IOWA STATE HIGHWAY COMMISSION

Materials Department
Special Investigations

FINAL REPORT OF R-234

A STUDY OF THE RELATIVE DURABILITY AND DRYING SHRINKAGE
OF CONCRETE USING VARIOUS RETARDERS

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by

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A Study of the Relative Durability and Drying Shrinkage of Concrete using Various Retarders

INTRODUCTION:

A number of concrete admixtures are presently used in various concretes principally for water reduction, retardation, or air entrainment. Whereas the use of these admixtures in concrete placement is well documented, there is limited information showing their effects on durability and drying shrinkage. Since the durability and the shrinkage of concrete can have a pronounced effect on a structure's longevity, wear characteristics, and reaction to loading, it is desirable to know the relative effects of different admixtures prior to concrete placement.

PURPOSE:

The purpose of this study is to provide information which could be used to establish durability and shrinkage criteria for evaluating the admixtures currently in use and those whose use may be proposed.

MATERIALS:

1. Aggregates
   The coarse aggregate was taken from the following:
   - Alden Limestone - Weaver
   - White Materials Corp., Gravel - Des Moines
   - Bentye Stone - Roverud
   The fine aggregate was from Hallett Construction Company's Ames Pit; and complying with section 4110 of the standard specifications.

2. Cement
   The cement was a blend of seven cements commonly used in Iowa complying with the requirements of type I cement and tested under Lab. No. AC7-5638.

3. Admixtures
   The air entraining admixture was Ad-Aire Lab. No. ACA6-20.
   The retarders used were the following:
   - A. Pozzolith 100R
   - B. Daratard 40
   - C. Protex FDA 25R
   - D. Plastiment
   - E. Sugar
   - F. Pozzolith 200R
   - G. Pozzolith 8 Improved

4. Concrete
   The concrete was proportioned to comply with the requirements of a D-57 structural mix. The slump was adjusted to 2 1/2 ± 1/2 inches. The amount of air entraining agent was adjusted to yield 6±1% air content as measured by ASTM C-231.
PROCEDURE:

Since it was required that the effects of both drying shrinkage and durability be studied, it was imperative that two sets of beams be made and tested. The procedure of each was as follows:

1. Drying Shrinkage Specimens
   A. Three 3"x3"x11" beams were cast for a control as well as for each concrete containing an admixture.
   B. All concretes were consolidated by external vibration.
   C. The specimens were cured initially in molds under polyethylene film and wet sample bags.
   D. The beams were removed from the molds 23 1/2 ± 1/2 hours after casting.
   E. The specimens were then placed in water at 73.4°±1°F for 1/2 hour.
   F. The beams were wiped with a damp cloth upon removal from the water storage and measured for length.
   G. The beams were then placed in water at 73.4°±3°F for 28 days and remeasured after 1/2 hour storage in water at 73.4°±1°F.
   H. The specimens were stored in air at 73.4°±2°F and relative humidity of 50 to 80%. Length determinations were made after periods of air storage of 4, 7, 14, and 28 days and of 8, 16, 32, and 64 weeks.
   I. A final measurement was taken on the beams after 128 weeks in air and after being placed in a 300°F oven for 72 hours.

2. Durability Specimens
   A. Three 4"x4"x18" beams were made for each retarder mix. Beams containing no retarders were also made as a control.
   B. All concretes were consolidated by external vibration.
   C. The beams were molded and covered with a polyethylene film for 20-48 hours.
   D. Curing was completed by allowing the specimens to stand 90 days in the moist room followed by one day in a 40°F water cooler.
   E. Testing was done under freeze and thaw conditions in accordance with ASTM C-291 with the following exceptions:
      1) Specimens were 18" in length.
      2) Beams were not randomly replaced after reading.
      3) Beams were not weighed.

RESULTS:

The results of the durability test are shown in table I and are pictured in figures 1, 2, and 3. An examination of the data and the graphs shows the effects of the various retarders to be very erratic and somewhat unexplainable. For example, a comparison of the graphs indicates that the retarders change positions of relative durability with the three different coarse aggregates. However, the graphs do show that there is a recovery in durability when a good quality coarse aggregate is used. Although this fact has been proven in previous studies, the experimental data does not show an overall superiority or rejection criterion for any one retarder without first specifying a coarse aggregate.

The results of the drying shrinkage test are also shown in table I. The graphs of drying shrinkage (figs. 4, 5, and 6) indicate that the better quality coarse aggregate will reduce the air shrinkage with all retarders. However, no retarder
exhibited the least drying shrinkage with all aggregates. Thus, there is still no basis for considering a retarder generally better. The uneven nature of the shrinkage curves is thought to be due to the change in humidity in the cement lab. Since accurate control of humidity is impossible with the present facilities, the specimens shrunk during dry weather and actually showed a growth in very humid weather (32nd week measurement, not shown on graphs). Also, the concrete mixing facilities left possibilities for unaccounted variables to enter into the test results.

SUMMARY

This study has shown that:

1. The coarse aggregate has a far greater influence on durability than any influence due to a retarder. There is no concluding evidence to justify considering any single retarder tested to be generally best. Any durability and shrinkage criterion taken from this study would be purely speculation because of the erratic and inconsistent data obtained.

2. There must be a complete investigation as to the dependability and repeatability of the freeze and thaw test procedure before projects of this magnitude can be conducted in the future.

Possible areas of more stringent control might be:

A. Mixing atmosphere
B. Vibration time
C. Frequency determination
D. Humidity control
Table I
Durability and Drying Shrinkage Results

<table>
<thead>
<tr>
<th>Coarse Aggregate</th>
<th>Retarder</th>
<th>% Air in Mix</th>
<th>Durability D. F.</th>
<th>% Growth</th>
<th>Shrinkage, 128 Weeks in Air, In.</th>
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</thead>
<tbody>
<tr>
<td>Weaver - Alden</td>
<td>None</td>
<td>5.8</td>
<td>96.0</td>
<td>0.012</td>
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<tr>
<td></td>
<td>Pozz. 100R</td>
<td>6.3</td>
<td>96.0</td>
<td>0.011</td>
<td>0.0057</td>
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<td>Daratard 40</td>
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<td>99.0</td>
<td>0.013</td>
<td>0.0044</td>
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<td>95.0</td>
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<td>98.0</td>
<td>0.010</td>
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<tr>
<td>Keefner - Des Moines</td>
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<td>Roverud - Bentye</td>
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<td>87.0</td>
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<td>Pozz.-8 Imp.</td>
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<td>95.0</td>
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</tbody>
</table>
THE INFLUENCE OF RETARDERS ON DURABILITY USING ALDEN STONE

FIGURE 1: FREEZE AND THAW CYCLES

- Pozzolith 8 - Improved
- Pozzolith 200R
- Sucrose
- Plastiment
- PDA 25R
- Parezted 40
- Pozzolith 100R
- Control

AVEN STONE USING DURABILITY ON FREEZE OF RETARDERS

FIGURE 1: THE INFLUENCE OF RETARDERS
Figure 2: The influence of retarders on durability using bentonite stone.
FIGURE 3 THE INFLUENCE OF RETARDERS ON DURABILITY USING KEEFER STONE

- Control
- Pozzolith 200R
- Sucrese
- Plastiment
- PCA 25R
- Daratard 40
- Pozzolith 100R
- Pozzolith 8 - Improved
- Plastiment
- Sucrose
- Pozzolith 200R
- Pozzolith 8 - Improved

Freeze and Thaw Cycles

Durability Factor

0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 76 78 80 82 84 86 88 90 92 94 96 98 100

FIGURE 3 THE INFLUENCE OF RETARDERS ON DURABILITY USING KEEFER STONE
FIGURE 4 THE INFLUENCE OF RETARDERS ON DRYING SHRINKAGE USING ALDEN STONE
FIGURE 5 THE INFLUENCE OF RETARDERS ON DRYING SHRINKAGE USING BENTYE STONE

- Control
- Pozzolith 100R
- Daratard 40
- PDA 25R
- Plastiment
- Sucrose
- Pozzolith 200R
- Pozzolith 8 – Improved

Time in air, weeks

Growth

Shrinkage, inches x 10^3
FIGURE 6 THE INFLUENCE OF RETARDERS ON DRYING SHRINKAGE USING KEEFNER STONE