geologist
515-296-1339

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1.0 INTRODUCTION

Many times during the past four years we have seen ranges in the durability factor for a single coarse aggregate source that were too great to be explained by variations in the coarse aggregate alone. The durability test (ASTM C 666 Method B) as presently used is a test of the concrete system rather than that of a particular coarse aggregate. An informal study of current durability factor data indicates that w/c ratio and/or percentage of air may be critical to beam growth and durability factor.

2.0 PURPOSE

The purpose of this project, R-258, is to determine the extent w/c ratio and air content variations have on beam growth and durability factor when other factors including coarse aggregate gradation are held constant.

3.0 MATERIALS

Hallett's sand, Ad-Aire, R-11 blend cement and the following four PCC limestone coarse aggregate sources will be used for this investigation.

A. Sedgwick Quarry - (Sp.G. - 2.64) This is a fine grained, vuggy dolomite from Delaware County. The coarse aggregate voids appear to afford frost-protection

characteristics to the concrete system, as well as to the aggregate itself.

B. Alden Quarry - (Sp.G. - 2.56) This is a coarse grained, crinoidal limestone from Hardin County. It appears to have frost-protection characteristics only slightly in excess of what would be needed to protect itself.

C. Kerford Quarry - (Sp.G. - 2.70) This is a fine grained limestone from eastern Nebraska. It is a dense, low-absorption stone that is durable in itself, but cannot afford any frost-protection characteristics to the concrete system.

D. Crescent Quarry - (Sp.G. - 2.64) This is a fine grained limestone from Pottawattamie County. It is a dense stone with low to moderate absorption and has a poor service record when used in PCC. This stone is able to take on significant amounts of water but only at a slow rate. Consequently, when sufficiently saturated with water it will fracture when subjected to freezing and thawing.

4.0 LABORATORY PROCEDURE

A. Test Method for Varying the Air Content Only:

The absolute volumes for a C-3 mix as given in the Standard Specifications will be used. The weights for each material are:

Cement		17.78 lbs.
Water	(all beams)	7.20 lbs.
Sand		37.72 lbs.

COARSE AGGREGATE	SOURCE			
Gradation	Sedgwick	Alden	W.Water	Crescent
1"-3/4"	11.43	11.08	11.69	11.43
3/4"-1/2"	11.44	11.09	11.69	11.44
1/2"-3/8"	11.43	11.09	11.69	11.43
3/8"-#4	11.43	11.08	11.69	11.43
Total lbs.	45.73	44.34	46.76	45.73

Ad-Aire	(3 beams)	1/4 oz/sk
Ad-Aire	(3 beams)	1/2 oz/sk
Ad-Aire	(3 beams)	3/4 oz/sk
Ad-Aire	(3 beams)	1 oz/sk
Ad-Aire	(3 beams)	1-1/4 oz/sk

B. Test Method for Varying the Water Only:

The batch weights used for this part of the study will be as given above with the following exceptions:

Water	(3 beams)	(w/c .400)	6.71 lbs.
Water	(3 beams)	(w/c .429)	7.20 lbs.
Water	(3 beams)	(w/c .450)	7.55 lbs.
Water	(3 beams)	(w/c .475)	7.97 lbs.
Water	(3 beams)	(w/c .500)	8.39 lbs.
Ad-Aire	(all beams)		3/4 oz/sk

C. Standard F&T 'A', Abrasion, Absorption, and Specific Gravity Tests will be Run on all Four Coarse Aggregate Sources.

5.0 INTERPRETATION OF RESULTS

The durability factors, percentage of growth, and related mix information are tabulated in Table I. The durability test (freezing in air and thawing in water, ASTM C 666 Method B) was continued for 300 cycles or until the dynamic modulus was reduced to 60% of the original modulus, whichever occurred first.

One of the purposes of this research project was to determine if variations in air or w/c ratio were partially responsible for some of the irregular results that we were experiencing from the durability test. While testing the second batch of beams made with Crescent stone we experienced abnormally high readings on all five sets of beams, especially the last two (Beam #s 308 & 309). The indication of an abnormally high final result on the above beams was observed while the testing was in progress and failure of the hardware was immediately suspected. A detailed check of the equipment indicated that all systems were functioning properly.

Since we were unable to determine if a new batch of PCC sand was collected and incorporated into the second group of Crescent beams, it was decided that we would rerun the

last two sets of beams (#s 308 & 309) using the standard fine aggregate, as well as, a superior fine aggregate (Bellevue sand) to determine if the fine aggregate was responsible for the variability in the freezer read-out.

The increase in durability afforded by the use of Bellevue fine aggregate was of insufficient magnitude to explain the radical difference experienced in the initial tests.

A check on the records indicated that a new batch of R-11-Z cement had been blended during the middle of the 1972 year and by coincidence the Cement Lab experienced some temporary problems when switching over to the new batch of R-11-Z blend cement during June and July of the same year. The people in the Cement Lab felt that the "fluffiness" of the new blend was responsible for the temporary problems that they experienced.

I now wonder if the fluffiness and/or partial hydration of the cement in the barrels might be responsible for some of the variations we experienced in our durability read-outs.

For what it is worth, the table of results is attached to the end of this report. It seems that everything mixed after July 5th went higher than expected.

6.0 SUMMARY

In conclusion:

1) Since we were unable to obtain reproducible results from these tests, no comment will be made on the attached table.

2) While the timing of the problem experienced by the Cement Lab and by the Special Investigations Lab (concerning the R-11-Z blend cement?) may be merely coincidental, I would recommend that a comparison be made by mixing beams using Crescent stone with both old and new R-11-Z blend cement.

Name	No.	Ratio	AEA Sack	Air				Frequency	Date 1972
Sedgwick	282	.429	1/4	4.4	96	.009	3/4	1853	04/25
	283	.429	1/2	5.2	96	.008	3/4	1850	04/25
	284	.429	3/4	5.7	95	.008	1 0/0	1850	04/25
	285	.429	1 0/0	6.1	96	.008	1 0/0	1810	04/26
	286	.429	1 1/4	6.4	96	.009	1 1/4	1830	04/26
Sedgwick	287	.400	3/4	4.8	95	.010	1/4	1860	05/03
	288	.429	3/4	5.2	95	.008	1 1/4	1837	05/0[illegible]
	289	.450	3/4	5.5	97	.009	1 1/4	1823	05/09
	290	.475	3/4	6.4	95	.009	2 1/2	1817	05/09
	291	.500	3/4	7.2	96	.009	3 1/2	1777	05/09
Crescent	293	.429	1/4	3.2	30	.178	3/4	1870	06/05
	294	.429	1/2	4.4	35	.132	1 0/0	1840	06/05
	295	.429	3/4	4.8	35	.114	1 1/4	1837	06/05
	296	.429	1 0/0	5.1	48	.091	1 1/4	1833	06/06
	297	.429	1 1/4	6.2	73	.078	1 1/2	1817	06/06
Crescent	305	.400	3/4	3.5	73	.090	1/4	1890	07/05
	306	.429	3/4	4.7	50	.107	3/4	1837	07/05
	307	.450	3/4	5.0	53	.124	1 1/2	1820	07/05
	*308	.475	3/4	5.9	90	.039	3 0/0	1783	07/06
	**309	.500	3/4	6.4	90	.056	4 1/2	1760	07/06
Alden	312	.429	1/4	4.3	93	.016	1/2	1743	07/17
	313	.429	1/2	4.6	93	.011	1 0/0	1733	07/17
	314	.429	3/4	4.9	94	.009	1 0/0	1730	07/17
	315	.429	1 0/0	5.0	93	.012	3/4	1720	07/18
	316	.429	1 1/4	5.5	95	.011	1 0/0	1703	07/18
Alden	318	.400	3/4	4.4	95	.015	1/2	1743	08/02
	319	.429	3/4	5.0	97	.018	1 1/2	1703	08/02
	320	.450	3/4	5.2	91	.014	1 3/4	1733	08/22
	321	.475	3/4	6.0	90	.013	3 0/0	1717	08/22
	322	.500	3/4	7.0	92	.015	5 0/0	1670	08/22
Kerford	323	.429	1/4	3.3	89	.058	1 1/4	1887	08/23
	324	.429	1/2	4.3	91	.027	2 0/0	1860	08/23
	325	.429	3/4	4.3	94	.021	1 1/4	1857	08/30
	326	.429	1 0/0	5.2	93	.023	1 1/2	1837	08/30
	332	.429	1 1/4	5.2	93	.028	1 1/4	1800	09/27
Kerford	333	.400	3/4	4.1	91	.047	1/2	1883	09/27
	334	.429	3/4	4.2	93	.037	1 1/2	1833	09/27
	335	.450	3/4	5.2	95	.026	2 0/0	1817	10/03
	336	.475	3/4	5.3	91	.029	4 0/0	1793	10/03
	337	.500	3/4	5.4	89	.043	6 0/0	1790	10/03
*Rerun #308	366	.475	3/4	5.3	30	.151	3 0/0	1823	
**Rerun #309	367	.500	3/4	5.6	25	.142	5 0/0	1793	
*Rerun #308	377	.475	3/4	5.7	45	.113	6 3/4	Bellevue sand	
**Rerun #309	378	.500	1 1/4	6.7	48	.127	6 +	Bellevue sand	