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Inv. 74-31

SALT-SCALE FREEZE AND THAW TESTS OF LOW SLUMP CONCRETE

REPORT ON
INVESTIGATION 74-31

Salt-Scale Freeze and Thaw Tests of Low Slump Concrete

Materials and Research Division
Missouri State Highway Department

Jefferson City, Missouri

May 20, 1975

CONCLUSIONS

The Research Section has recently completed an investigation of low slump concrete's resistance to salt-scale freeze and thaw tests. Two 12" x 12" x 1½" panels were fabricated with a mortar dike placed along the edge of the slab for the purpose of impounding a 5% calcium chloride solution. The panels were then subjected to one freeze-thaw cycle per day for 100 cycles, with the panels being observed and rated every five cycles.

Based on the results of the salt-scale freeze and thaw tests, which indicated that low slump concrete was not resistant to surface mortar deterioration, it is recommended that low slump concrete not be used for bridge deck patching or overlay without a sealer or protective system being applied.

INTRODUCTION

Deterioration of concrete bridge decks is a problem of major concern to the Missouri State Highway Department. The Materials and Research Division has been evaluating various products or mixes which are designed to repair, restore, and/or prevent rapid deterioration of the bridge deck.

One such material which the Division felt would be worthwhile to evaluate is low slump concrete, a high cement content portland cement concrete mix using a minimum amount of water.

The Iowa State Highway Department has been using low slump concrete since the mid 1960's, both as a patching material and a complete overlay system. The results they have obtained have been encouraging as to the use and durability of low slump concrete.

Because of the favorable results Iowa had obtained with their field installations, it was decided to run a salt-scale freeze and thaw test on panels of low slump concrete, with no protective covering, to evaluate its resistance to scaling when used as a overlay.

MATERIALS AND SPECIMEN PREPARATION

Two 12" x 12" x 1½" panels were constructed for testing. The 1½ inch depth was selected because it was desired to run resistance tests on the panels, and 1½ inches was the depth that would be used for overlaying a bridge deck.

The mix design was based on the Iowa specifications for low slump concrete given in the report "An Evaluation of Concrete Bridge Deck Resurfacing in Iowa". The mix design called for the following: a slump of 3/4 inch ± 1/4 inch, a w/c ratio of 3.70 gals./sack, a cement factor of 8.75 bags per cubic yard, and an air content of 6%. The mix was designed using the absolute volumes given by Iowa. Information about the mix design is given in Appendix A.

The coarse aggregate used was Callaway Limestone and the fine aggregate was Missouri River Sand. The physical characteristics of these aggregates and the gradations used are given in Appendix A. The cement used was Alpha - Type I and had a specific gravity of 3.14. An air-entraining admixture and a water reducing admixture were both used. The air entraining agent was Darex AEA and was used at a rate of 3/4 fl. oz. per 100 lb. of cement. The water reducer was Darex WRDA with HYCOL and was used at a rate of 3 fl. oz. per 100 lb. of cement.

A batch size of 1.0 cubic foot was used with a trial batch first being mixed. The mixing procedure used is given in Appendix B. The second batch mixed was used to fabricate the specimens and had the following characteristics: a slump of 3/4 inch, a w/c ratio of 3.52 gal./sack, an air content of 5.3%, and a rodded density of 150.5 pcf. The concrete was placed in the forms in one lift and consolidated by raising and dropping the forms slightly and striking the sides of the forms with a leather mallet. A wire mesh was placed in the bottom of the panels for resistance tests.

The panels were wood floated and given a broom finish. A sand and cement mortar dike was then constructed around each panel. Wet burlap covered with polyethylene was placed over the panels for 24 hours, at which time the forms were stripped and the panels placed in the moist room. After 13 days in the moist room, the panels were allowed to air dry for 14 days.

TESTING PROCEDURE

At the end of the 28 day curing period, resistance tests were performed on both of the panels and they were then placed in the salt-scale freeze and thaw test.

Approximately 250 ml. of a 5% calcium chloride solution was poured over each panel and the panels were subjected to one freeze-thaw cycle per day. The panels were then rated every five cycles through 100 cycles at which time the panels were removed from test. Before the panels were rated, they were subjected to a light brushing of the surface to remove the loose material which would be expected to be removed under traffic conditions. A fresh calcium chloride solution was placed over the panels before they were put back into test. Photographs were taken periodically when the panels were rated. A descriptive rating scale used in evaluating the panels is given in Appendix C.

RESULTS AND DISCUSSIONS

The resistance of the low slump concrete panels to water penetration was about the same as for any other bare concrete. The results of the resistance tests for the panels are given below:

Time of Soak	Resistance (ohms) Panel 1	Panel 2
1 Min.	472	473
5 Min.	472	720
10 Min.	500	720
15 Min.	720	720
30 Min.	720	720
60 Min.	720	720
120 Min.	720	720

The ratings given to the panels are shown in Appendix D and the photographs showing their progressive deterioration are given in Appendix E. The ratings are shown for every 10 cycles although the panels were rated every five cycles. As the photographs illustrate, the deterioration was of a general nature, scaling of the surface mortar and pitting over and around the coarse aggregate particles. The areas affected by scaling and pitting were not localized but rather uniformly distributed over the entire surface area. The deterioration of the panels took the form of the amount of surface area affected by scaling and pitting increasing, and the depth of pitting increasing. The deterioration occurred at a fairly uniform rate with no rapid acceleration of deterioration. The panels were taken out of test at the end of 100 cycles.

The results of this investigation did not correspond with those of Iowa in regard to salt scaling resistance of low slump concrete. In their report, "An Evaluation of Concrete Bridge Deck Resurfacing in Iowa," it was stated that the laboratory specimen fabricated from low slump concrete had a salt scaling resistance rating of two at 100 cycles, whereas the specimens for this investigation had reached a rating of five at 100 cycles. Both investigations used a rating scale of one to five, which may or may not have been the same depending on how the Iowa scale was interpreted.

In previous tests conducted by the Research Section, both air entrained and non-air entrained bare concrete panels were used as standards in salt-scale tests. Although it may be erroneous or misleading to make a comparison between the different studies, it appears that the air entrained panels performed much better than the low slump concrete panels studied in this investigation and at least somewhat better than the panels reported in the Iowa study. However, the non-air entrained concrete panels reached failure in approximately half the number of cycles required for the low slump concrete.

Although this investigation did not really evaluate low slump concrete as a patching material, the laboratory results indicated that it would not be adequate without a surface protection, for either patching or overlaying a bridge deck because of its susceptibility to scaling. However, Iowa has had favorable field experience using low slump concrete with, no known surface treatment, as a patching material and an overlay system. The favorable field experience, together with Iowa's better lab results indicate that it may be beneficial to re-evaluate the material after contacting Iowa to determine the differences in the procedures used.

There are three readily noticeable differences in test procedures between Missouri and Iowa, although it is not known what effect, if any, these had on the test results. The panels constructed by Iowa were 12" x 12" x 2½" with a 10" wide dished surface formed in the top to hold the calcium chloride solution, while the panels constructed by Missouri were 12" x 12" x 1½" with a flat surface and a mortar dike around the edge to hold the calcium chloride solution.

Another difference was in the method of cure. The Iowa method of cure was 24 hours moist followed by 20 days of 50-75% humidity, whereas the Missouri method of cure was 24 hours under wet burlap and polyethylene, followed by 13 days in moist room, followed by 14 days air curing.

There was also a difference in the number of freeze-thaw cycles per day that the specimens were subjected to. The Iowa panels were subjected to two freeze-thaw cycles per day whereas the Missouri panels received only one freeze-thaw cycle per day.

One difficulty, which could have influenced the panels' resistance to scaling, was encountered during fabrication of the panels. Because of low water content, stiffness of the mix, and thin layer of concrete, it was difficult to obtain enough mortar to properly finish the surface. Because of this, the concrete may possibly have been overworked. It would be interesting to know if Iowa had this problem.

APPENDIX A

MIX DESIGN

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AGGREGATE CHARACTERISTICS

MIX DESIGN

Slump - 3/4" $\pm$ 1/4"

W/C Ratio - 3.70 gal./sack

Cement Factor - 8.75 sacks/cu. yd.

Air Content - 6%

Admixtures - Air Entraining and Water Reducing

Batch Size - 1.0 cu. ft.

The mix design was based on the absolute volume given in the Iowa State Highway Commission supplemental specifications for low slump concrete. The basic absolute volumes per unit volume of concrete are as follows:

Coarse Aggregate	0.312088
Fine Aggregate	0.312088
Air	0.060000
Water	0.160255
Cement	0.155569

The mix design calculations were performed using the oven dry weight of the aggregate and allowing for the moisture content of both coarse aggregate and fine aggregate.

AGGREGATE CHARACTERISTICS

Coarse Aggregate

Callaway Limestone

Specific Gravity - 2.65

Dry Rodded Unit Wt. - 99 pcf

24 Hr. Absorption - 0.8%

Moisture Content - 0.1%

Gradation	
Sieve Size	% Passing
3/4"	100
1/2"	100
3/8"	80
#4	21
#10	1
#200	0.8

Fine Aggregate

Missouri River Sand

Specific Gravity - 2.62

Dry Rodded Unit Wt. - 112 pcf

24 Hr. Absorption - 0.4%

Moisture Content - 1.0%

Gradation	
Sieve Size	% Passing
3/8"	100
#4	98
#10	88
#20	59
#30	40
#40	24
#50	12
#100	1
#200	0.2

APPENDIX B

MIXING PROCEDURE

MIXING PROCEDURE

1. Add fine aggregate and cement
2. Dry mix for one minute
3. Add coarse aggregate
4. Dry mix for one minute
5. Add air entraining agent to approximately 30% of mixing water and add to mix
6. Mix for approximately 15 seconds
7. Add water reducing admixture to approximately 30% of mixing water and add to mix
8. Add additional water until a slump of $3/4 \pm 1/4$ inch is reached. (Record weight of water held back, if any)
9. Continue mixing until 3 minutes have elapsed since point "5".
10. Determine slump, rodded density, and air content
11. Return concrete used for slump test to mixer and remix for a few revolutions.
12. Fabricate specimens

APPENDIX C

RATING SCALE FOR SALT-SCALE

FREEZE AND THAW TESTS

Rating Scale for Salt-Scale Freeze and Thaw Tests

0 - No failure, however, some broom marks may begin to slough with some very minor surface mortar loss.

1 - Pitting uniformly distributed over the exposure area over the aggregate particles only, pits involving approximately 10% of the total area.

- OR -

Scaling of the immediate surface mortar only regardless or in combination with some shallow pitting involving approximately 10% of the total area.

2 - Pitting uniformly distributed over the exposure area over the aggregate particles only, pits involving approximately 20% of the total area.

- OR -

Scaling of the immediate surface mortar only regardless or in combination with some shallow pitting involving approximately 40% of the total area.

- OR -

Scaling of approximately 1/8" depth within a localized area within the exposure surface of approximately 20% of total area with no apparent failure except minor spots on the remainder of the exposure area.

3 - Pitting advanced to consume approximately 30% of the total area with some very minor surface scaling otherwise.

- OR -

Scaling of the immediate surface mortar only regardless or in combination with some shallow pitting involving approximately 100% of the total area.

- OR -

Scaling of approximately 1/8" depth within a localized area within the exposure surface of approximately 40% of total area with minor surface scaling otherwise.

4 - Pitting advanced to a stage where pitting only cannot be the only mechanism of failure. Pitting is observed over all coarse aggregate particles and surface mortar scaling has begun on the remainder of the exposure surface area.

- OR -

Scaling of the surface mortar has progressed deeper into the concrete, however, has not deteriorated beyond a 1/8" depth over the entire surface.

5 - Pitting no longer distinguishable. Scaling of mortar has progressed to a uniform depth of approximately 1/4" leaving the aggregate in relief.

- OR -

Scaling has progressed to a depth greater than 3/8" over 20% of the area and the remainder scaled to a depth of 1/8" to 1/4" depth.

APPENDIX D

RATINGS FOR SALT-SCALE FREEZE AND THAW TESTING

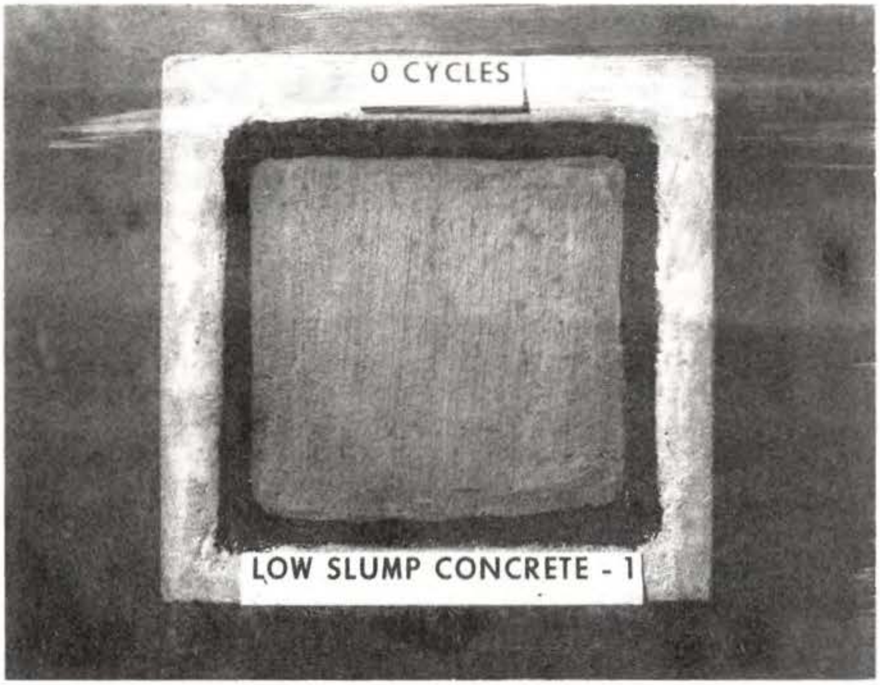
RATINGS FOR SALT-SCALE

FREEZE AND THAW TESTING

Test Cycle	Ratings Panel 1	Panel 2
0	0	0
10	0.5	0.5
20	1.0	1.0
30	1.75	2.0
40	3.0	3.0
50	3.0	3.25
60	3.0	3.25
70	3.5	3.5
80	4.0	4.25
90	4.25	4.5
100	5.0	5.0

APPENDIX E

PHOTOGRAPHS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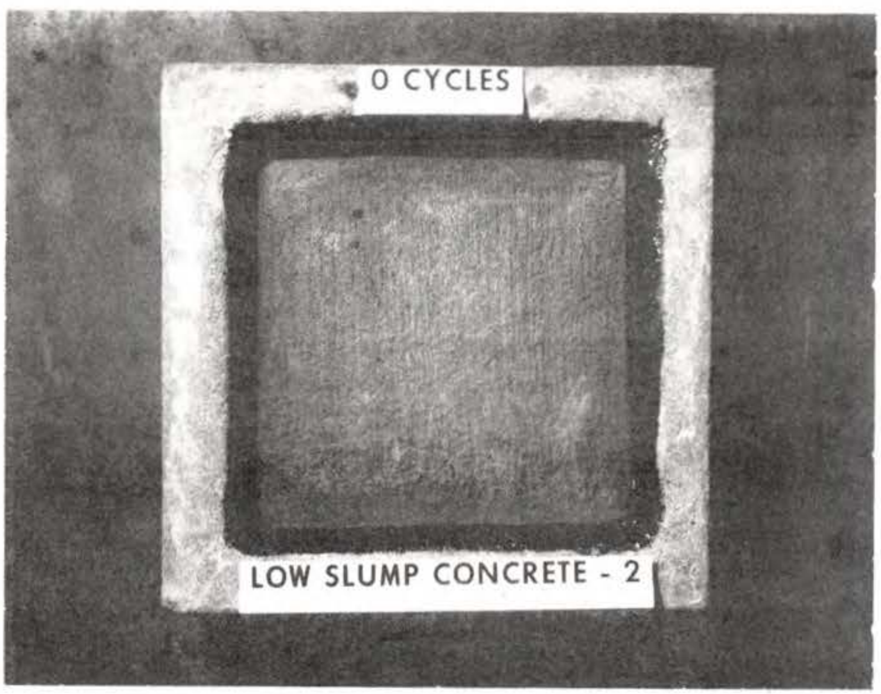
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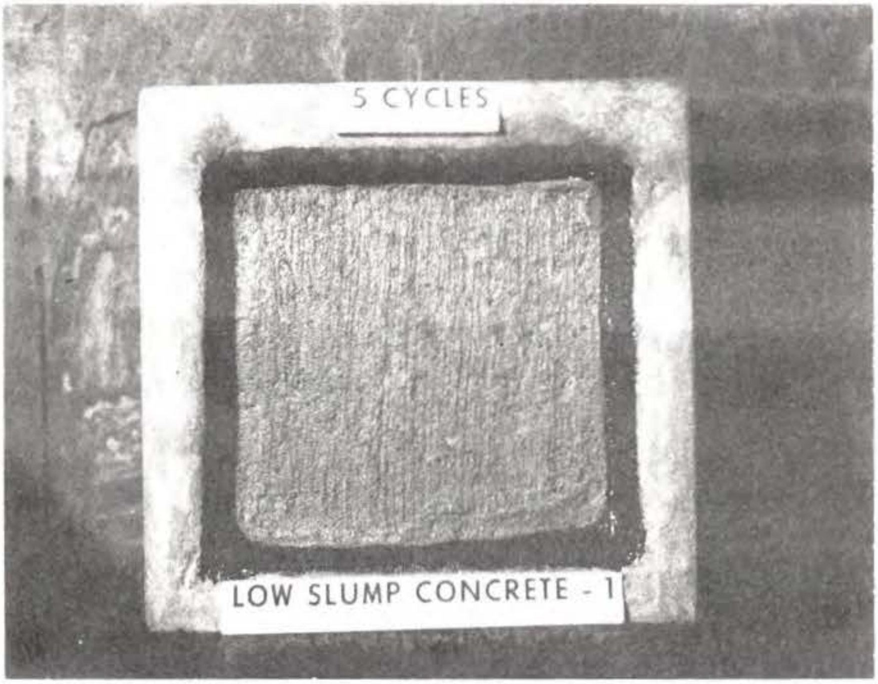
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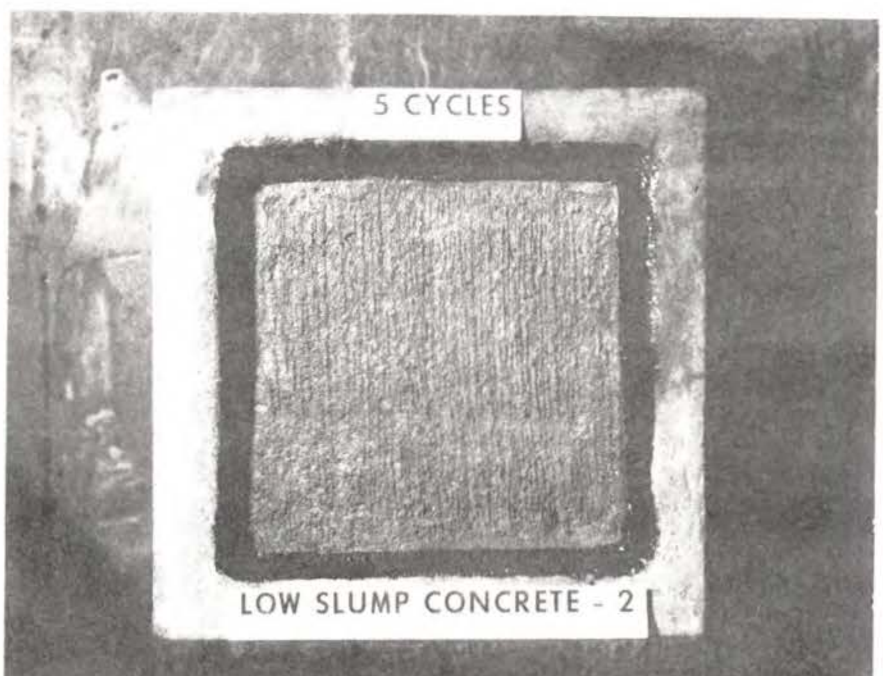
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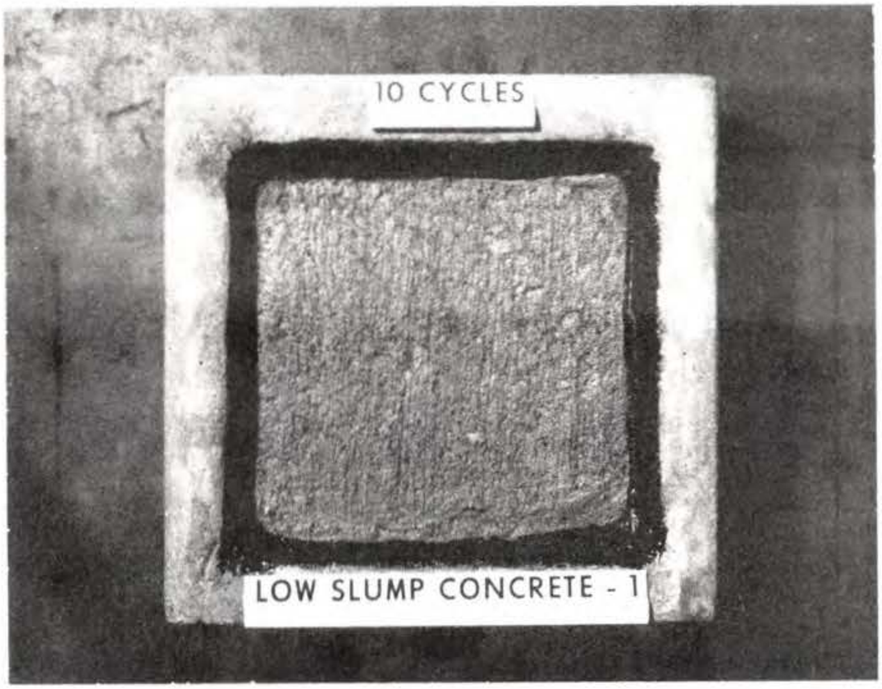
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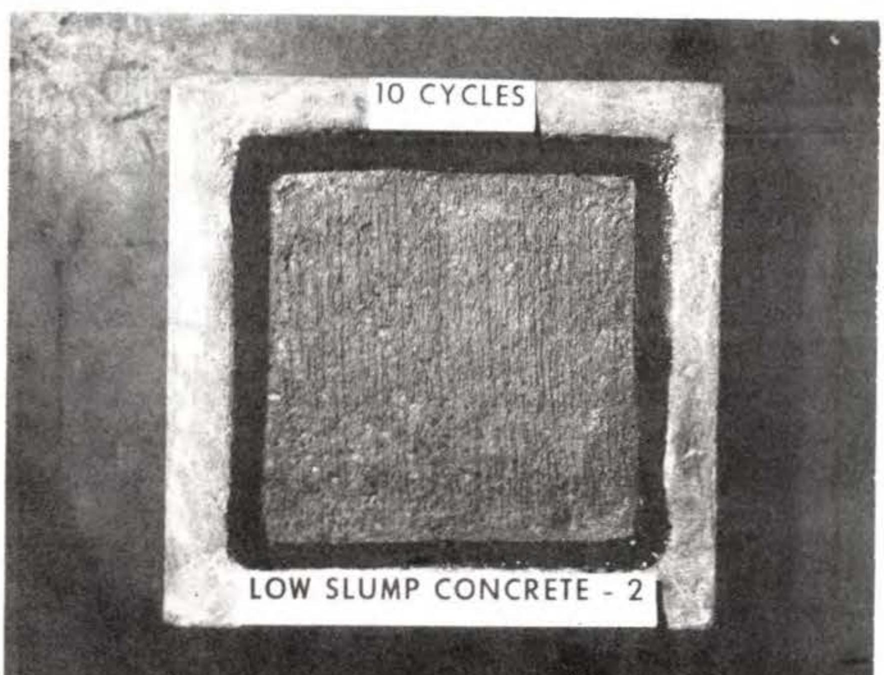
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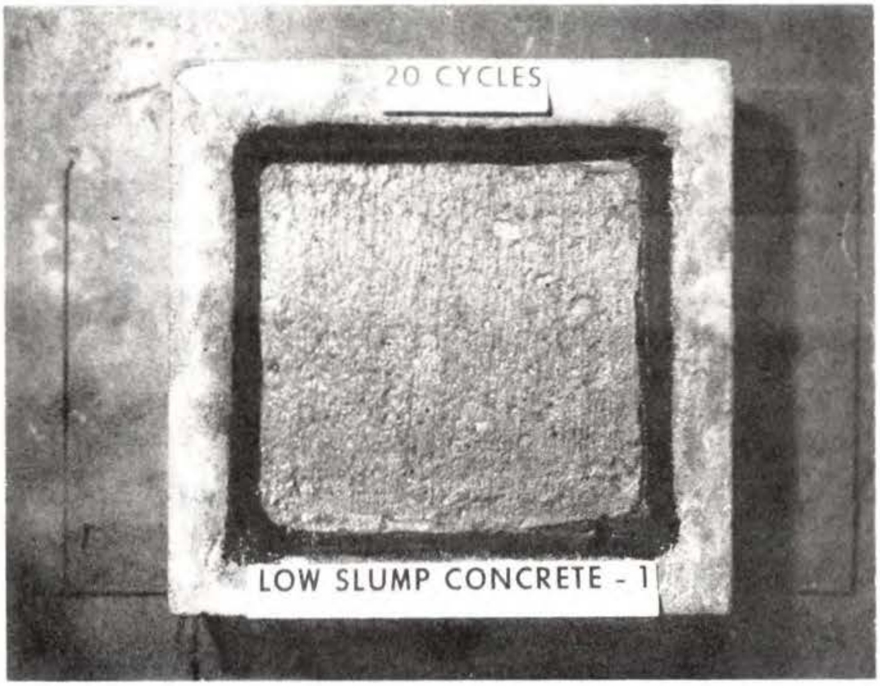
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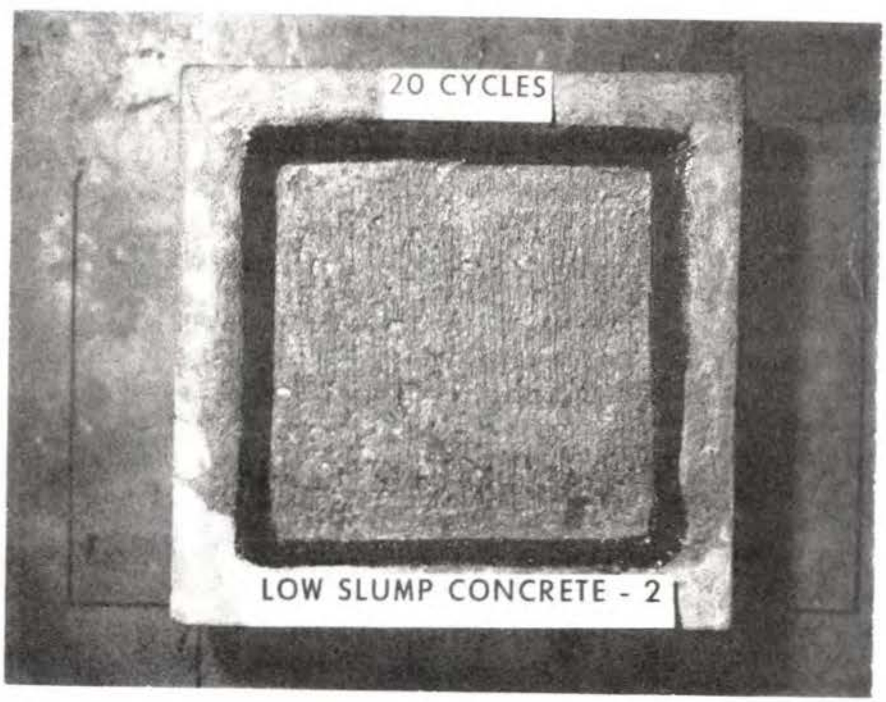
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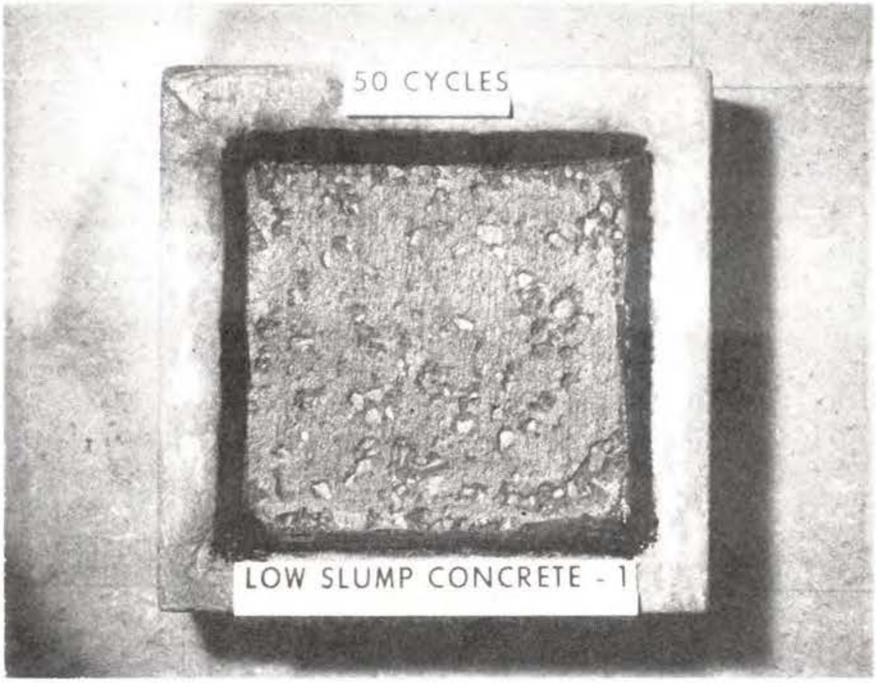
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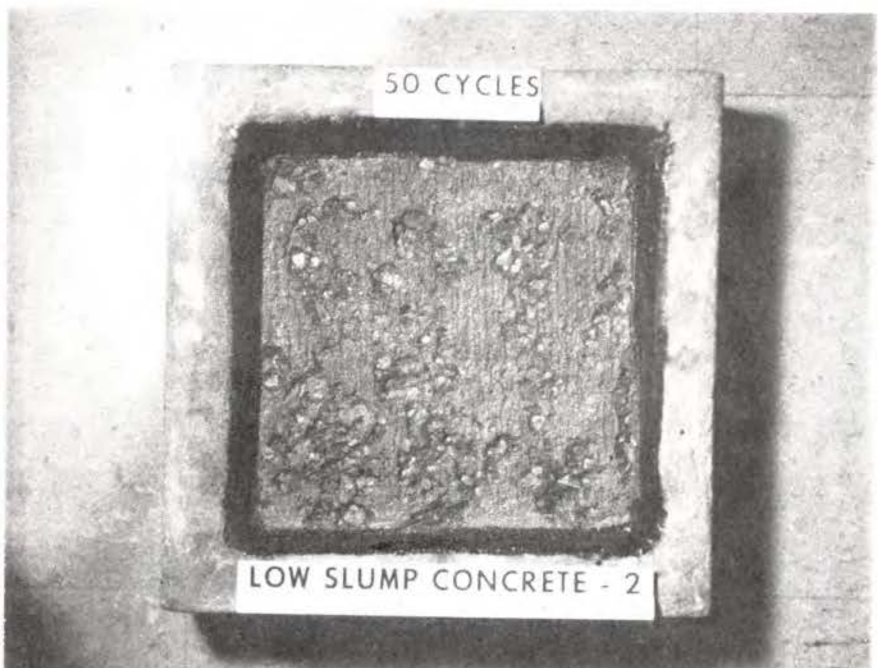
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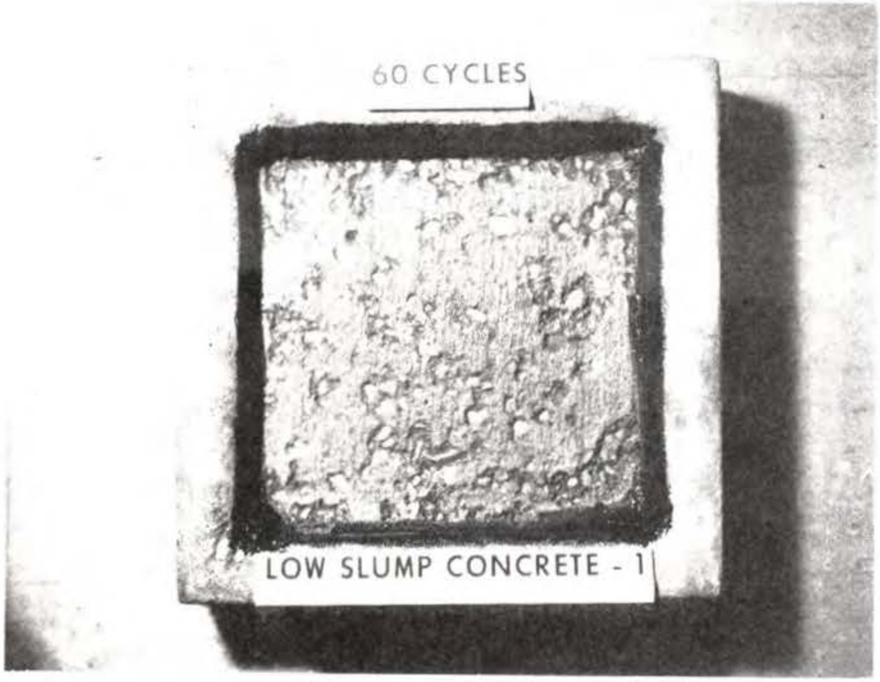
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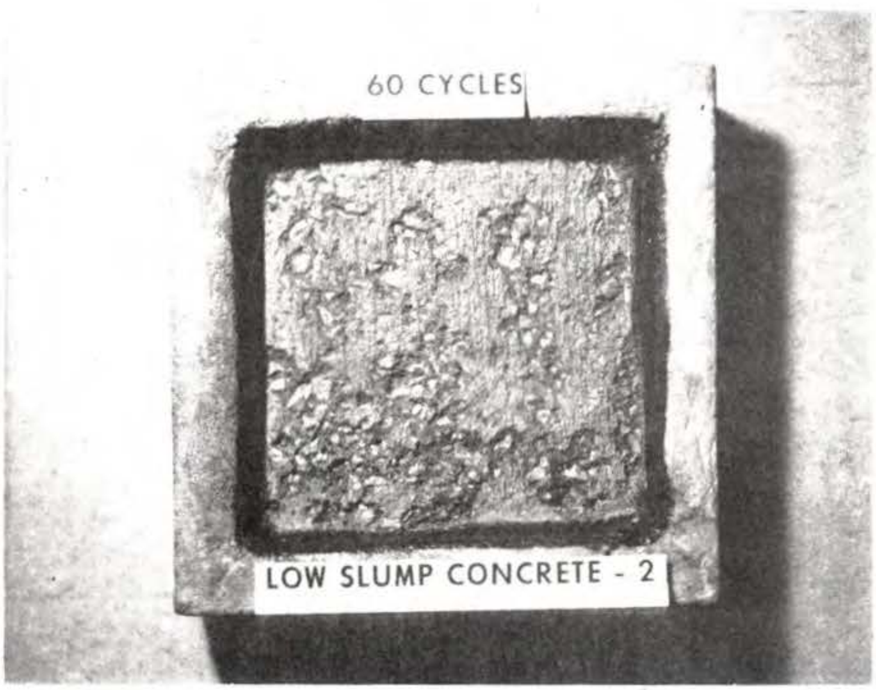
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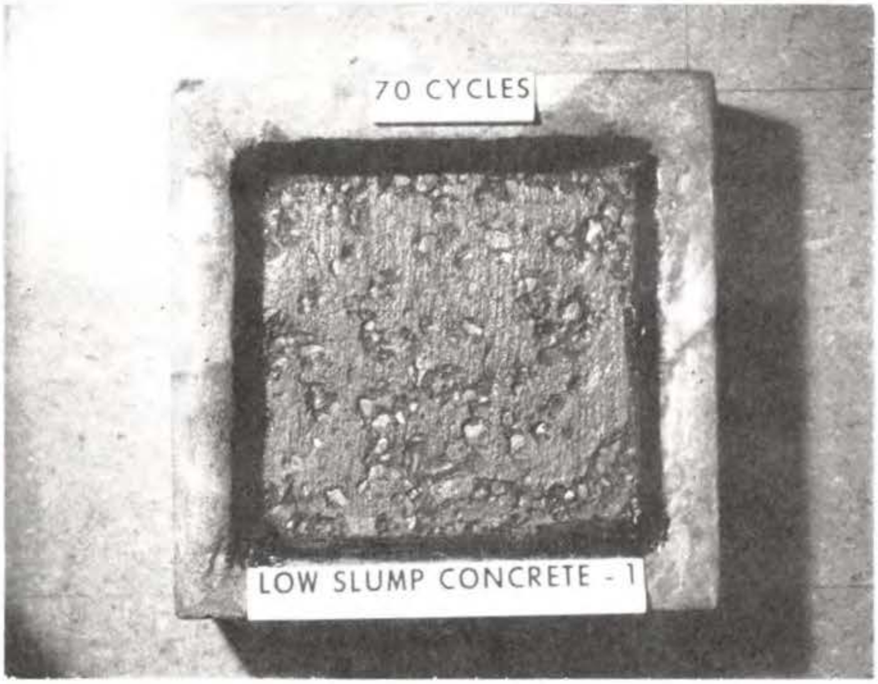
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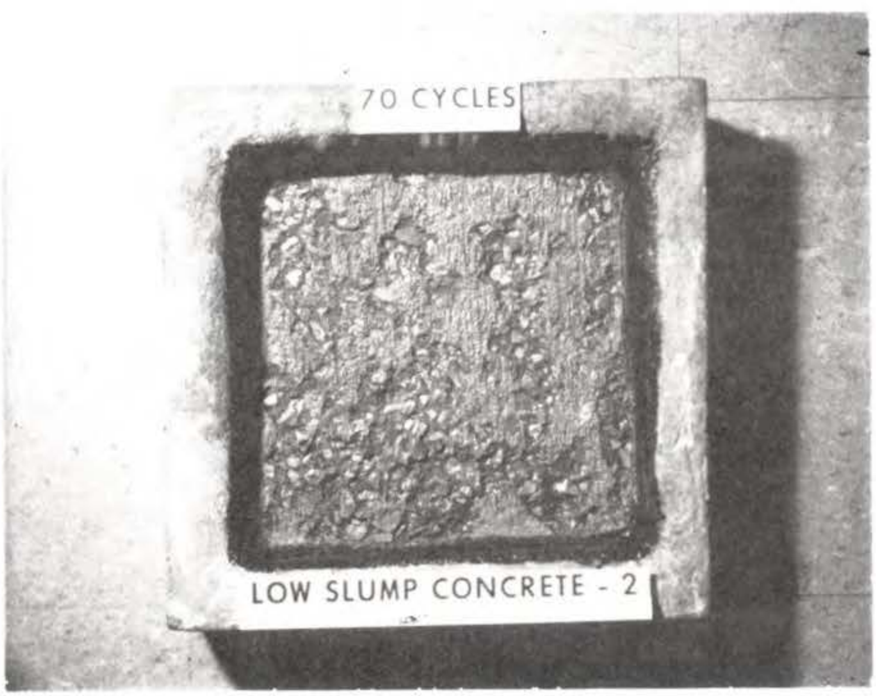
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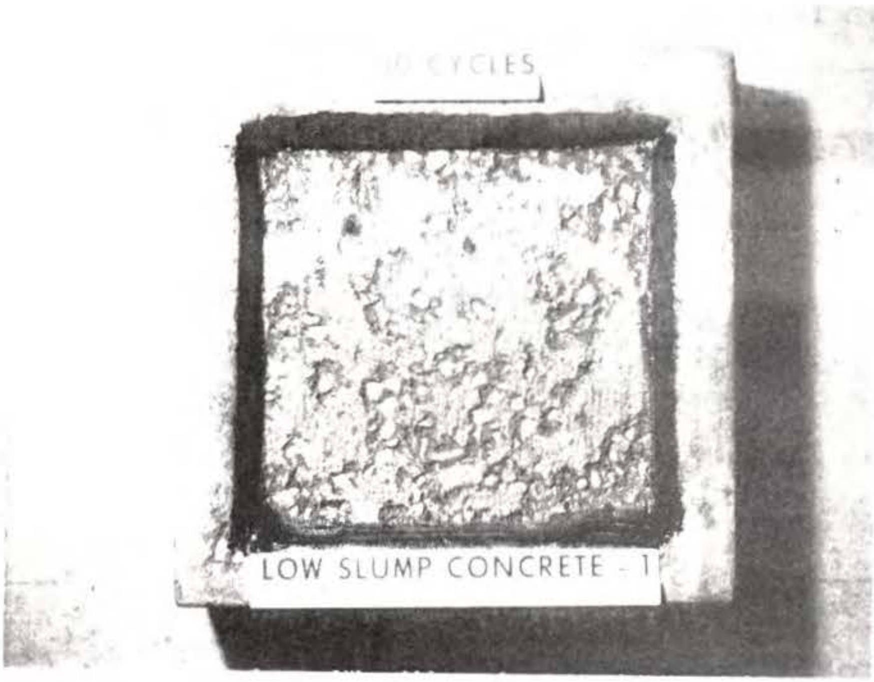
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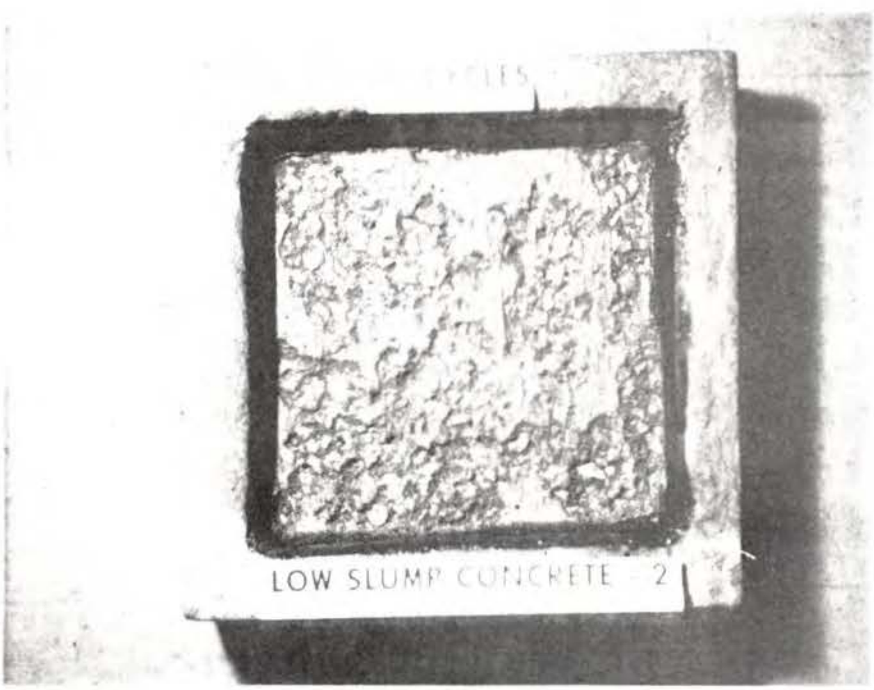
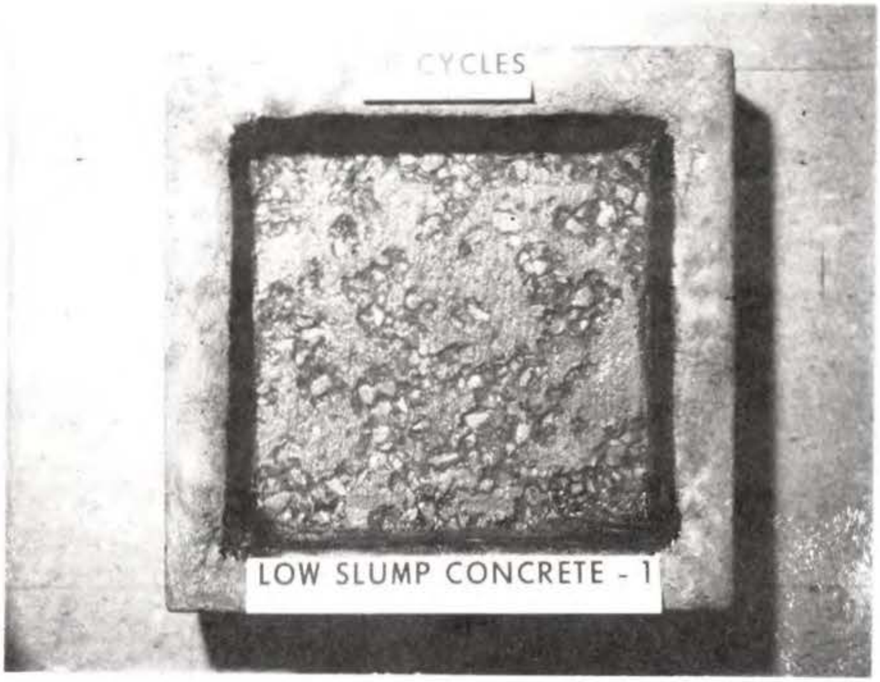
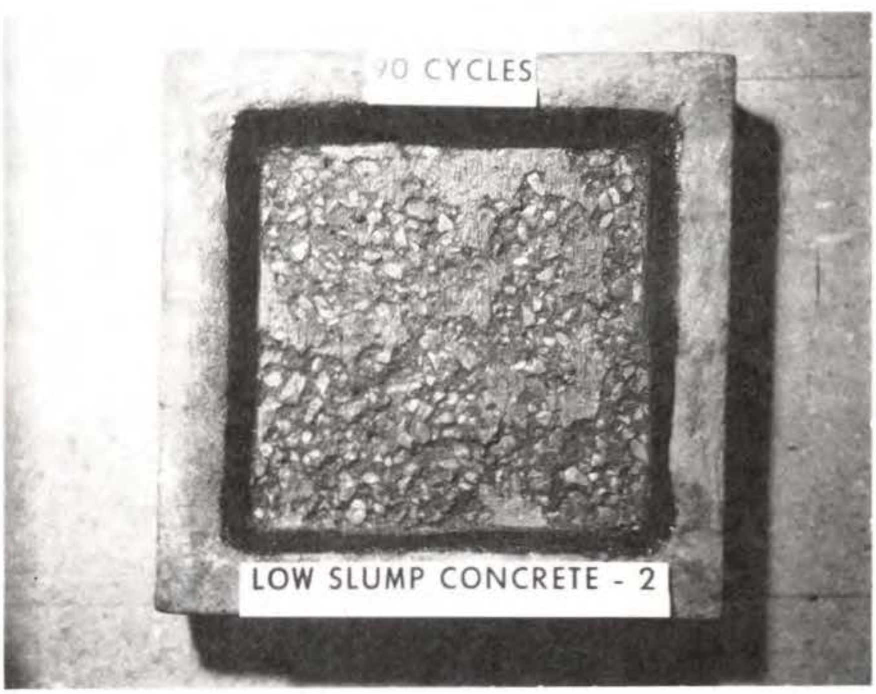
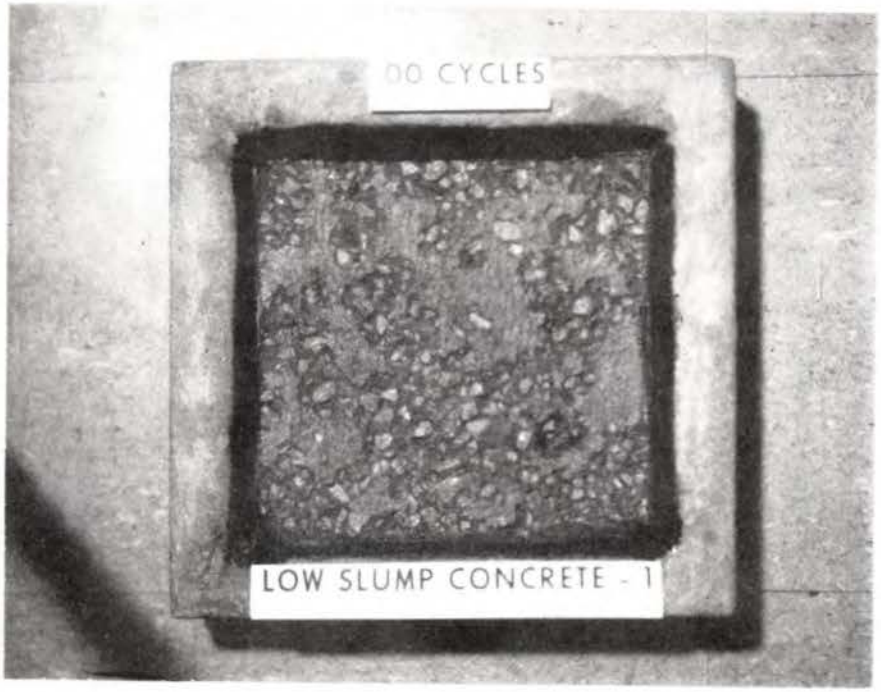
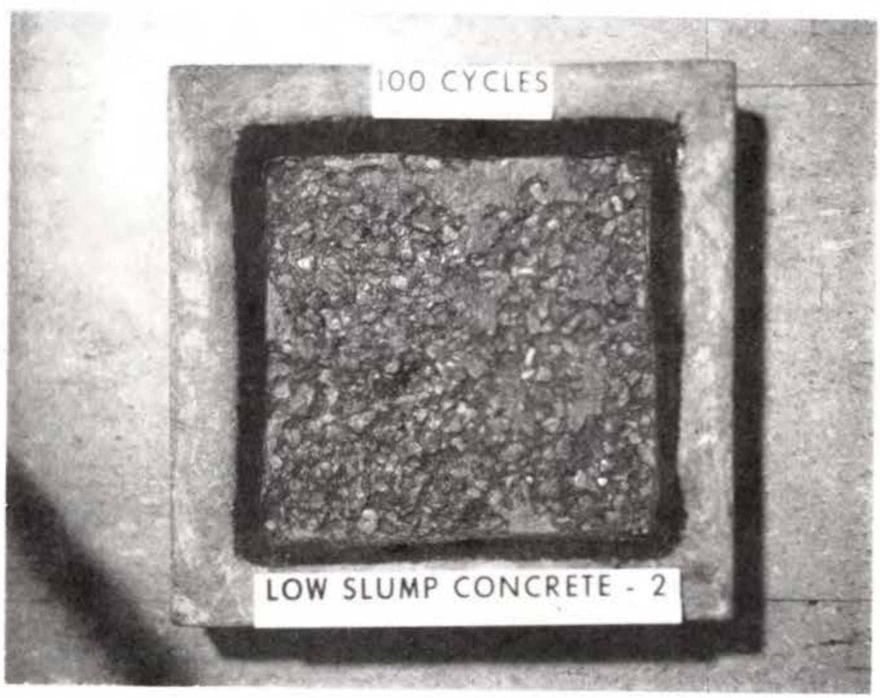

CYCLES
LOW SLUMP CONCRETE - 2


CYCLES
LOW SLUMP CONCRETE - 1


90 CYCLES
LOW SLUMP CONCRETE - 2


00 CYCLES
LOW SLUMP CONCRETE - 1


100 CYCLES
LOW SLUMP CONCRETE - 2