Final Report
for
Materials Laboratory Research
Project MLR-85-9

LENGTH CHANGE OF P.C. CONCRETE DUE TO MOISTURE CONTENT

by
Vernon J. Marks
515-239-1447
Office of Materials
Highway Division
Iowa Department of Transportation
Ames, Iowa 50010

March 1987

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ABSTRACT

Portland cement concrete is an outstanding structural material but stresses and cracks often occur in large structures due to drying shrinkage. The objective of this research was to determine the change in length due to loss of moisture from placement through complete drying of portland cement concrete.

The drying shrinkage was determined for four different combinations of Iowa DOT structural concrete mix proportions and materials. The two mix proportions used were an Iowa DOT D57 (bridge deck mix proportions) and a water reduced modified C4 mix. Three 4"x4"x18" beams were made for each mix. After moist curing for three days, all beams were maintained in laboratory dry air and the length and weight were measured at 73°F ± 3°F. The temperature was cycled on alternate days from 73°F to 90°F through four months. From four months through six months, the temperature was cycled one day at 73°F and six days at 130°F. It took approximately six months for the concrete to reach a dry condition with these temperatures.

The total drying shrinkage for the four mixes varied from .0106 in. to .0133 in. with an average of .0120 in. The rate of shrinkage was approximately .014% shrinkage per 1% moisture loss for all four mixes. The rate and total shrinkage for all four mixes was very similar and did not seem to depend on the type of coarse aggregate or the use of a retarder.

INTRODUCTION

For years, portland cement concrete (pcc) has been an outstanding material for use in structures. Today, reinforced concrete is used for segmental construction of very impressive bridge structures. There is one characteristic, however, of pcc that continues to pose a problem in its use for large structures. As the water used to allow mixing and placement of the concrete begins to leave and the concrete drys out, the concrete shrinks. This shrinkage results in stresses and quite often cracks in the structure.

OBJECTIVE

The objective of this research was to determine the change in length due to loss of moisture from placement through complete drying of pcc.

MATERIALS

All portland cement used in this research (AC6-350) was a blend of Type I from ten different producers. The fine aggregate (AAS5-126) for all four mixes was a natural sand from the Moline Consumers Company Pit on the Mississippi River at Cordova, Illinois. The air entraining agent (ACA6-9) was Carter-Waters single strength Ad Aire which is a neutralized vinsol resin. The retarder (ACI6-1) for mix #2 was a Pozzolith 100XR produced by Master Builders. Three different coarse aggregates were used for the research. Crushed limestone from the Alpha Crushed Stone, Inc. Bowser Springville Quarry (AAC5-753) in Linn Couny was used for mixes #1 and #2. The coarse aggregate for mix #3 was from the Nieman Construction Company Quarry at Waucoma (AAC5-752) in Fayette County and the coarse aggregate for mix #4 was a

gravel from the Martin-Marietta Pit at West Des Moines (AAG5-177) in Polk County.

MIX PROPORTIONS

The two mix proportions used for this research were as shown below for the Iowa DOT D57 and modified C4 mixes:

Mix Proportions

Absolute Volumes

Material	D-57	Modified C-4
Cement	0.134209	0.118330
Water	0.172781	0.147022
Fine Aggregate	0.316505	0.337324
Coarse Aggregate	0.316505	0.337324
Entrained Air	0.06	0.06

The actual batch weights per cubic foot and the test data on the consistency of the concrete are as follows:

Actual Batch Weights (per cu.ft.) and Test Data

Mix Proportions	Mix 1 D-57	Mix 2 Modified C-4	Mix 3 D-57	Mix 4 D-57
Cement (lbs)	26.3	23.2	26.3	26.3
Water (lbs)	10.1	8.4	10.1	10.0
Fine Agg. (lbs)	52.9	56.4	52.9	52.9
Coarse Agg. (lbs)	49.2	52.4	53.1	52.9
Coarse Agg. Source	Bowser Springville	Bowser Springville	Waucoma	Martin-Mar. W.Des Moines
Coarse Agg. Sp. Gr.	2.49	2.49	2.69	2.68
Air Agent (cc)	4.96	4.38	7.44	7.43
Retarder (cc)	None	20.57	None	None
Slump (inches)	2 1/4	2 1/2	2 1/2	2 1/4
Air Content (%)	6.4	6.4	6.8	6.5
Unit Weight(lb/cu.ft.)	43.5	43.4	44.1	44.3

RESEARCH PROCEDURE

All concrete was mixed in a 1 3/4 cu. ft. Lancaster paddle-type mixer on June 9, 1986. A D57 proportion was used for mix #1 with a crushed limestone with a relatively high absorption from the Bowser Springville Quarry. Mix #2 utilized the same coarse aggregate but used a modified C4 proportion with a retarder. Mix #3 used a D57 proportion but a crushed limestone with a relatively low absorption from the Waucoma Quarry in Fayette County. A gravel coarse aggregate from the Martin-Marietta Pit at West Des Moines was used for mix #4.

Three 4"x4"x18" beams with brass buttons (for length measurements) were made for each of the four mixes. All beams were cured for the first 24 hours in the steel forms covered with a moist cloth and plastic. The beams were stripped when they were 24 hours old and placed in a moist room through 72 hours. The moist room was maintained at 73°F ± 3°F with a 100% humidity. At the age of 72 hours, all beams were removed from the moist room and stored in laboratory air at 73°F ± 3°F through 21 days. At an age of 21 days, all beams were placed in an oven and cycled for 24 hours at 90°F ± 3°F followed by 24 hours at 73°F ± 3°F. All lengths and weights were measured at the end of the 24 hours of 73°F ± 3°F. Cycling of 90°F and 73°F was continued through 121 days. At the age of 121 days, a temperature of 130°F was used except for the 24 hours prior to the weighing and measuring when the temperature was 73°F ± 3°F.

DISCUSSION OF RESULTS

The total shrinkage (Appendix A) on the beams varied from .0106 in. to .0133 in. with an average of .0120 in. (0.067%) for the 18 in. long beam specimens. These four mixes exhibited a relatively small variation in the total shrinkage. All of these mixes were between 2 1/4" and 2 1/2" in slump. The rate of drying shrinkage was also relatively uniform and was approximately .014% shrinkage per 1% moisture loss (Appendix B1).

The moisture loss (Appendix B2) was more rapid at an early age below 40 days and was less but relatively uniform from 40 through 140 days and then as the beams became nearly dry, the moisture loss became very small. One interesting result was that at slightly elevated temperatures, it took over six months for the beams to become dry.

The rate of shrinkage (Appendix B3) was more rapid through approximately 60 days and then at a lesser rate from 60 through 200 days.

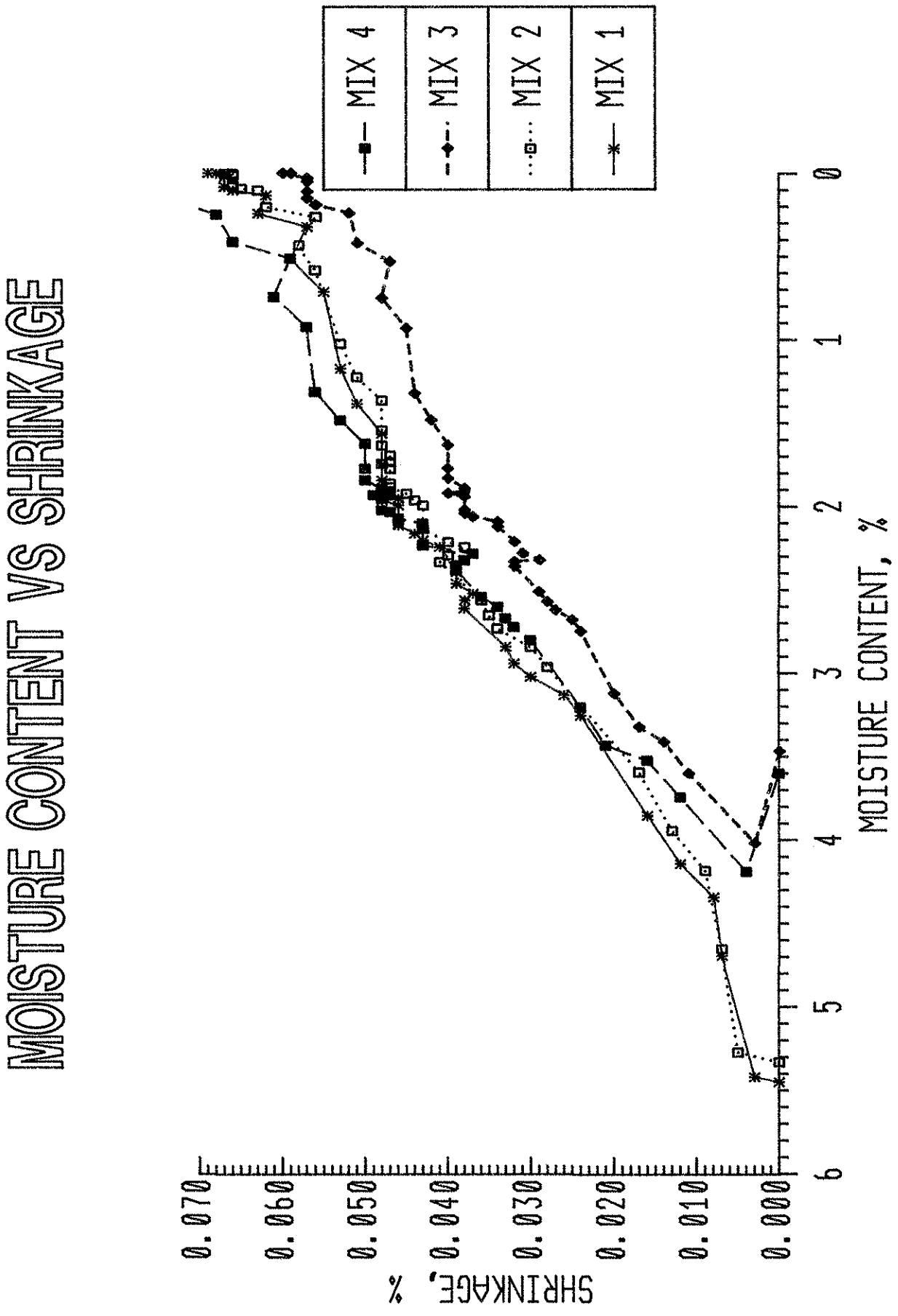
CONCLUSIONS

From this research on shrinkage of Iowa portland cement structural concrete mixes due to moisture content, it is evident that:

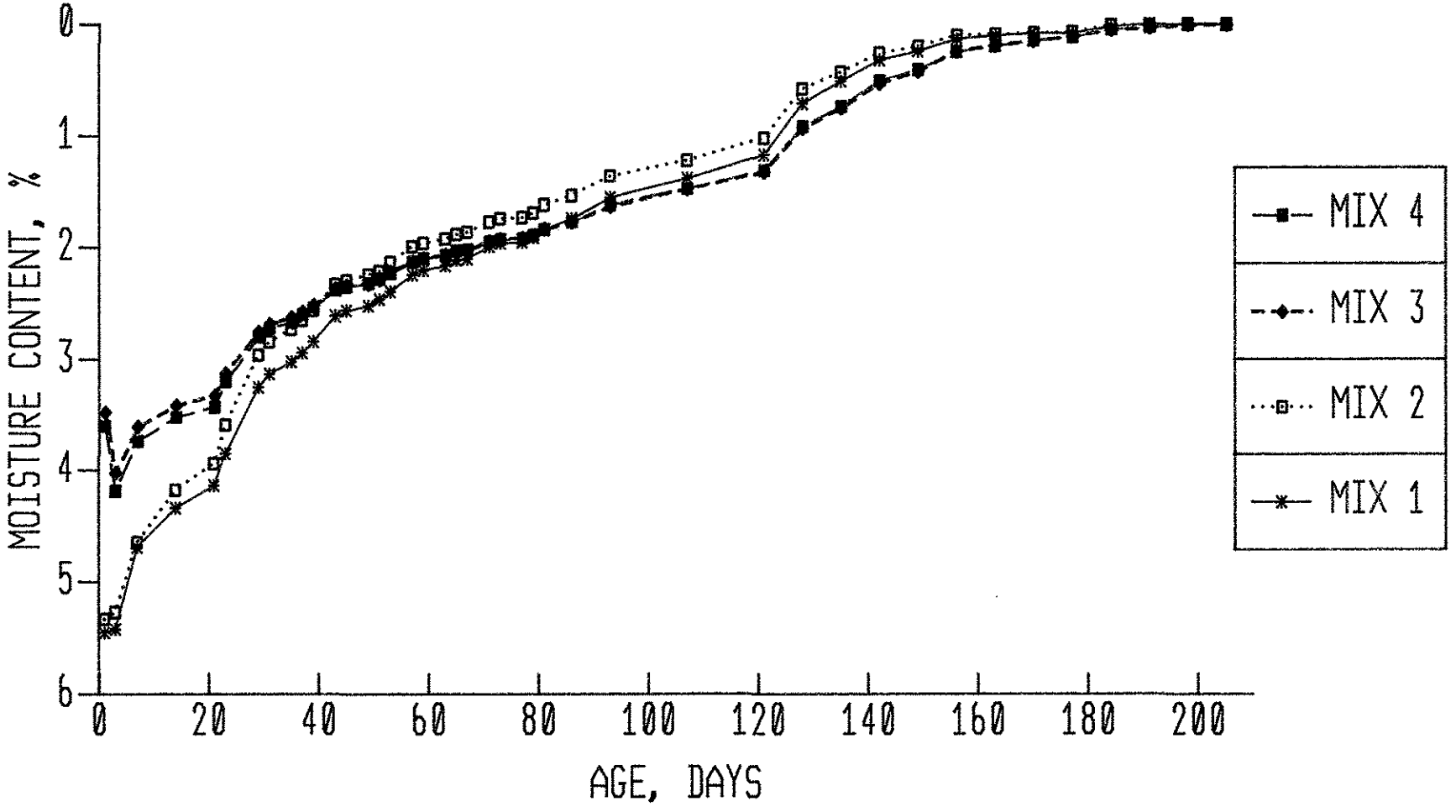
1. The total drying shrinkage of the relatively low slump Iowa DOT bridge deck concrete is relatively constant at approximately 0.07 of a percent.
2. Based upon this research, the type of coarse aggregate, cement content or use of a retarder has little influence on the total drying shrinkage that occurs in portland cement concrete.

Summary of Length Change Vs Moisture Loss
(Average of three beams)

	Mix 1		Mix 2		Mix 3		Mix 4	
Age Days	Weight grams	Length change inches	Weight grams	Length change inches	Weight grams	Length change inches	Weight grams	Length change inches
1	10,918	.0329	10,828	.0239	11,080	.0301	11,066	.0316
3	10,915	.0323	10,822	.0230	11,138	.0295	11,129	.0308
7	10,840	.0316	10,758	.0226	11,093	.0282	11,080	.0294
14	10,803	.0314	10,710	.0222	11,073	.0276	11,057	.0287
21	10,783	.0307	10,685	.0215	11,064	.0270	11,047	.0279
23	10,753	.0301	10,649	.0208	11,042	.0265	11,023	.0273
29	10,691	.0285	10,584	.0188	11,003	.0257	10,980	.0262
31	10,678	.0282	10,572	.0185	10,995	.0256	10,972	.0259
35	10,667	.0275	10,561	.0178	10,989	.0252	10,966	.0256
37	10,658	.0272	10,552	.0176	10,983	.0251	10,959	.0255
39	10,648	.0270	10,593	.0174	10,977	.0249	10.952	.0252
43	10,624	.0260	10,520	.0166	10,961	.0243	10.935	.0245
45	10,619	.0261	10,515	.0167	10,958	.0244	10,932	.0245
49	10,615	.0263	10,510	.0170	10,956	.0248	10,929	.0248
51	10,609	.0259	10,507	.0167	10,952	.0246	10,925	.0249
53	10,601	.0258	10,499	.0162	10,945	.0243	10,919	.0238
57	10,586	.0255	10,485	.0162	10,935	.0240	10,909	.0239
59	10,582	.0252	10,481	.0160	10,932	.0239	10,905	.0238
63	10,578	.0249	10,477	.0158	10,929	.0235	10,902	.0233
65	10,572	.0247	10,473	.0155	10,926	.0233	10,898	.0231
67	10,571	.0246	10,471	.0154	10,924	.0232	10,897	.0230
71	10,560	.0246	10,462	.0154	10,916	.0232	10,889	.0230
73	10,557	.0242	10,459	.0152	10,914	.0229	10,887	.0227
77	10,556	.0246	10,458	.0155	10,913	.0233	10,886	.0231
79	10,552	.0245	10,454	.0155	10,910	.0232	10,883	.0229
81	10,545	.0242	10,447	.0152	10,904	.0229	10,877	.0226
86	10,534	.0242	10,438	.0152	10,897	.0229	10,870	.0226
93	10,516	.0242	10,420	.0152	10,883	.0229	10,854	.0226
100	10,503	-----	10,410	-----	10,873	-----	10,845	-----
107	10,497	.0238	10,405	.0148	10,867	.0225	10,839	.0220
114	10,485	-----	10,393	-----	10,856	-----	10,828	-----
121	10,475	.0233	10,385	.0144	10,849	.0221	10,821	.0215
128	10,427	.0230	10,340	.0139	10,808	.0220	10,779	.0213
135	10,407	.0222	10,324	.0134	10,788	.0215	10,760	.0206
142	10,387	.0227	10,307	.0138	10,765	.0216	10,736	.0209
149	10,379	.0216	10,301	.0128	10,753	.0210	10,725	.0197
156	10,367	.0218	10,290	.0126	10,734	.0207	10,708	.0194
163	10,364	.0210	10,289	.0122	10,728	.0200	10,702	.0188
170	10,362	.0208	10,288	.0121	10,724	.0199	10,697	.0186
177	10,362	.0208	10,287	.0121	10,720	.0198	10,694	.0186
184	10,356	.0208	10,281	.0121	10,713	.0198	10,686	.0186
191	10,354	.0208	10,281	.0121	10,711	.0198	10,684	.0186
198	10,352	.0205	10,278	.0119	10,707	.0193	10,680	.0181
205	10,354	.0207	10,280	.0121	10,708	.0195	10,681	.0183


MOISTURE CONTENT VS SHRINKAGE
MIX 4
MIX 3
MIX 2
MIX 1
SHRINKAGE, %
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
MOISTURE CONTENT, %
0
1
2
3
4
5
6

MOISTURE CONTENT VS AGE



SHRINKAGE VS AGE