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Forty-Two-Year Test Results for PCA Series 374 on Long-Term Properties of Concrete

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Oak Ridge National Laboratory 1992

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FORTY-TWO-YEAR TEST RESULTS FOR PCA SERIES 374 ON LONG-TERM PROPERTIES OF CONCRETE

by

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Submitted by

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FORTY-TWO-YEAR TEST RESULTS FOR PCA SERIES 374 ON LONG-TERM PROPERTIES OF CONCRETE

by

Martha G. Van Geem, P.E.*

INTRODUCTION

Construction Technology Laboratories, Inc. (CTL) has performed testing to determine physical properties of concrete cast in 1950. Work was performed in accordance with P.O. No. 37X-SK412V from the U.S. Department of Energy, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory. Compressive strength, modulus of rupture, pulse velocity, and unit weight were determined from portions of twenty-two 6 x 6 x 30 in. beams from Portland Cement Association (PCA) Series 374. Petrographic examinations were also performed on seven specimens to determine depth of carbonation, presence of microcracking, alteration of hydration products (chemical shrinkage), and aggregate-paste interactions. Specimens were moist-cured for 42 years at the PCA/CTL facilities in Skokie, Illinois.

Physical properties of concrete from Series 374 at ages 1 day, 7 days, 28 days, 3 months, 1 year, 3 years, 10 years, and 34 years are presented in References 1 and 2.

Oak Ridge National Laboratory has indicated that results presented in this report will be used as input in the Structural Materials Information Center, a materials property data base containing information on the time variation of properties under the influence of pertinent environmental stressors and aging factors.

SPECIMENS

Fifty-five 6 x 6 x 30-in. moist-cured concrete beams cast in 1950 were available for testing. Martin Marietta Energy Systems selected 22 specimens for testing. Table 1 presents the identification number of specimens tested, the cement type, the cement content,

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and water-cement ratio. All specimens were moist-cured in a fog room at the PCA/CTL facilities in Skokie, Illinois for 42 years.

TESTING SEQUENCE

The test sequence was initiated by testing one 18-in. end of the 30-in. beam in flexure. Pulse velocity and unit weight were then measured on the short end which had nominal dimensions of approximately 6 x 6 x 8 in. Cubes were then cut from the two ends of the 30-in. beams for compression tests. A one-inch slice of the beam was cut for petrographic examination and two nominal 4-in. diameter cores were extracted from the remainder of the beam for compression and unit weight tests.

FLEXURAL STRENGTH OF BEAMS

The modulus of rupture of one 18-in. end of each 30-in. beam was determined in accordance with ASTM C78-84, "Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading.)" In earlier tests of specimens from PCA Series 374, two flexural breaks were obtained from each specimen. In this study one break was obtained so that adequate concrete would be available for cores. Specimens were removed from the moist room, placed on a cart, and covered with burlap before flexural testing. Specimens were tested within 30 minutes of removal from moist room. Table 2 presents modulus of rupture test results.

PULSE VELOCITY OF BEAM PORTION

Pulse velocity was measured on the short end of each 6 x 6 x 30 in. beam broken in flexure. These ends had approximate nominal dimensions of 6 x 6 x 8 in. Specimen dimensions varied depending on where the beam broke in flexure. Pulse velocity measurements are presented in Table 3.

UNIT WEIGHT OF BEAM PORTION

Unit weight was also measured on the short end of each 6 x 6 x 30 in. beam broken in flexure. Unit weights were determined from specimen weights in air and water and are presented in Table 4.

COMPRESSIVE STRENGTH USING PORTIONS OF BEAMS BROKEN IN FLEXURE

The original ends of each 6 x 6 x 30 in. beam were sawed to form cubes with nominal dimensions of 6 x 6 x 6 in. Cubes were tested in accordance with ASTM C116-90, "Standard Test Method for Compressive Strength of Concrete Using Portions of Beams Broken in Flexure." In earlier tests of specimens from PCA Series 374, the length of the beam portion was left rough and not sawed to form a 6-in. cube. In this study cubes were sawed so that adequate concrete would be available for cores. Test results are presented in Table 5. Two cubes were tested for each 6 x 6 x 30 in. specimen.

COMPRESSIVE STRENGTH OF CORES

Two cores were drilled from the remainder of the 6 x 6 x 30 in. beam after cubes and petrographic specimens were extracted. Cores had a nominal diameter of 4 in. and a nominal length of 6 in. Unit weights of cores are presented in Table 6. Cores were tested according to ASTM C42-90, "Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete." Because it was anticipated some core strengths would exceed 10,000 psi, all core ends were surface ground to plane conditions rather than capped with capping compound. Test results including specimen dimensions and loading information are presented in Table 7. Results are summarized in Table 8.

PETROGRAPHIC EXAMINATION

Petrographic examinations were performed on portions of seven beams. Specimens were selected on the basis that each represented concrete made from a different type of portland cement. Petrographic slices were sawed from portions of beams after testing in flexure and removing 6 x 6 x 6 in. cubes from ends. Tests were performed in accordance with ASTM C 856-83 (reapproved 1988), "Standard Practice for Petrographic Examination of Hardened Concrete." Results are presented in Appendix A.

SUMMARY

This report presents results of physical tests performed at Construction Technology Laboratories, Inc. (CTL) to determine properties of concrete cast in 1950 and moist-cured for 42 years. Compressive strength, modulus of rupture, pulse velocity, and unit weight were determined from portions of twenty-two 6 x 6 x 30 in. beams from Portland Cement Association (PCA) Series 374. Petrographic examinations were also performed on seven specimens to determine depth of carbonation, presence of microcracking, alteration of hydration products (chemical shrinkage), and aggregate-paste interactions.

TABLE 1 — CEMENT TYPE AND QUANTITY FOR TESTED SPECIMENS FROM PCA SERIES 374

PCA Series 374 Mix Identification No.*	ORNL Material Code No.	ASTM C150 Cement Type	Cement Content, lbs per cu yd of concrete	Water/Cement Ratio
11T-2B	01CB069	**	422	0.47
11T-2C	01CB069	**	422	0.47
19B-1A	01CB093	I	566	0.45
19B-1B	01CB093	I	566	0.45
19B-2A	01CB094	I	423	0.60
19B-2B	01CB094	I	423	0.60
21-1A	N/A	II	565	0.43
21-1B	N/A	II	565	0.43
21-2A	N/A	II	427	0.56
21-2B	N/A	II	427	0.56
21T-1A	01CB099	***	563	0.39
21T-1B	01CB099	***	563	0.39
21T-2B	01CB100	***	423	0.49
21T-2C	01CB100	***	423	0.49
31-1A	N/A	III	565	0.49
31-1B	N/A	III	565	0.49
31-2A	N/A	III	427	0.60
31-2B	N/A	III	427	0.60
43A-3A	01CB124	IV	284	0.78
43A-3C	01CB124	IV	284	0.78
51-1C	N/A	V	565	0.41
51-2B	N/A	V	423	0.54

* The first numeral in the cement designation indicates the cement type. A "T" after the first set of numbers indicates flake Vinsol resin was ground with cement clinker.
The numbers 1, 2, or 3 to the right of the hyphen indicate the nominal quantity of 94-lb bags of cement per cu yd of concrete as follows: 1 = 6 bags, 2 = 4-1/2 bags, and 3 = 3 bags.

** Type I cement with flake Vinsol resin ground with cement clinker to produce the cement.

*** Type II cement with flake Vinsol resin ground with cement clinker to produce the cement.

TABLE 2 - ASTM C 78 FLEXURAL STRENGTH OF CONCRETE (USING SIMPLE BEAM WITH THIRD POINT LOADING) FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374

Specimen Identification		Width, inches	Average Width, inches	Depth, inches	Average Depth, inches	Span, inches	Maximum Load, lbs	Modulus of Rupture, psi
374	1	6.08		6.04				
11-T	2	6.06	6.07	6.07	6.06	18	8,900	720
2B	3	6.09		6.08				
374	1	6.07		6.08				
11-T	2	6.09	6.07	6.07	6.07	18	9,200	740
2C	3	6.04		6.06				
374	1	6.03		6.07				
19B	2	6.00	6.01	6.06	6.06	18	11,500	940
1A	3	6.01		6.07				
374	1	6.06		6.06				
19B	2	6.04	6.03	6.05	6.05	18	11,500	940
1B	3	6.01		6.06				
374	1	6.04		6.00				
19B	2	5.98	6.00	6.00	6.00	18	10,500	880
2A	3	6.00		6.01				
374	1	6.05		6.04				
19B	2	6.01	6.03	6.10	6.06	18	10,300	840
2B	3	6.03		6.04				

TABLE 2 - ASTM C 78 FLEXURAL STRENGTH OF CONCRETE (USING SIMPLE BEAM WITH THIRD POINT LOADING) FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374 (CONT.)

Specimen Identification		Width, inches	Average Width, inches	Depth, inches	Average Depth, inches	Span, inches	Maximum Load, lbs	Modulus of Rupture, psi
374	1	6.03		6.06				
21	2	6.07	6.05	6.02	6.03	18	12,000	980
1A	3	6.07		6.01				
374	1	6.05		6.04				
21	2	6.07	6.06	6.04	6.04	18	11,500	940
1B	3	6.05		6.03				
374	1	5.96		6.03				
21	2	5.99	6.00	6.04	6.03	18	11,000	910
2A	3	6.04		6.02				
374	1	6.02		6.05				
21	2	6.06	6.05	6.01	6.03	18	9,800	800
2B	3	6.08		6.02				
374	1	6.07		6.03				
21T	2	6.01	6.05	6.05	6.04	18	10,600	860
1A	3	6.07		6.05				
374	1	6.04		5.98				
21T	2	6.04	6.05	5.97	5.97	18	11,800	990
1B	3	6.07		5.97				
374	1	6.06		6.07				
21T	2	6.06	6.05	6.06	6.06	18	10,000	810
2B	3	6.02		6.06				
374	1	6.08		6.07				
21T	2	6.10	6.08	6.06	6.06	18	10,500	850
2C	3	6.06		6.05				

TABLE 2 - ASTM C 78 FLEXURAL STRENGTH OF CONCRETE (USING SIMPLE BEAM WITH THIRD POINT LOADING) FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374 (CONT.)

Specimen Identification		Width, inches	Average Width, inches	Depth, inches	Average Depth, inches	Span, inches	Maximum Load, lbs	Modulus of Rupture, psi
374	1	6.05		6.03				
31	2	6.05	6.04	6.06	6.06	18	12,000	970
1A	3	6.01		6.09				
374	1	6.03		6.10				
31	2	6.05	6.04	6.12	6.11	18	10,500	840
1B	3	6.05		6.10				
374	1	6.00		6.06				
31	2	5.99	5.99	6.06	6.05	18	9,600	790
2A	3	6.00		6.03				
374	1	6.01		6.10				
31	2	6.01	6.01	6.09	6.09	18	11,000	890
2B	3	6.00		6.08				
374	1	6.03		6.09				
43A	2	6.04	6.03	6.07	6.07	18	8,800	710
3A	3	6.02		6.06				
374	1	6.05		6.10				
43A	2	6.04	6.04	6.04	6.04	18	9,500	770
3C	3	6.04		6.00				
374	1	6.05		6.04				
51	2	6.07	6.06	6.10	6.05	18	12,500	1010
1C	3	6.07		6.02				
374	1	6.08		6.01				
51	2	6.07	6.07	6.02	6.03	18	9,800	800
2B	3	6.08		6.05				

TABLE 3 - PULSE VELOCITY TEST RESULTS
FOR 42 YR OLD CONCRETE SPECIMENS FROM PCA SERIES 374

Specimen Identification	Pulse Velocity Reading 1	Pulse Velocity Reading 2	Average Pulse Velocity Reading	Length, in.	Pulse Velocity, ft/sec
11T-2B	42.2	41.3	41.8	8.00	15,970
11T-2C	40.4	39.5	40.0	7.88	16,440
19B-1A	38.4	37.5	38.0	8.00	17,570
19B-1B	39.9	40.0	40.0	8.00	16,690
19B-2A	40.2	39.2	39.7	8.00	16,790
19B-2B	38.7	39.3	39.0	7.88	16,840
21-1A	37.3	37.9	37.6	7.88	17,460
21-1B	40.0	39.1	39.6	8.13	17,130
21-2A	39.6	39.3	39.5	8.00	16,900
21-2B	40.0	40.0	40.0	8.00	16,670
21T-1A	38.1	38.5	38.3	8.00	17,410
21T-1B	37.5	37.9	37.7	8.00	17,680
21T-2B	39.7	39.5	39.6	7.88	16,580
21T-2C	39.2	40.9	40.1	8.00	16,650
31-1A	40.7	39.3	40.0	7.88	16,420
31-1B	39.2	40.2	39.7	7.88	16,540
31-2A	39.5	39.0	39.3	7.75	16,450
31-2B	41.3	39.0	40.2	8.00	16,600
43A-3A	41.3	40.6	41.0	7.88	16,040
43A-3C	42.0	40.6	41.3	8.00	16,140
51-1C	37.0	36.4	36.7	7.88	17,890
51-2B	39.2	38.1	38.7	8.00	17,250

TABLE 4 - UNIT WEIGHT OF CONCRETE ENDS BROKEN IN FLEXURE FOR 42 YR OLD CONCRETE SPECIMENS FROM PCA SERIES 374

Specimen Identification	Weight in Air, lbs	Weight in Water, lbs	Unit Weight, lbs per cu ft
11T-2B	25.13	14.67	149.9
11T-2C	25.05	14.68	150.7
19B-1A	25.80	15.41	154.9
19B-1B	25.95	15.50	155.0
19B-2A	25.53	15.22	154.5
19B-2B	24.97	14.86	154.1
21-1A	25.46	15.26	155.8
21-1B	26.11	15.65	155.8
21-2A	25.29	15.09	154.7
21-2B	25.80	15.40	154.8
21T-1A	25.59	15.22	154.0
21T-1B	25.46	15.20	154.8
21T-2B	25.46	15.06	152.8
21T-2C	25.35	15.00	152.8
31-1A	25.11	14.91	153.6
31-1B	25.36	15.05	153.5
31-2A	25.00	14.85	153.7
31-2B	25.58	15.17	153.3
43A-3A	24.51	14.31	149.9
43A-3C	25.20	14.74	150.3
51-1C	25.50	15.32	156.3
51-2B	25.38	15.15	154.8

TABLE 5 - ASTM C 116 COMPRESSIVE STRENGTH OF CONCRETE USING PORTIONS OF BEAMS BROKEN IN FLEXURAL FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374

Specimen Identification		Width, in.	Average Width, in.	Depth, in.	Average Depth, in.	Maximum Load, lbs	Compressive Strength, psi	Average Compressive Compressive Strength of Two Ends, psi
11T-2B	1	6.10	6.10	6.18	6.18	245,000	6,500	
	2	6.10		6.19				
11T-2B	1	6.08	6.09	6.23	6.22	246,000	6,500	6,500
	2	6.09		6.22				
11T-2C	1	6.06	6.07	6.24	6.23	252,000	6,670	
	2	6.08		6.22				
11T-2C	1	6.08	6.08	6.19	6.19	248,000	6,590	6,630
	2	6.07		6.20				
19B-1A	1	6.08	6.07	6.26	6.25	370,000	9,760	
	2	6.05		6.24				
19B-1A	1	6.04	6.02	6.21	6.21	366,000	9,780	9,770
	2	6.01		6.22				
19B-1B	1	6.08	6.06	6.25	6.22	375,000	9,950	
	2	6.04		6.20				
19B-1B	1	6.01	6.00	6.20	6.20	350,000	9,400	9,680
	2	6.00		6.21				
19B-2A	1	6.01	6.01	6.21	6.20	265,000	7,120	
	2	6.01		6.19				
19B-2A	1	6.00	6.05	6.17	6.17	286,000	7,670	7,400
	2	6.09		6.18				
19B-2B	1	6.03	6.00	6.20	6.23	267,000	7,150	
	2	5.98		6.26				
19B-2B	1	6.07	6.06	6.22	6.20	279,000	7,430	7,290
	2	6.05		6.19				
21-1A	1	6.04	6.01	6.20	6.20	342,000	9,180	
	2	5.99		6.20				
21-1A	1	6.08	6.05	6.22	6.21	370,000	9,850	9,520
	2	6.03		6.20				
21-1B	1	5.84	5.93	6.22	6.21	398,000	10,810	
	2	6.03		6.20				
21-1B	1	6.01	6.02	6.19	6.18	398,000	10,700	10,760
	2	6.03		6.18				
21-2A	1	6.04	6.04	6.22	6.25	310,000	8,220	
	2	6.04		6.28				
21-2A	1	6.04	6.04	6.15	6.17	300,000	8,050	8,140
	2	6.04		6.19				
21-2B	1	6.01	6.02	6.26	6.24	300,000	7,990	
	2	6.03		6.22				
21-2B	1	6.10	6.09	6.16	6.18	314,000	8,350	8,170
	2	6.08		6.20				
21T-1A	1	6.05	6.04	6.20	6.19	374,000	10,010	
	2	6.03		6.18				
21T-1A	1	6.05	6.06	6.16	6.16	373,000	10,000	10,010
	2	6.07		6.16				

TABLE 5 - ASTM C 116 COMPRESSIVE STRENGTH OF CONCRETE USING PORTIONS OF BEAMS BROKEN IN FLEXURAL FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374 (CONT.)

Specimen Identification		Width, in.	Average Width, in.	Depth, in.	Average Depth, in.	Maximum Load, lbs	Compressive Strength, psi	Average Compressive Compressive Strength of Two Ends, psi
	1	6.08		6.16				
21T-1B	2	6.04	6.06	6.14	6.15	368,000	9,880	
	1	6.09		6.18				
21T-1B	2	6.06	6.07	6.15	6.17	392,000	10,480	10,180
	1	6.08		6.17				
21T-2B	2	6.09	6.08	6.19	6.18	290,000	7,710	
	1	6.05		6.19				
21T-2B	2	6.05	6.05	6.20	6.19	291,000	7,770	7,740
	1	6.07		6.20				
21T-2C	2	6.09	6.08	6.22	6.21	296,000	7,850	
	1	6.10		6.19				
21T-2C	2	6.10	6.10	6.19	6.19	298,000	7,900	7,880
	1	6.06		6.18				
31-1A	2	6.08	6.07	6.17	6.17	330,000	8,810	
	1	6.11		6.20				
31-1A	2	6.04	6.07	6.20	6.20	336,000	8,920	8,870
	1	6.10		6.21				
31-1B	2	6.10	6.10	6.21	6.21	322,000	8,500	
	1	6.10		6.23				
31-1B	2	6.15	6.12	6.21	6.22	328,000	8,610	8,560
	1	6.06		6.23				
31-2A	2	6.06	6.06	6.19	6.21	271,000	7,210	
	1	6.09		6.17				
31-2A	2	6.06	6.07	6.18	6.17	273,000	7,280	7,250
	1	6.10		6.26				
31-2B	2	6.09	6.09	6.19	6.22	276,000	7,290	
	1	6.12		6.18				
31-2B	2	6.09	6.10	6.21	6.20	256,000	6,770	7,030
	1	6.08		6.22				
43A-3A	2	6.07	6.07	6.20	6.21	182,000	4,830	
	1	6.04		6.21				
43A-3A	2	6.10	6.07	6.22	6.21	188,000	4,990	4,910
	1	6.08		6.21				
43A-3C	2	6.05	6.06	6.19	6.20	191,000	5,090	
	1	6.03		6.19				
43A-3C	2	6.05	6.04	6.19	6.19	179,000	4,790	4,940
	1	6.04		6.22				
51-1C	2	6.09	6.06	6.20	6.21	415,000	11,030	
	1	6.04		6.22				
51-1C	2	6.09	6.06	6.20	6.21	415,000	11,030	11,030
	1	6.04		6.24				
51-2B	2	6.08	6.06	6.21	6.22	296,000	7,860	
	1	6.01		6.21				
51-2B	2	6.04	6.02	6.24	6.23	296,000	7,900	7,880

TABLE 6 - UNIT WEIGHT OF CONCRETE CORES FOR 42 YR OLD CONCRETE SPECIMENS FROM PCA SERIES 374

Specimen Identification	Weight in Air, lbs	Weight in Water, lbs	Unit Weight, lbs per cu ft	Average Unit Weight, lbs per cu ft
11T-2B	6.35	3.71	150.1	
11T-2B	6.47	3.78	150.1	150.1
11T-2C	6.39	3.73	149.9	
11T-2C	6.39	3.74	150.3	150.1
19B-1A	6.75	4.05	156.0	
19B-1A	6.52	3.92	156.5	156.2
19B-1B	6.53	3.91	155.5	
19B-1B	6.51	3.89	155.0	155.3
19B-2A	5.56	3.30	153.5	
19B-2A	6.48	3.85	153.7	153.6
19B-2B	6.50	3.85	153.1	
19B-2B	6.50	3.87	154.2	153.7
21-1A	6.55	3.93	156.0	
21-1A	6.52	3.89	154.7	155.3
21-1B	6.72	4.03	155.9	
21-1B	6.59	3.96	156.4	156.1
21-2A	6.58	3.93	154.9	
21-2A	N/A	N/A	N/A	154.9
21-2B	6.67	3.99	155.3	
21-2B	6.50	3.89	155.4	155.4
21T-1A	6.52	3.89	154.7	
21T-1A	6.53	3.90	154.9	154.8
21T-1B	6.66	3.96	153.9	
21T-1B	6.50	3.87	154.2	154.1

TABLE 6 - UNIT WEIGHT OF CONCRETE CORES FOR 42 YR OLD CONCRETE SPECIMENS FROM PCA SERIES 374 (CONT.)

Specimen Identification	Weight in Air, lbs	Weight in Water, lbs	Unit Weight, lbs per cu ft	Average Unit Weight, lbs per cu ft
21T-2B	6.62	3.92	153.0	
21T-2B	6.55	3.87	152.5	152.8
21T-2C	6.50	3.84	152.5	
21T-2C	6.62	3.91	152.4	152.5
31-1A	6.51	3.87	153.9	
31-1A	6.50	3.86	153.6	153.8
31-1B	6.51	3.86	153.3	
31-1B	6.54	3.87	152.8	153.1
31-2A	6.54	3.90	154.6	
31-2A	6.62	3.94	154.1	154.4
31-2B	5.68	3.35	152.1	
31-2B	6.55	3.89	153.7	152.9
43A-3A	6.30	3.67	149.5	
43A-3A	6.44	3.75	149.4	149.4
43A-3C	6.33	3.71	150.8	
43A-3C	6.49	3.80	150.5	150.7
51-1C	6.60	3.97	156.6	
51-1C	6.60	3.98	157.2	156.9
51-2B	6.53	3.91	155.5	
51-2B	6.52	3.89	154.7	155.1

TABLE 7 - TEST RESULTS OF ASTM C42-90 STANDARD TEST METHOD FOR COMPRESSIVE STRENGTH OF DRILLED CORES OF CONCRETE FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374

Core Identification	11T-2B	11T-2B	11T-2C	11T-2C
Maximum Nominal Aggregate Size, in	1	1	1 1/4	1
Concrete Age at Test, approximate years	42	42	42	42
Moisture Condition at Test	Moist	Moist	Moist	Moist
Orientation of Core Axis in Structure	Vertical	Vertical	Vertical	Vertical
Diameter 1, in	4.02	4.01	3.99	4.02
Diameter 2, in	4.02	4.02	3.91	4.02
Average Diameter, in	4.02	4.02	3.95	4.02
Cross-Sectional Area, sq in	12.67	12.66	12.25	12.69
Length Ground, in	5.8	5.9	5.9	5.8
Loading Rate, psi/sec	35	35	35	35
Maximum Load, lbs	86,250	85,250	87,000	92,000
Uncorrected Compressive Strength, psi	6,810	6,730	7,100	7,250
Ratio of Capped Length to Diameter, L/D	1.45	1.47	1.50	1.45
Correction Factor - ASTM C 42	0.953	0.956	0.960	0.954
Corrected Compressive Strength, psi	**6,490**	**6,440**	**6,810**	**6,920**
Fracture Pattern	conical	conical	conical	conical
Notes:				

TABLE 7 - TEST RESULTS OF ASTM C42-90 STANDARD TEST METHOD FOR COMPRESSIVE STRENGTH OF DRILLED CORES OF CONCRETE FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374 (CONT.)

Core Identification	19B-1A	19B-1A	19B-1B	19B-1B
Maximum Nominal Aggregate Size, in	1	1	1	1
Concrete Age at Test, approximate years	42	42	42	42
Moisture Condition at Test	Moist	Moist	Moist	Moist
Orientation of Core Axis in Structure	Vertical	Vertical	Vertical	Vertical
Diameter 1, in	4.02	4.00	3.99	3.99
Diameter 2, in	4.01	4.00	3.99	3.99
Average Diameter, in	4.01	4.00	3.99	3.99
Cross-Sectional Area, sq in	12.65	12.54	12.52	12.51
Length Ground, in	5.9	5.8	5.8	5.7
Loading Rate, psi/sec	35	35	35	35
Maximum Load, lbs	138,500	144,750	138,000	138,500
Uncorrected Compressive Strength, psi	10,950	11,540	11,030	11,070
Ratio of Capped Length to Diameter, L/D	1.48	1.46	1.46	1.44
Correction Factor - ASTM C 42	0.958	0.955	0.955	0.953
Corrected Compressive Strength, psi	**10,490**	**11,020**	**10,530**	**10,550**
Fracture Pattern	conical	conical	conical	conical
Notes:				

TABLE 7 - TEST RESULTS OF ASTM C42-90 STANDARD TEST METHOD FOR COMPRESSIVE STRENGTH OF DRILLED CORES OF CONCRETE FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374 (CONT.)

Core Identification	19B-2A	19B-2A	19B-2B	19B-2B
Maximum Nominal Aggregate Size (in)	1	1	1	3/4
Concrete Age at Test (approximate years)	42	42	42	42
Moisture Condition at Test	Moist	Moist	Moist	Moist
Orientation of Core Axis in Structure	Vertical	Vertical	Vertical	Vertical
Diameter 1 (in)	3.73	4.00	4.00	3.99
Diameter 2 (in)	3.73	4.00	3.99	4.00
Average Diameter (in)	3.73	4.00	4.00	3.99
Cross-Sectional Area (sq in)	10.91	12.54	12.53	12.53
Length Ground (in)	5.7	5.9	5.9	5.9
Loading Rate (psi/s)	35	35	35	35
Maximum Load (lbs)	82,500	87,500	96,500	93,500
Uncorrected Compressive Strength (psi)	7,560	6,980	7,700	7,460
Ratio of Capped Length to Diameter (L/D)	1.54	1.47	1.47	1.47
Correction Factor (ASTM C42)	0.963	0.956	0.957	0.956
Corrected Compressive Strength (psi)	**7,280**	**6,670**	**7,370**	**7,130**
Fracture Pattern	conical	conical	conical	conical
Notes:				

TABLE 7 - TEST RESULTS OF ASTM C42-90 STANDARD TEST METHOD FOR COMPRESSIVE STRENGTH OF DRILLED CORES OF CONCRETE FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374 (CONT.)

Core Identification	21-1A	21-1A	21-1B	21-1B
Maximum Nominal Aggregate Size (in)	1	1	1 1/4	1 1/8
Concrete Age at Test (approximate years)	42	42	42	42
Moisture Condition at Test	Moist	Moist	Moist	Moist
Orientation of Core Axis in Structure	Vertical	Vertical	Vertical	Vertical
Diameter 1 (in)	3.99	4.00	4.01	3.99
Diameter 2 (in)	3.99	3.99	4.02	3.99
Average Diameter (in)	3.99	3.99	4.02	3.99
Cross-Sectional Area (sq in)	12.50	12.53	12.67	12.50
Length Ground (in)	5.8	5.9	5.9	5.9
Loading Rate (psi/s)	35	35	35	35
Maximum Load (lbs)	150,000	149,250	151,250	141,500
Uncorrected Compressive Strength (psi)	12,000	11,910	11,930	11,320
Ratio of Capped Length to Diameter (L/D)	1.46	1.48	1.47	1.47
Correction Factor (ASTM C42)	0.956	0.957	0.956	0.956
Corrected Compressive Strength (psi)	**11,470**	**11,400**	**11,410**	**10,830**
Fracture Pattern	conical	conical	conical	conical
Notes:				

TABLE 7 - TEST RESULTS OF ASTM C42-90 STANDARD TEST METHOD FOR COMPRESSIVE STRENGTH OF DRILLED CORES OF CONCRETE FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374 (CONT.)

Core Identification	21-2A	21-2A	21-2B	21-2B
Maximum Nominal Aggregate Size (in)	1 1/8	1	1	1 1/8
Concrete Age at Test (approximate years)	42	42	42	42
Moisture Condition at Test	Moist	Moist	Moist	Moist
Orientation of Core Axis in Structure	Vertical	Vertical	Vertical	Vertical
Diameter 1 (in)	4.02	2.76	4.02	4.00
Diameter 2 (in)	4.02	2.76	4.01	4.00
Average Diameter (in)	4.02	2.76	4.01	4.00
Cross-Sectional Area (sq in)	12.67	6.00	12.65	12.54
Length Ground (in)	5.8	5.5	5.9	5.8
Loading Rate (psi/s)	35	35	35	35
Maximum Load (lbs)	113,750	46,500	103,000	105,000
Uncorrected Compressive Strength (psi)	8,980	7,750	8,140	8,370
Ratio of Capped Length to Diameter (L/D)	1.45	2.00	1.47	1.46
Correction Factor (ASTM C42)	0.954	1.000	0.956	0.955
Corrected Compressive Strength (psi)	**8,570**	**7,750**	**7,780**	**7,990**
Fracture Pattern	conical	conical	conical	conical
Notes:				

TABLE 7 - TEST RESULTS OF ASTM C42-90 STANDARD TEST METHOD FOR COMPRESSIVE STRENGTH OF DRILLED CORES OF CONCRETE FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374 (CONT.)

Core Identification	21T-1A	21T-1A	21T-1B	21T-1B
Maximum Nominal Aggregate Size (in)	1	1	1	1
Concrete Age at Test (approximate years)	42	42	42	42
Moisture Condition at Test	Moist	Moist	Moist	Moist
Orientation of Core Axis in Structure	Vertical	Vertical	Vertical	Vertical
Diameter 1 (in)	3.99	3.99	4.02	4.00
Diameter 2 (in)	4.00	3.99	4.01	4.00
Average Diameter (in)	3.99	3.99	4.02	4.00
Cross-Sectional Area (sq in)	12.53	12.49	12.67	12.54
Length Ground (in)	6.0	5.9	5.9	5.9
Loading Rate (psi/s)	35	35	35	35
Maximum Load (lbs)	128,000	134,000	145,250	134,750
Uncorrected Compressive Strength (psi)	10,220	10,720	11,470	10,740
Ratio of Capped Length to Diameter (L/D)	1.50	1.48	1.48	1.47
Correction Factor (ASTM C42)	0.960	0.957	0.957	0.957
Corrected Compressive Strength (psi)	**9,810**	**10,270**	**10,980**	**10,280**
Fracture Pattern	conical	conical	conical	conical
Notes:				

TABLE 7 - TEST RESULTS OF ASTM C42-90 STANDARD TEST METHOD FOR COMPRESSIVE STRENGTH OF DRILLED CORES OF CONCRETE FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374 (CONT.)

Core Identification	21T-2B	21T-2B	21T-2C	21T-2C
Maximum Nominal Aggregate Size (in)	1	1 1/4	1	1
Concrete Age at Test (approximate years)	42	42	42	42
Moisture Condition at Test	Moist	Moist	Moist	Moist
Orientation of Core Axis in Structure	Vertical	Vertical	Vertical	Vertical
Diameter 1 (in)	4.02	4.02	4.02	3.99
Diameter 2 (in)	4.01	4.01	4.02	3.99
Average Diameter (in)	4.01	4.01	4.02	3.99
Cross-Sectional Area (sq in)	12.66	12.65	12.66	12.50
Length Ground (in)	5.9	5.9	5.9	5.9
Loading Rate (psi/s)	35	35	35	35
Maximum Load (lbs)	106,000	104,500	103,000	102,500
Uncorrected Compressive Strength (psi)	8,370	8,260	8,130	8,200
Ratio of Capped Length to Diameter (L/D)	1.47	1.48	1.48	1.48
Correction Factor (ASTM C42)	0.956	0.957	0.957	0.958
Corrected Compressive Strength (psi)	**8,010**	**7,910**	**7,790**	**7,860**
Fracture Pattern	conical	conical	conical	conical
Notes:				

TABLE 7 - TEST RESULTS OF ASTM C42-90 STANDARD TEST METHOD FOR COMPRESSIVE STRENGTH OF DRILLED CORES OF CONCRETE FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374 (CONT.)

Core Identification	31-1A	31-1A	31-1B	31-1B
Maximum Nominal Aggregate Size (in)	3/4	1 1/8	1	1
Concrete Age at Test (approximate years)	42	42	42	42
Moisture Condition at Test	Moist	Moist	Moist	Moist
Orientation of Core Axis in Structure	Vertical	Vertical	Vertical	Vertical
Diameter 1 (in)	3.99	4.00	4.01	3.99
Diameter 2 (in)	3.99	4.00	4.00	3.99
Average Diameter (in)	3.99	4.00	4.01	3.99
Cross-Sectional Area (sq in)	12.51	12.55	12.61	12.51
Length Ground (in)	5.9	5.9	5.9	5.9
Loading Rate (psi/s)	35	35	35	35
Maximum Load (lbs)	112,500	107,000	122,000	113,000
Uncorrected Compressive Strength (psi)	8,990	8,530	9,670	9,030
Ratio of Capped Length to Diameter (L/D)	1.48	1.48	1.47	1.47
Correction Factor (ASTM C42)	0.957	0.957	0.956	0.957
Corrected Compressive Strength (psi)	**8,610**	**8,160**	**9,250**	**8,640**
Fracture Pattern	conical	conical	conical	conical
Notes:				

TABLE 7 - TEST RESULTS OF ASTM C42-90 STANDARD TEST METHOD FOR COMPRESSIVE STRENGTH OF DRILLED CORES OF CONCRETE FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374 (CONT.)

Core Identification	31-2A	31-2A	31-2B	31-2B
Maximum Nominal Aggregate Size (in)	1	1	1	1
Concrete Age at Test (approximate years)	42	42	42	42
Moisture Condition at Test	Moist	Moist	Moist	Moist
Orientation of Core Axis in Structure	Vertical	Vertical	Vertical	Vertical
Diameter 1 (in)	4.02	4.00	3.99	3.73
Diameter 2 (in)	4.01	4.00	4.00	3.73
Average Diameter (in)	4.02	4.00	3.99	3.73
Cross-Sectional Area (sq in)	12.66	12.55	12.53	10.92
Length Ground (in)	5.9	5.9	5.9	5.9
Loading Rate (psi/s)	35	35	35	35
Maximum Load (lbs)	91,250	86,000	82,750	81,000
Uncorrected Compressive Strength (psi)	7,210	6,850	6,600	7,420
Ratio of Capped Length to Diameter (L/D)	1.47	1.48	1.48	1.59
Correction Factor (ASTM C42)	0.956	0.958	0.957	0.967
Corrected Compressive Strength (psi)	**6,890**	**6,560**	**6,320**	**7,170**
Fracture Pattern	conical	conical	conical	conical
Notes:				

TABLE 7 - TEST RESULTS OF ASTM C42-90 STANDARD TEST METHOD FOR COMPRESSIVE STRENGTH OF DRILLED CORES OF CONCRETE FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374 (CONT.)

Core Identification	43A-3A	43A-3A	43A-3C	43A-3C
Maximum Nominal Aggregate Size (in)	1	1	1	1
Concrete Age at Test (approximate years)	42	42	42	42
Moisture Condition at Test	Moist	Moist	Moist	Moist
Orientation of Core Axis in Structure	Vertical	Vertical	Vertical	Vertical
Diameter 1 (in)	3.99	3.99	4.01	3.99
Diameter 2 (in)	4.01	3.99	4.01	4.00
Average Diameter (in)	4.00	3.99	4.01	3.99
Cross-Sectional Area (sq in)	12.58	12.51	12.65	12.53
Length Ground (in)	5.9	5.9	5.9	5.9
Loading Rate (psi/s)	35	35	35	35
Maximum Load (lbs)	59,750	62,500	59,000	59,000
Uncorrected Compressive Strength (psi)	4,750	4,990	4,660	4,710
Ratio of Capped Length to Diameter (L/D)	1.48	1.47	1.48	1.47
Correction Factor (ASTM C42)	0.958	0.956	0.958	0.956
Corrected Compressive Strength (psi)	**4,550**	**4,780**	**4,460**	**4,500**
Fracture Pattern	conical	conical	conical	conical
Notes:				

TABLE 7 - TEST RESULTS OF ASTM C42-90 STANDARD TEST METHOD FOR COMPRESSIVE STRENGTH OF DRILLED CORES OF CONCRETE FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374 (CONT.)

Core Identification	51-1C	51-1C	51-2B	51-2B
Maximum Nominal Aggregate Size (in)	1	1	1	1
Concrete Age at Test (approximate years)	42	42	42	42
Moisture Condition at Test	Moist	Moist	Moist	Moist
Orientation of Core Axis in Structure	Vertical	Vertical	Vertical	Vertical
Diameter 1 (in)	3.99	3.99	3.99	3.99
Diameter 2 (in)	3.99	3.99	3.99	3.99
Average Diameter (in)	3.99	3.99	3.99	3.99
Cross-Sectional Area (sq in)	12.51	12.52	12.51	12.51
Length Ground (in)	5.9	5.9	5.8	5.9
Loading Rate (psi/s)	35	35	35	35
Maximum Load (lbs)	140,750	141,500	100,000	102,250
Uncorrected Compressive Strength (psi)	11,250	11,310	7,990	8,180
Ratio of Capped Length to Diameter (L/D)	1.47	1.47	1.46	1.47
Correction Factor (ASTM C42)	0.956	0.957	0.956	0.956
Corrected Compressive Strength (psi)	**10,760**	**10,810**	**7,640**	**7,820**
Fracture Pattern	conical	conical	conical	conical
Notes:				

TABLE 8 - SUMMARY OF ASTM C42-90 TEST RESULTS FOR COMPRESSIVE STRENGTH OF CONCRETE CORES FOR 42 YR OLD SPECIMENS FROM PCA SERIES 374

Beam Identification No.	Compressive Strength, psi		
	Core No. 1	Core No. 2	Average
11T-2B	6,490	6,440	6,470
11T-2C	6,810	6,920	6,870
19B-1A	10,490	11,020	10,760
19B-1B	10,530	10,550	10,540
19B-2A	7,280	6,670	6,980
19B-2B	7,370	7,130	7,250
21-1A	11,470	11,400	11,440
21-1B	11,410	10,830	11,120
21-2A	8,570	7,750	8,160
21-2B	7,780	7,990	7,890
21T-1A	9,810	10,270	10,040
21T-1B	10,980	10,280	10,630
21T-2B	8,010	7,910	7,960
21T-2C	7,790	7,860	7,830
31-1A	8,610	8,160	8,390
31-1B	9,250	8,640	8,950
31-2A	6,890	6,560	6,730
31-2B	6,320	7,170	6,750
43A-3A	4,550	4,780	4,670
43A-3C	4,460	4,500	4,480
51-1C	10,760	10,810	10,790
51-2B	7,640	7,820	7,730

REFERENCES

(1.) Van Geem, M. G. and Naus, D. J., "Summary of Test Results for Portland Cement Association Study on Long-Term Properties of Concrete.", Report No. ORNL/NRC/LTR-91/26, Oak Ridge National Laboratory for the U.S. Department of Energy, Oak Ridge, 1992.

(2.) Wood, Sharon, "Evaluation of the Long-Term Properties of Concrete," *ACI Materials Journal*, American Concrete Institute, Detroit, Vol. 88, No. 6, November-December 1991, 14 pages.

APPENDIX A: RESULTS OF PETROGRAPHIC EXAMINATION

CTL
5420 Old Orchard Road, Skokie, Illinois 60077-1030
Phone: 708/965-7500 Fax: 708/965-6541

PETROGRAPHIC SERVICES REPORT

CTL Project No.: 102323 *Date:* August 20, 1992

Re: Petrographic Examination of Seven Concrete Slices from 6 x 6 x 30-in. Specimens, Martin Marietta Energy Systems

Seven concrete slices, (See Figures 1, 3, 5, 7, 9, 11 & 13), were received on June 10, 1992 from Ms. Martha G. Van Geem, Senior Engineer of CTL on behalf of Oak Ridge National Laboratory, Martin Marietta Energy Systems of Oak Ridge, Tennessee.

Reportedly, the concrete slices were taken from 6 x 6 x 30-in. specimens that were cast in 1950 (42 years old) as part of PCA Series 374. The concrete slices list is as follows:

SERIES	MIX ID	MIX DESCRIPTION
374	19B-1A	TYPE I CEMENT
374	21-1A	TYPE II CEMENT
374	31-1A	TYPE III CEMENT
374	43A-3C	TYPE IV CEMENT
374	51-2B	TYPE V CEMENT
374	11T-2B	AIR-ENTRAINING CEMENT
374	21T-2A	AIR-ENTRAINING CEMENT

Ms. Van Geem requested full petrographic examination on each concrete slice to evaluate overall quality of concrete.

FINDINGS

1. The concrete mix was produced using 1-in. to 3/4-in.-size gravel composed mainly of siliceous and calcareous rocks. Fine aggregate is of natural sand. Aggregate is evenly graded and uniformly distributed.

2. The paste microstructural characteristics and other, important features of the seven concrete slices are summarized in Table No. 1. Highlights of these characteristics and features are as follows:

   a. The majority of the concrete slices exhibit moderate (0.45 to 0.55) water-to-cement ratio, based on paste properties, except Slice No. 43A-3C which has a moderately high (0.55 to 0.65) and 31-1A is 0.50 to 0.60 water-to-cement ratio.

   b. The majority of the concrete slices are not air-entrained except Slice Nos. 11T-2B and 21T-2A.

   c. All of the concrete slices exhibit carbonation confined to 0.1 in. to 0.2 in. depth from the top surface.

   d. Carbonate dust was observed in the paste but is not detrimental.

3. Concrete appears dense and well-consolidated. No significant cracks (macro and micro), joints or large voids were observed in the concrete samples.

4. No evidence of alkali-silica reaction, such as gel, reaction rims, and/or cracks from aggregate particles, was observed in the concrete samples.

5. Additional details of the petrographic examinations are presented in the attached form.

METHODS OF TEST

Petrographic examination of the concrete slice samples was performed in accordance with ASTM C 856-83 (reapproved 1988), "Standard Practice for Petrographic Examination of Hardened Concrete." Each concrete slice sample was lapped on one side and examined at stereomicroscope magnifications up to 45X. For thin section examination, a rectangular block was cut near the top surface of the sample, placed on a glass microscope slide with epoxy resin,

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and reduced to a thickness of approximately 20 micrometers (0.0008 in.). The thin section was examined using a polarized-light microscope at magnifications up to 250X to determine aggregate and paste mineralogy and microstructure.

Arturo G. Nisperos
Senior Petrographer
Supervisor, Petrographic Services

AGN/nem

Attachment

102323

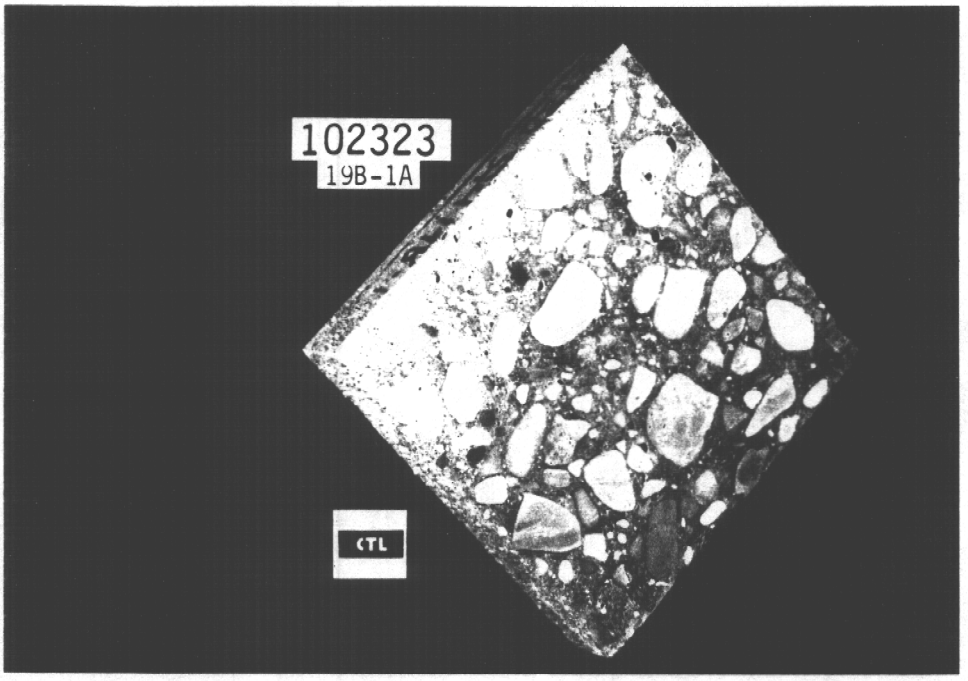

FIG. 1 OBLIQUE VIEW OF CONCRETE SLICE NO. 19B-1A, AS RECEIVED FOR TESTING.

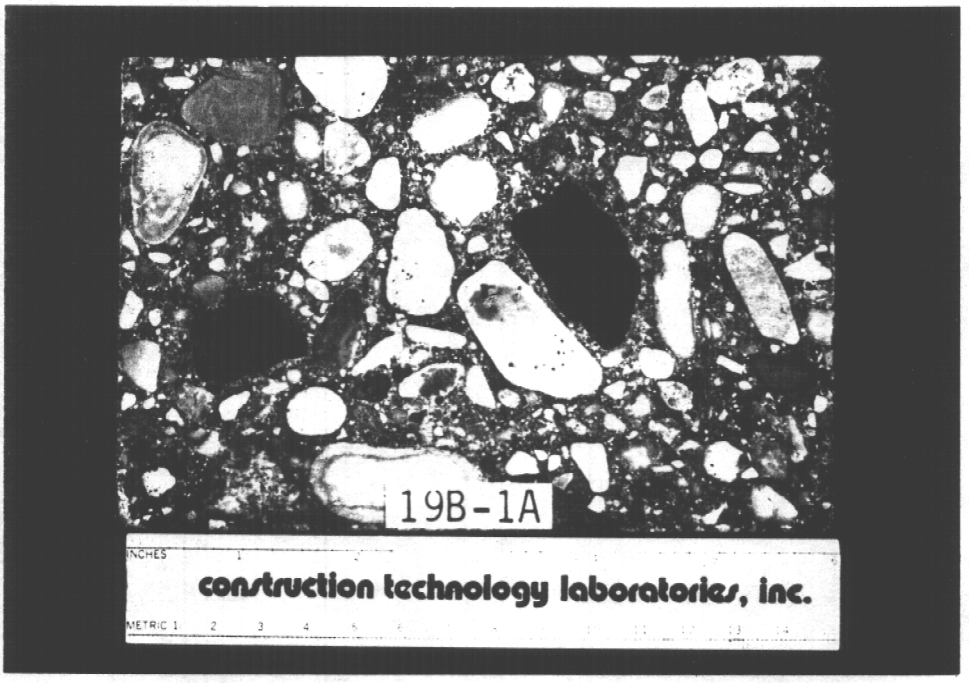

FIG. 2 LAPPED SLICE SIDE OF CONCRETE SPECIMEN NO. 19B-1A.

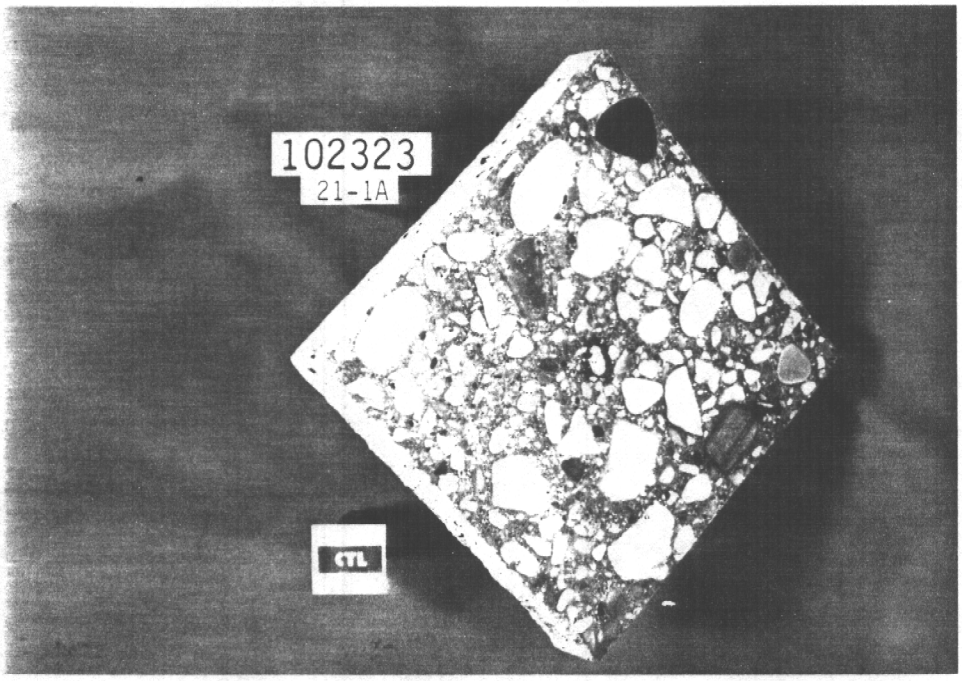

FIG. 3 OBLIQUE VIEW OF CONCRETE SLICE NO. 21-1A, AS RECEIVED FOR TESTING.

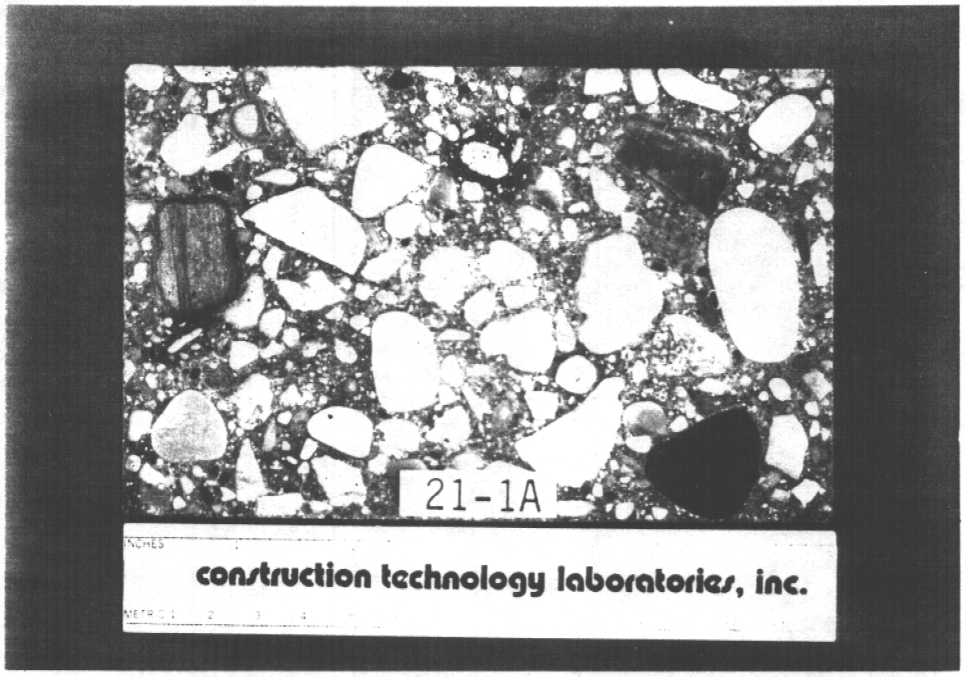

FIG. 4 LAPPED SLICE SIDE OF CONCRETE SPECIMEN NO. 21-1A.

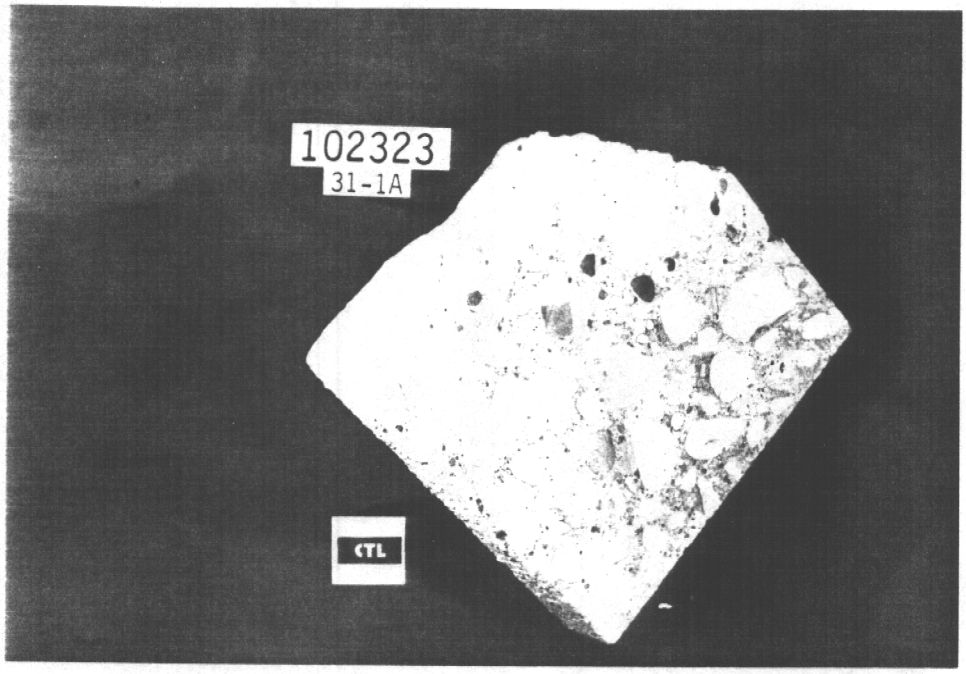

FIG. 5 OBLIQUE VIEW OF CONCRETE SLICE NO. 31-1A, AS RECEIVED FOR TESTING.

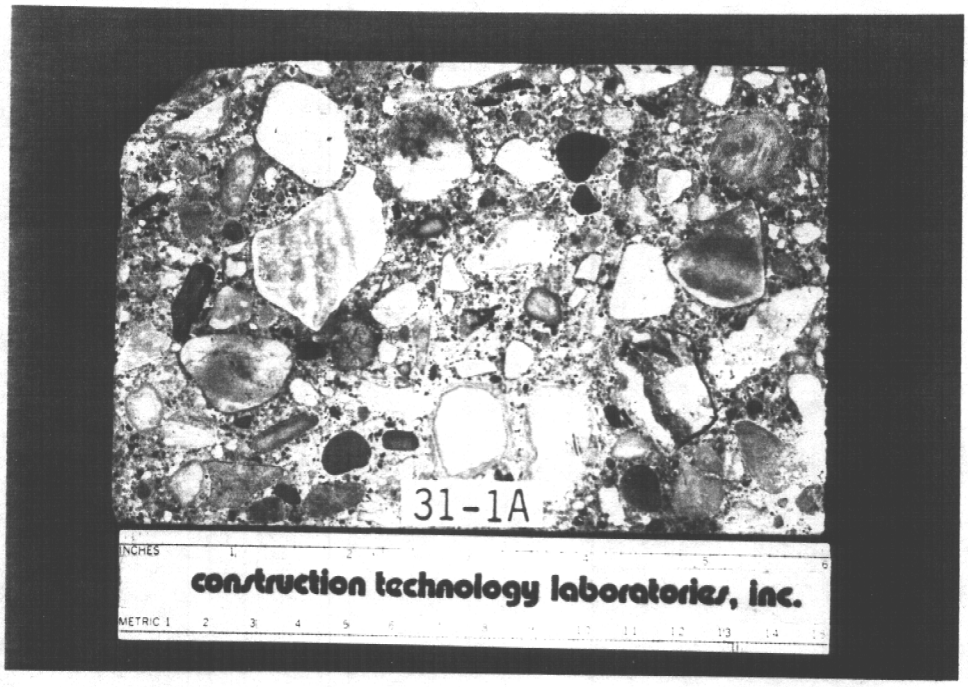

FIG. 6 LAPPED SLICE SIDE OF CONCRETE SPECIMEN NO. 31-1A.

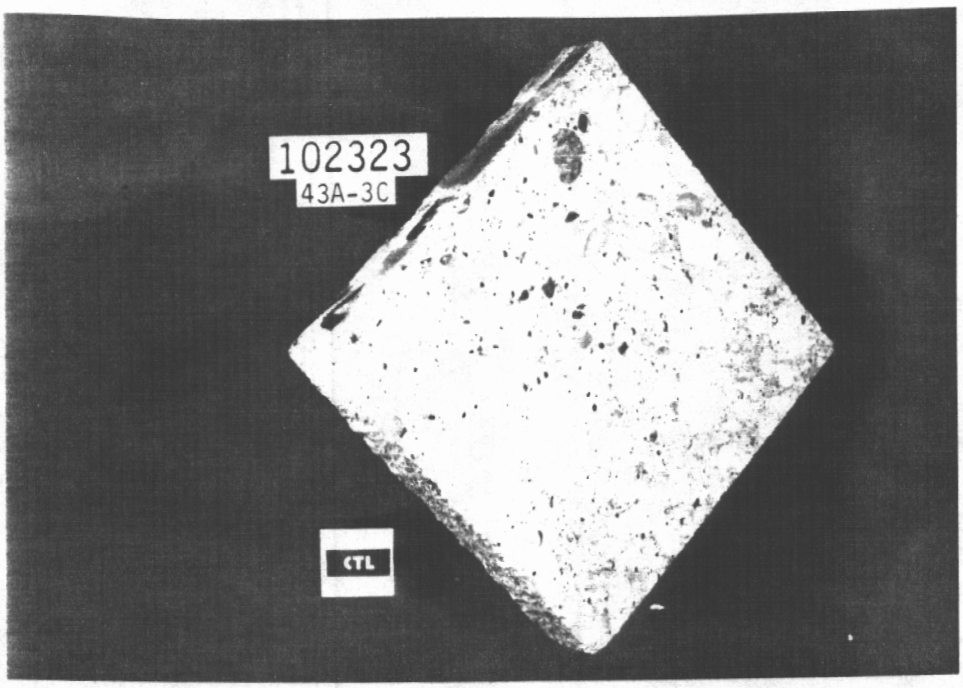

FIG. 7 OBLIQUE VIEW OF CONCRETE SLICE NO. 43A-3C, AS RECEIVED FOR TESTING.

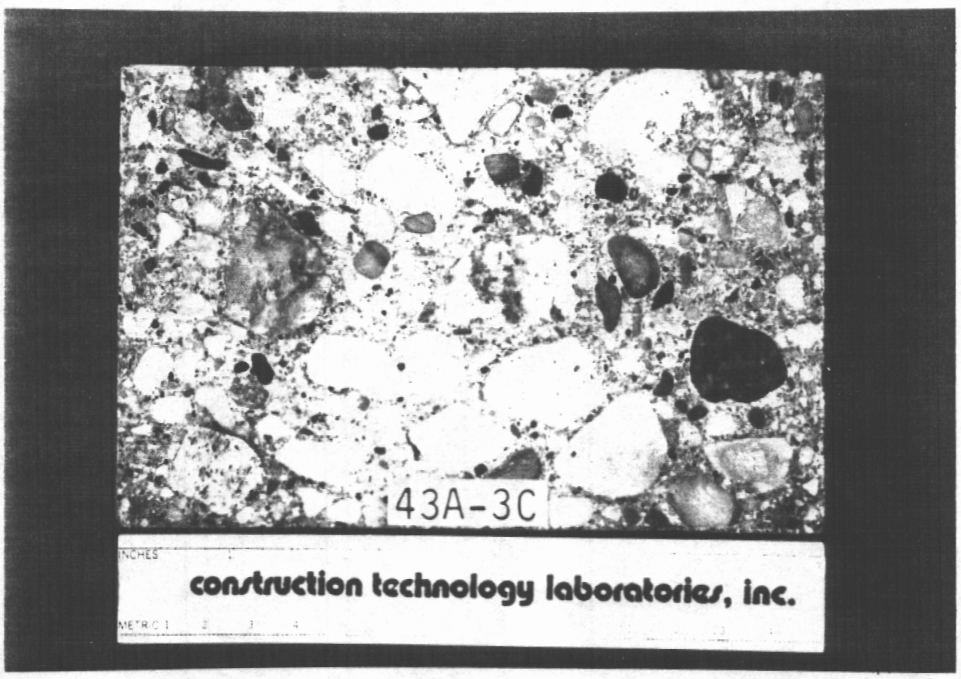

FIG. 8 LAPPED SLICE SIDE OF CONCRETE SPECIMEN NO. 43A-3C.

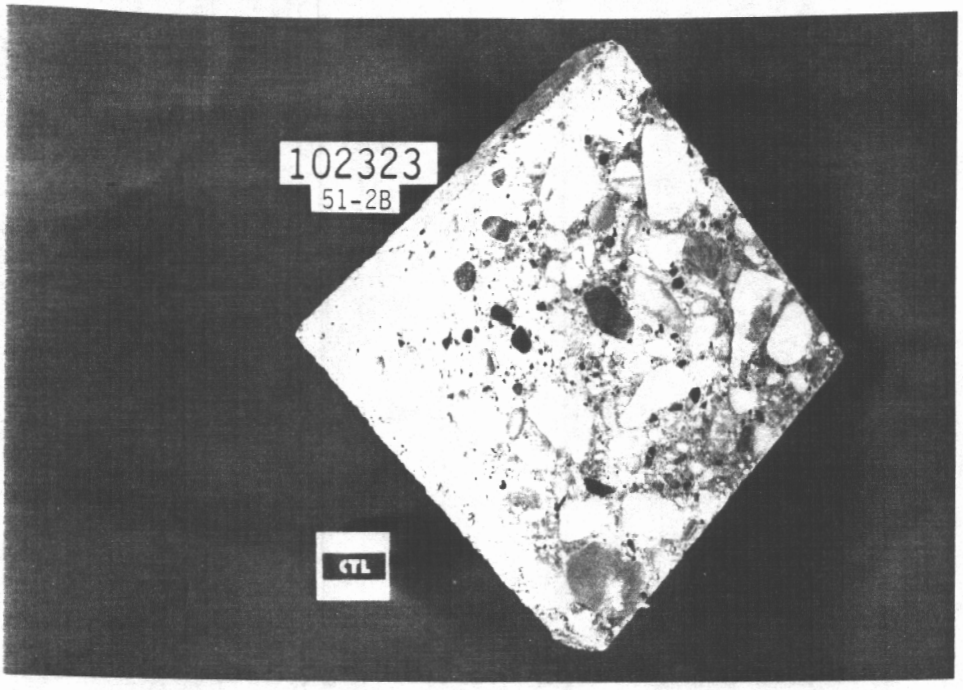

FIG. 9 OBLIQUE VIEW OF CONCRETE SLICE NO. 51-2B, AS RECEIVED FOR TESTING.

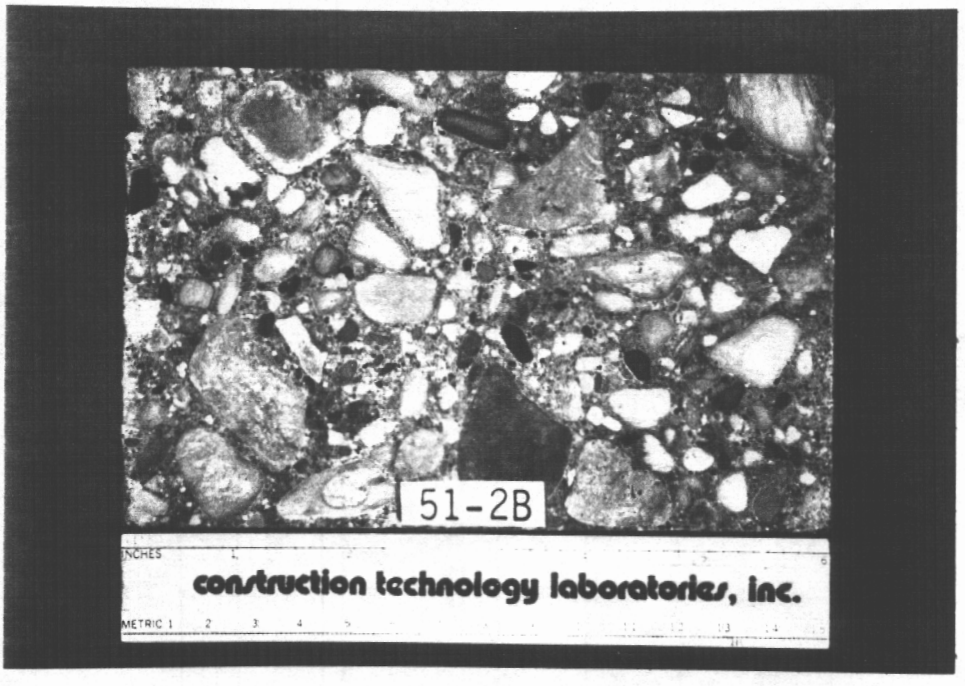

FIG. 10 LAPPED SLICE SIDE OF CONCRETE SPECIMEN NO. 51-2B.

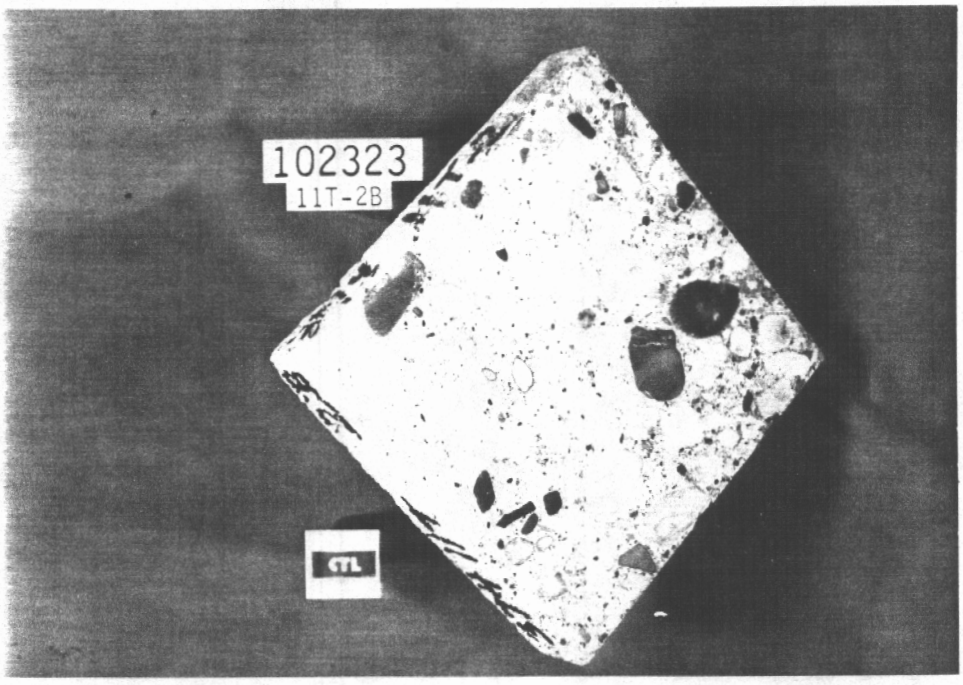

FIG. 11 OBLIQUE VIEW OF CONCRETE SLICE NO. 11T-2B, AS RECEIVED FOR TESTING.

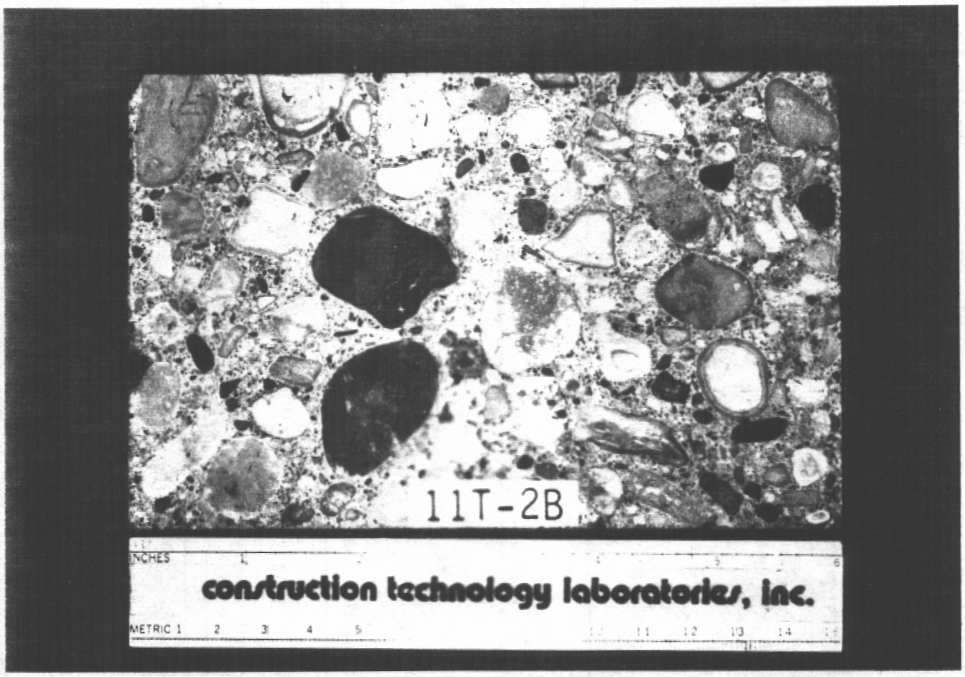

FIG. 12 LAPPED SLICE SIDE OF CONCRETE SPECIMEN NO. 11T-2B.

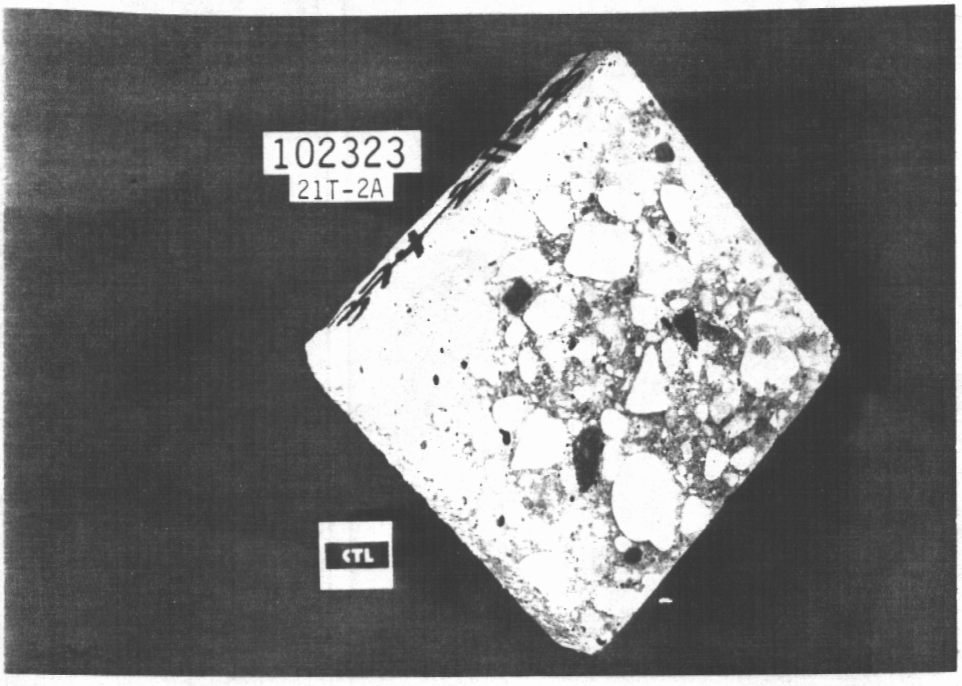

FIG. 13 OBLIQUE VIEW OF CONCRETE SLICE NO. 21T-2A, AS RECEIVED FOR TESTING.

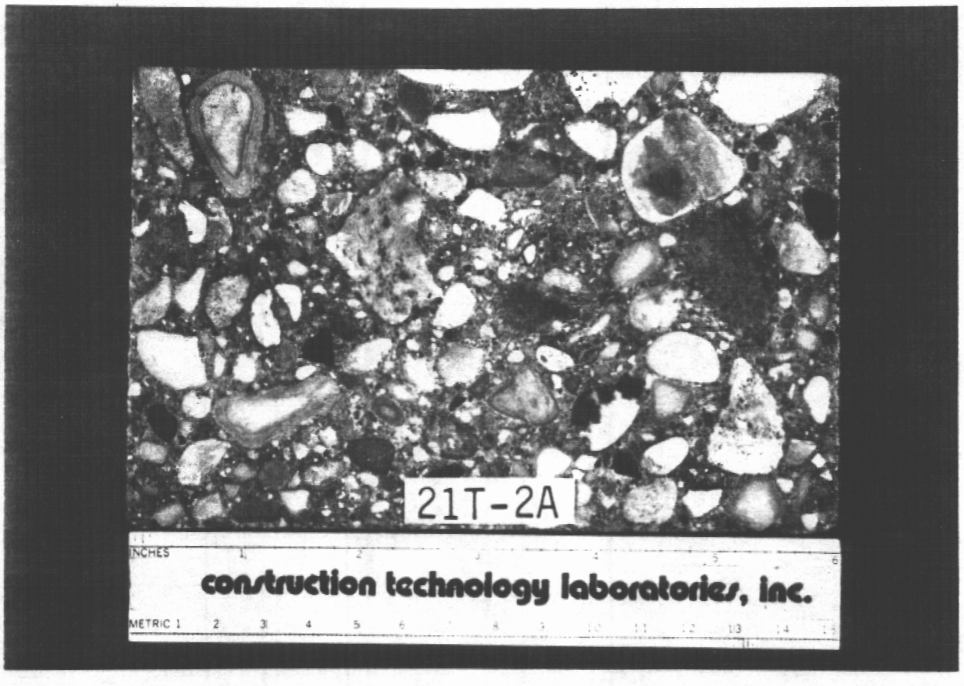

FIG. 14 LAPPED SLICE SIDE OF CONCRETE SPECIMEN NO. 21T-2A.

CTL

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C 856

CTL PROJECT NO.: 102323
CLIENT: Martin Marietta Energy Systems, Inc.
STRUCTURE: Concrete Slice from 6 x 6 x 30-in. Specimen, PCA Series 374
LOCATION: PCA, Skokie, Illinois

DATE: August 20, 1992
PROBLEM: Quality Evaluation
EXAMINED BY: A. G. Nisperos

SAMPLE:

Identification: Series 374, No. 19B-1A.

Dimensions: 6" x 6" x 1".

Top Surface: Irregular, broom-finish.

Bottom Surface: Smooth, formed-surface.

Cracks, Joints, Large Voids: No significant cracks observed. Some irregular voids up to 0.2 in. in diameter scattered over concrete specimen.

Reinforcement: None observed.

AGGREGATES (A)

Coarse (C): Gravel composed mainly of siliceous rocks (quartzites, arkose, chert, etc.) and calcareous rocks (dolomite, limestone), and other rock fragments.

Fine (F): Natural sand consisting mainly of quartz, feldspar, chert, shale and variety of rock fragments.

Gradation & Top Size: 1-inch to 3/4-inch sizes to maximum size of 1-1/2 inches. Evenly-graded.

Shape & Distribution: CA is subrounded to rounded, tabular to subspherical, some elongated; FA is subangular to subrounded and spherical; uniform distribution.

PASTE

Color: Medium-light gray.

Hardness: Moderately hard.

Luster: Subvitreous.

Calcium Hydroxide*: 5 - 10%.

Unhydrated Portland Cement Clinker Particles (UPC's)*: 5 - 8%.

Depth of Carbonation: 0.1 in. depth from top surface.

Air Content: Less than 1% mostly entrapped air voids.

Fly Ash*: None observed.

Paste-Aggregate Bond: Moderately strong (hammer-induced). Freshly broken surfaces pass through aggregate particles.

Secondary Deposits: Some calcium hydroxide along aggregate fringes.

Microcracking: None observed.

ESTIMATED WATER-CEMENT RATIO: Moderate (0.45 to 0.55).

MISCELLANEOUS: Carbonate rock dust observed in the paste but not causing any detrimental effect. No evidence of alkali aggregate reaction is observed.

*percent by volume of paste

CTL

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C 856

CTL PROJECT NO.: 102323
CLIENT: Martin Marietta Energy Systems, Inc.
STRUCTURE: Concrete Slice from 6 x 6 x 30-in. Specimen, PCA Series 374
LOCATION: PCA, Skokie, Illinois

DATE: August 20, 1992
PROBLEM: Quality Evaluation
EXAMINED BY: A. G. Nisperos

SAMPLE:

Identification: Series 374, No. 21-1A.

Dimensions: 6" x 6" x 1".

Top Surface: Irregular, broom-finish.

Bottom Surface: Smooth, formed-surface.

Cracks, Joints, Large Voids: No significant cracks observed. Some irregular voids up to 0.2 in. in diameter scattered over concrete specimen.

Reinforcement: None observed.

AGGREGATES (A)

Coarse (C): Gravel composed mainly of siliceous rocks (quartzites, arkose, chert, etc.) and calcareous rocks (dolomite, limestone), and other rock fragments.

Fine (F): Natural sand consisting mainly of quartz, feldspar, chert, shale and variety of rock fragments.

Gradation & Top Size: 1-inch to 3/4-inch sizes to maximum size of 1-1/2 inches. Evenly-graded.

Shape & Distribution: CA is subrounded to rounded, tabular to subspherical, some elongated; FA is subangular to subrounded and spherical; uniform distribution.

PASTE

Color: Medium-light gray.

Hardness: Moderately hard.

Luster: Subvitreous.

Calcium Hydroxide*: 5 - 10%.

Unhydrated Portland Cement Clinker Particles (UPC's)*: 5 - 8%.

Depth of Carbonation: 0.1 in. depth from top surface.

Air Content: Less than 1% mostly entrapped air voids.

Fly Ash*: None observed.

Paste-Aggregate Bond: Moderately strong (hammer-induced). Freshly broken surfaces pass through aggregate particles.

Secondary Deposits: Some calcium hydroxide along aggregate fringes.

Microcracking: None observed.

ESTIMATED WATER-CEMENT RATIO: Moderate (0.45 to 0.55).

MISCELLANEOUS: Carbonate rock dust observed in the paste but not causing any detrimental effect. No evidence of alkali aggregate reaction is observed.

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*percent by volume of paste

CTL

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C 856

CTL PROJECT NO.: 102323
CLIENT: Martin Marietta Energy Systems, Inc.
STRUCTURE: Concrete Slice from 6 x 6 x 30-in. Specimen, PCA Series 374
LOCATION: PCA, Skokie, Illinois

DATE: August 20, 1992
PROBLEM: Quality Evaluation
EXAMINED BY: A. G. Nisperos

SAMPLE:

Identification: Series 374, No. 31-1A.

Dimensions: 6" x 6" x 1".

Top Surface: Irregular, broom-finish.

Bottom Surface: Smooth, formed-surface.

Cracks, Joints, Large Voids: No significant cracks observed. Some irregular voids up to 0.2 in. in diameter scattered over concrete specimen.

Reinforcement: None observed.

AGGREGATES (A)

Coarse (C): Gravel composed mainly of siliceous rocks (quartzites, arkose, chert, etc.) and calcareous rocks (dolomite, limestone), and other rock fragments.

Fine (F): Natural sand consisting mainly of quartz, feldspar, chert, shale and variety of rock fragments.

Gradation & Top Size: 1-inch to 3/4-inch sizes to maximum size of 1-1/2 inches. Evenly-graded.

Shape & Distribution: CA is subrounded to rounded, tabular to subspherical, some elongated; FA is subangular to subrounded and spherical; uniform distribution.

PASTE

Color: Light gray.

Hardness: Moderately hard.

Luster: Subvitreous.

Calcium Hydroxide*: 10 - 15%.

Unhydrated Portland Cement Clinker Particles (UPC's)*: 3 - 6%.

Depth of Carbonation: 0.1 in. depth from top surface.

Air Content: Less than 1% mostly entrapped air voids.

Fly Ash*: None observed.

Paste-Aggregate Bond: Moderately strong (hammer-induced). Freshly broken surfaces pass through aggregate particles.

Secondary Deposits: Some calcium hydroxide along aggregate fringes.

Microcracking: None observed.

ESTIMATED WATER-CEMENT RATIO: Moderate to moderately high (0.50 to 0.60).

MISCELLANEOUS: Carbonate rock dust observed in the paste but not causing any detrimental effect. No evidence of alkali aggregate reaction is observed.

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*percent by volume of paste

CTL

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C 856

CTL PROJECT NO.: 102323
CLIENT: Martin Marietta Energy Systems, Inc.
STRUCTURE: Concrete Slice from 6 x 6 x 30-in. Specimen, PCA Series 374
LOCATION: PCA, Skokie, Illinois

DATE: August 20, 1992
PROBLEM: Quality Evaluation
EXAMINED BY: A. G. Nisperos

SAMPLE:

Identification: Series 374, No. 43A-3C.

Dimensions: 6" x 6" x 1".

Top Surface: Irregular, broom-finish.

Bottom Surface: Smooth, formed-surface.

Cracks, Joints, Large Voids: No significant cracks observed. Some irregular voids up to 0.2 in. in diameter scattered over concrete specimen.

Reinforcement: None observed.

AGGREGATES (A)

Coarse (C): Gravel composed mainly of siliceous rocks (quartzites, arkose, chert, etc.) and calcareous rocks (dolomite, limestone), and other rock fragments.

Fine (F): Natural sand consisting mainly of quartz, feldspar, chert, shale and variety of rock fragments.

Gradation & Top Size: 1-inch to 3/4-inch sizes to maximum size of 1-1/2 inches. Evenly-graded.

Shape & Distribution: CA is subrounded to rounded, tabular to subspherical, some elongated; FA is subangular to subrounded and spherical; uniform distribution.

PASTE

Color: Light gray.

Hardness: Moderately hard to moderately soft.

Luster: Subvitreous.

Calcium Hydroxide*: 15 - 20%.

Unhydrated Portland Cement Clinker Particles (UPC's)*: 3 - 5%.

Depth of Carbonation: 0.1 in. depth from top surface.

Air Content: 2 - 3% mostly entrapped air voids less than 2%, nonuniformly distributed.

Fly Ash*: None observed.

Paste-Aggregate Bond: Moderately strong to moderately weak (hammer induced). Freshly broken surfaces pass through and around aggregate particles.

Secondary Deposits: Some calcium hydroxide and ettringite partly line air voids.

Microcracking: None observed.

ESTIMATED WATER-CEMENT RATIO: Moderately high (0.55 to 0.65).

MISCELLANEOUS: Carbonate rock dust observed in the paste but not causing any detrimental effect. No evidence of alkali aggregate reaction is observed.

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*percent by volume of paste

CTL

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C 856

CTL PROJECT NO.: 102323
CLIENT: Martin Marietta Energy Systems, Inc.
STRUCTURE: Concrete Slice from 6 x 6 x 30-in. Specimen, PCA Series 374
LOCATION: PCA, Skokie, Illinois

DATE: August 20, 1992
PROBLEM: Quality Evaluation
EXAMINED BY: A. G. Nisperos

SAMPLE:

Identification: Series 374, No. 51-2B.

Dimensions: 6" x 6" x 1".

Top Surface: Irregular, broom-finish.

Bottom Surface: Smooth, formed-surface.

Cracks, Joints, Large Voids: No significant cracks observed. Some irregular voids up to 0.2 in. in diameter scattered over concrete specimen.

Reinforcement: None observed.

AGGREGATES (A)

Coarse (C): Gravel composed mainly of siliceous rocks (quartzites, arkose, chert, etc.) and calcareous rocks (dolomite, limestone), and other rock fragments.

Fine (F): Natural sand consisting mainly of quartz, feldspar, chert, shale and variety of rock fragments.

Gradation & Top Size: 1-inch to 3/4-inch sizes to maximum size of 1-1/2 inches. Evenly-graded.

Shape & Distribution: CA is subrounded to rounded, tabular to subspherical, some elongated; FA is subangular to subrounded and spherical; uniform distribution.

PASTE

Color: Medium-light gray.

Hardness: Moderately hard.

Luster: Subvitreous.

Calcium Hydroxide*: 5 - 10%.

Unhydrated Portland Cement Clinker Particles (UPC's)*: 5 - 8%.

Depth of Carbonation: 0.1 in. depth from top surface.

Air Content: Less than 1% mostly entrapped air voids.

Fly Ash*: None observed.

Paste-Aggregate Bond: Moderately strong (hammer induced). Freshly broken surfaces pass through aggregate particles.

Secondary Deposits: Some calcium hydroxide along aggregate fringes.

Microcracking: None observed.

ESTIMATED WATER-CEMENT RATIO: Moderate (0.45 to 0.55).

MISCELLANEOUS: Carbonate rock dust observed in the paste but not causing any detrimental effect. No evidence of alkali aggregate reaction is observed.

*percent by volume of paste

CTL

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C 856

CTL PROJECT NO.: 102323
CLIENT: Martin Marietta Energy Systems, Inc.
STRUCTURE: Concrete Slice from 6 x 6 x 30-in. Specimen, PCA Series 374
LOCATION: PCA, Skokie, Illinois

DATE: August 20, 1992
PROBLEM: Quality Evaluation
EXAMINED BY: A. G. Nisperos

SAMPLE:

Identification: Series 374, No. 11T-2B.

Dimensions: 6" x 6" x 1".

Top Surface: Irregular, broom-finish.

Bottom Surface: Smooth, formed-surface.

Cracks, Joints, Large Voids: No significant cracks observed. Some irregular voids up to 0.2 in. in diameter scattered over concrete specimen.

Reinforcement: None observed.

AGGREGATES (A)

Coarse (C): Gravel composed mainly of siliceous rocks (quartzites, arkose, chert, etc.) and calcareous rocks (dolomite, limestone), and other rock fragments.

Fine (F): Natural sand consisting mainly of quartz, feldspar, chert, shale and variety of rock fragments.

Gradation & Top Size: 1-inch to 3/4-inch sizes to maximum size of 1-1/2 inches. Evenly-graded.

Shape & Distribution: CA is subrounded to rounded, tabular to subspherical, some elongated; FA is subangular to subrounded and spherical; uniform distribution.

PASTE

Color: Light gray.

Hardness: Moderately hard to moderately soft.

Luster: Subvitreous.

Calcium Hydroxide*: 15 - 20%.

Unhydrated Portland Cement Clinker Particles (UPC's)*: 3 - 5%.

Depth of Carbonation: 0.1 in. depth from top surface.

Air Content: 6 - 8% with lots of microscopic air voids that appear in clusters around aggregate fringes; nonuniformly distributed.

Fly Ash*: None observed.

Paste-Aggregate Bond: Moderately strong to moderately weak (hammer induced). Freshly broken surfaces pass through and around aggregate particles.

Secondary Deposits: Some calcium hydroxide and ettringite partly line air voids.

Microcracking: None observed.

ESTIMATED WATER-CEMENT RATIO: Moderate to moderately high (0.45 to 0.55).

MISCELLANEOUS: Carbonate rock dust observed in the paste but not causing any detrimental effect. No evidence of alkali aggregate reaction is observed.

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*percent by volume of paste