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Petrographic Analysis of Portland Cement Concrete Cores from Pease Air National Guard Base, New Hampshire

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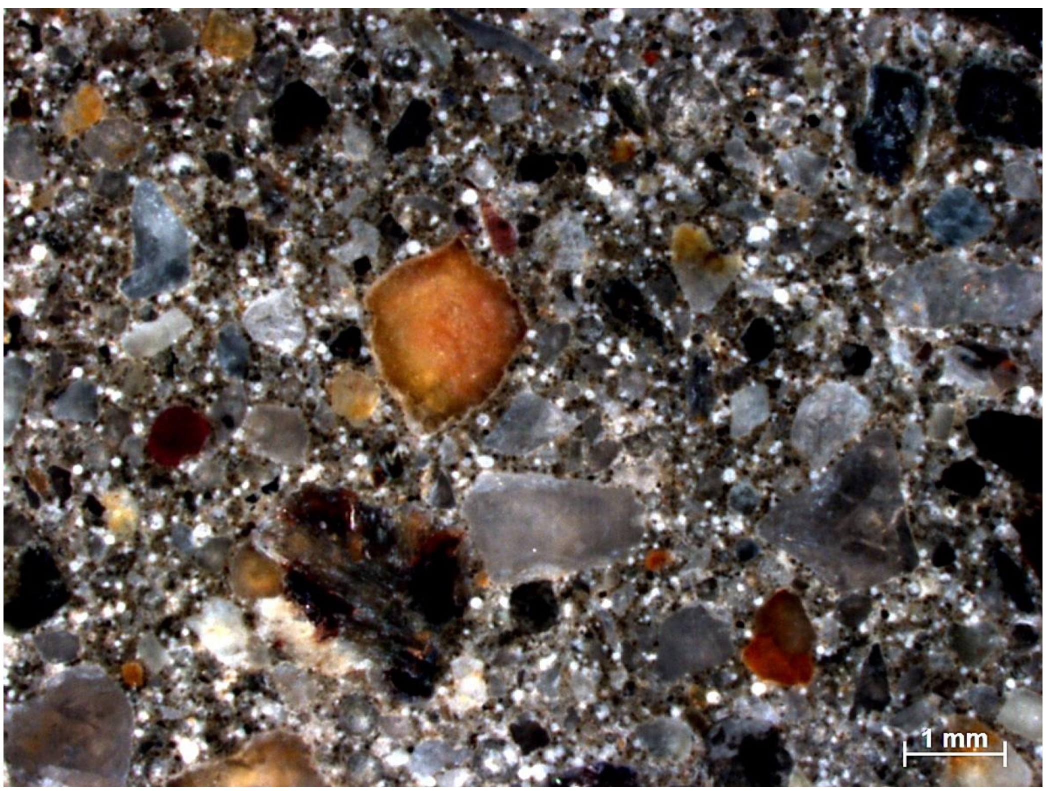

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Preface

This study was conducted in support of the Air Force Civil Engineer Center (AFCEC) to assess concrete obtained from Pease Air National Guard Base, New Hampshire. The technical monitor was Dr. Robert D. Moser of the U.S. Army Engineer Research and Development (ERDC).

The work was performed by the Concrete and Materials Branch (GMC), of the Engineering Systems and Materials Division (GM), US Army Engineer Research and Development Center (ERDC), Geotechnical and Structures Laboratory (ERDC-GSL). At the time of publication, Christopher M. Moore was Chief, CEERD-GMC; Dr. Gordon W. McMahon was Chief, CEERD-GM. The Deputy Director of ERDC-GSL was Dr. William P. Grogan and the Director was Mr. Bart Durst.

COL Bryan Green was the Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

1 Scope

The Concrete and Materials Branch (CMB), Geotechnical and Structures Laboratory, U.S. Army Engineer Research and Development Center, was requested by the Air Force Civil Engineer Center (AFCEC) to perform petrographic analysis of a concrete core sample from Pease ANGB. A total of three cores were provided to the CMB which were checked in under CMB Serial Number 160159-11 to 160159-13. Table 1 lists the cores received with the CMB serial number, original sample identifier, age of the core, and the lab tests performed for each core. The core underwent petrographic examination according to ASTM C-856. The petrographic analysis focused on determining whether deterioration caused by alkali-silica reaction (ASR) was present and, if so, to what degree.

The following sections provide a summary of the methods utilized, results obtained from each core, and a summary and recommendations regarding potential impacts on the site investigated.

Table 1. CMB checkin id, AFCEC section id and core id, age of the concrete being evaluated and tests performed.

CMB ID	AFCEC Section ID -Core ID	Core Age (yrs.)	Lab Tests Performed
160159-11	T07A2-35	31	ASTM C-856
160159-12	T07A2-33	61	ASTM C-856
160159-13	T03A-24	61	ASTM C-856

2 Methods

2.1 Petrographic Analysis

Modes of distress such physical distress and dimensional stability, were assessed by visual examination of the as received cores as well as a petrographic analysis performed on polished cross sections conducted according to ASTM C856 - *Standard Practice for Petrographic Examination of Hardened Concrete*. A 1 in (25 mm) thick section of a core was cut and prepared for the petrographic analysis. The section for petrographic analysis was polished using diamond incrusted polishing pads. The polished sample was imaged using a Zeiss Stereo Discovery V20 microscope at magnifications of 5 X to 40 X. An overall image was obtained for the sample at low magnification, and at least three selected sites were also imaged at higher magnification. Specific focus was given to microcracking, air void structure, aggregate deterioration, and any other possible modes of concrete deterioration that are relevant for service life estimation.

3 Results and Discussion

3.1 160159-11 (T07A2)

The as-received core from location T07A2 is shown in Figures 1 and 2. The core was 16.25 inches (41.3 cm) long and approximately 6 inches (15.24 cm) in diameter. The surface of the sample had 2 fine cracks measuring 0.08 mm and 0.15 mm. Initial observation of the sample noted cracking throughout the sample. There were 2 vertical cracks, one measured 3.9 inches (9.9 cm) from the surface and was 0.25 mm wide. The second was located at 14.5 inches (36.83 cm) depth in the core and was 1.5 inches (3.81 cm) long and 0.25 mm wide. Horizontal cracks were evaluated at 3.5 in (8.9 cm), 4.0 in (10.2 cm), 7.0 in (17.8 cm), 8.0 in (20.3 cm), 10.25 in (26.0 cm), and 11.5 in (29.2 cm). They ranged in width from 0.2 mm to 1.75 mm. Cracking in coarse aggregates, where the crack extends through the cement fraction, was observed throughout the core. Cracks, entrained air voids and entrapped air voids were infilled by a white deposit. Carbonation staining was observed within the top 2 mm of the sample. The aggregates were angular to sub-round (granitic to gneissic in composition) (Figure 3).

Figure 1. 160159-11 (T07A2), the as received core sample.

Figure 2. To view of the as-received sample (T07A2). The surface of the sample had 2 fine cracks measuring 0.08 mm and 0.15 mm.

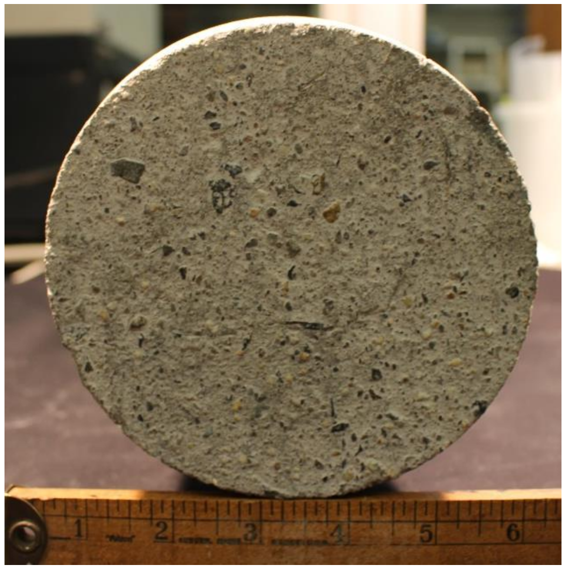
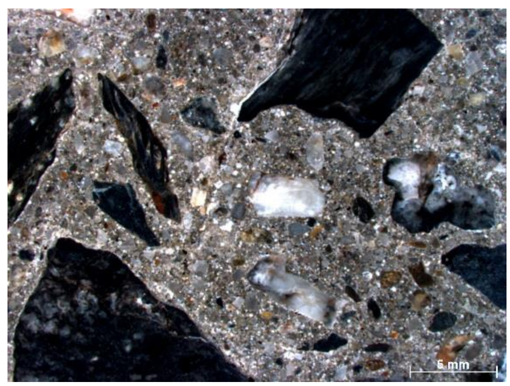


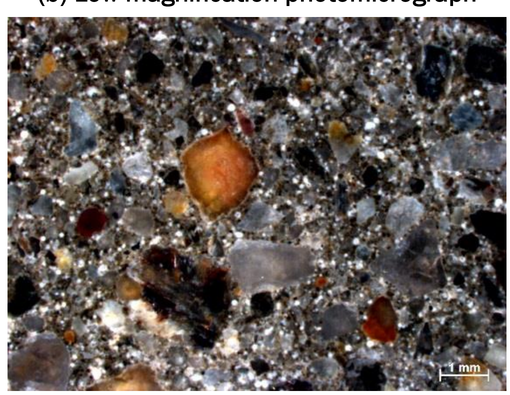
Figure 3. Low and high magnification photomicrographs of 160159-11 – T07A2, (a) very little carbonation staining at the surface, (b) infilling of voids and crack at coarse aggregate boundary, (c) crack in coarse aggregate into the paste, (d) view of cement and fine aggregate, with infilling of voids.

(a) Low magnification photomicrograph



(b) Low magnification photomicrograph

(c) Low magnification photomicrograph



(d) High magnification photomicrograph

3.2 160159-12 (T07A3)

The as-received core from location T07A3 is shown in Figures 4 and 5. The core was 14.2 inches (36.1 cm) long and approximately 6 inches (15.24 cm) in diameter. The surface of the sample had cracks measuring 0.5 mm to 7.0 mm. Initial observation of the sample noted cracking throughout the sample. There were 4 vertical cracks, one measured 2.5 inches (6.35 cm) and another, 4.5 inches (11.4 cm) from the surface and were 1.75 mm and 1.55 mm wide respectively. The other 2 were located at 8.8 inches (22.4 cm) depth in the core and were 6.0 inches (15.24 cm) long and were 2.0 to 2.5 mm wide. Horizontal cracks were evaluated at 5.4 in (13.7 cm), 6.0 in (15.24 cm), 7.2 in (18.3 cm), and 7.8 in (19.8 cm). The horizontal cracks at 5.4 in (13.7 cm) and 7.8 in (19.8 cm) were complete delamination cracks. Others ranged in width from 0.6 mm to 1.5 mm. The cracking in coarse aggregates, where the crack extends through the cement fraction, was observed throughout the core. Cracks, entrained air voids and entrapped air voids were infilled by a white deposit. Carbonation staining was observed within the top 2 mm of the sample and down surface cracks. The aggregates were angular to sub-round (granitic to gneissic in composition) (Figure 6).

Figure 4. 160159-12 (T07A3), the as received core sample.

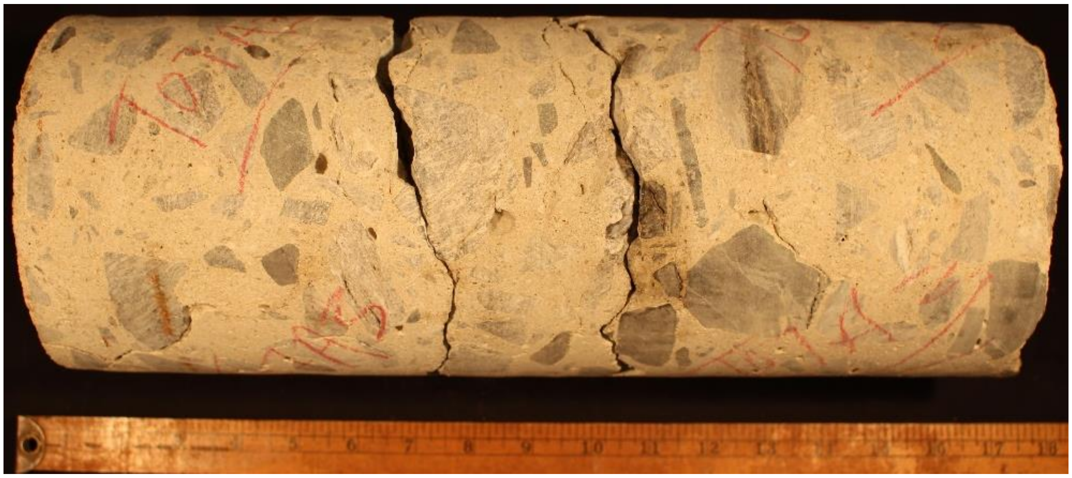
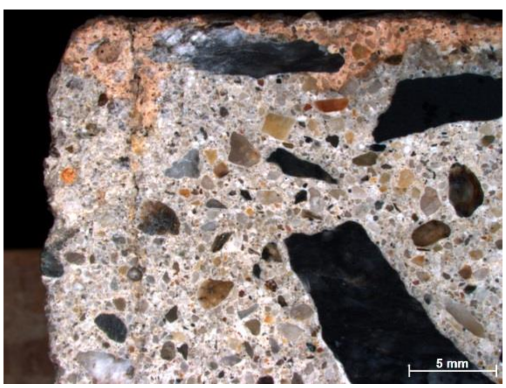


Figure 5. To view of the as-received sample (T07A3). The surface of the sample had cracks measuring 0.5 mm to 7.0 mm.

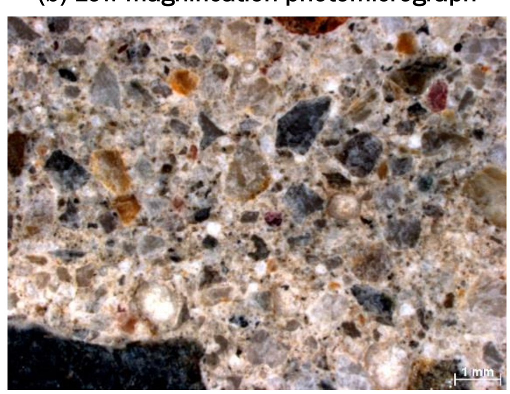
Figure 6. Low and high magnification photomicrographs of 160159-12 – T07A3, (a) carbonation staining at the surface and down crack, (b) crack along coarse aggregate, (c) highly fractured coarse aggregate with what appears to be gel infilling crack and voids, (d) view of cement and fine aggregate, with infilling of voids.



(a) Low magnification photomicrograph

(b) Low magnification photomicrograph

(c) Low magnification photomicrograph



(d) High magnification photomicrograph

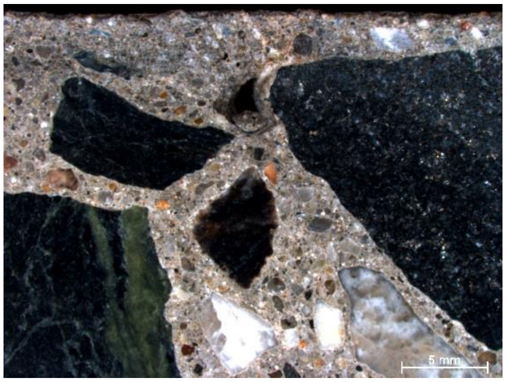
3.3 160159-13 (T03A)

The as-received core from location T03A is shown in Figures 7 and 8. The core was 15.5 inches (39.4 cm) long and approximately 6 inches (15.24 cm) in diameter. The surface of the sample had 6 fine cracks measuring less than 0.08 mm. Initial observation of the sample noted cracking the top 1.0 to 1.5 inches (2.54-3.81 cm) of the sample. There were 2 vertical cracks, one measured 1.0 inches (2.54 cm) from the surface and was 2.0 mm wide. The second was located at 1.5 inches (3.81 cm) from the surface and was 0.2 mm wide. Cracking in coarse aggregates, where the crack extends through the cement fraction, was observed throughout the core. Cracks entrained air voids and entrapped air voids were infilled by a white deposit. Entrapped air voids ranged in size from 1.0 mm to 19 mm. Carbonation staining was observed within the top 2 mm of the sample. The aggregates were angular to sub-round (granitic to gneissic in composition) (Figure 9).

Figure 7. 160159-13 (T03A), the as received core sample.

Figure 8. To view of the as-received sample (T03A). The surface of the sample had 6 fine cracks measuring less than 0.08 mm.

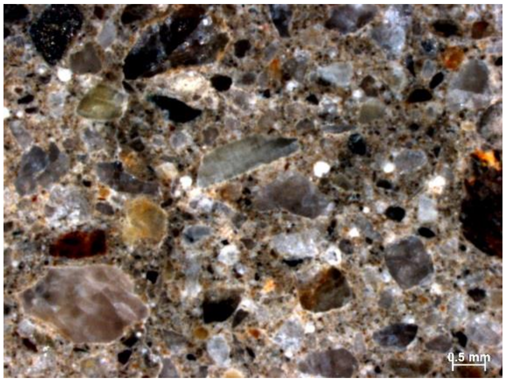
Figure 9. Low and high magnification photomicrographs of 160159-13 – T03A, (a) very little carbonation staining at the surface, (b) iron staining within around coarse aggregate, (c) highly fractured coarse aggregate with what appears to be ASR gel infilling voids and around deboned surface , (d) view of cement and fine aggregate, with infilling of voids and iron staining.



(a) Low magnification photomicrograph

(b) Low magnification photomicrograph

(c) Low magnification photomicrograph



(d) High magnification photomicrograph

4 Summary and Conclusions

This study examined three concrete cores provided to the ERDC by the AFCEC from Pease ANGB. The cores were subjected to an in-depth analysis consisting of visual and petrographic examination. The results of the study include the following:

- Moderate to full infilling of air voids was observed in all three cores. This may be mineral deposition such as ettringite and/or calcium hydroxide as well as alkali-silica gel deposited in voids. Microcracks and debonded aggregate interfaces were observed particularly in cores T07A3 and T03A. Microcracks were partially infilled with deposits of alkali-silica gel.

- All the samples exhibited cracking in coarse aggregate fraction with cracks extending through the mortar fraction / paste. Cracking did not appear to be severe enough to have significant degradation of mechanical properties but is evidence of distress.

- Internal delamination planes were observed in the core 160159-11 and 160159-12, with 160159-12 having the most extensive damag

- The concrete appeared to contain anticipated constituents at proportions typical for concrete of this age.

- Freeze-thaw damage may be aggravated by the low amount of empty air voids due to mineral infilling. Some of this may be due to the time period the concrete was constructed, prior to consistent air entrainment practices.

Contact Information

For any questions related to the results of this study please contact:

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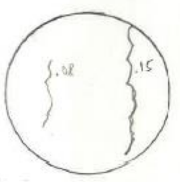
Appendix

3 160159-11

Hole No.

DRILLING LOG	DIVISION	INSTALLATION	SHEET OF SHEETS

1. PROJECT AFCEC	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station) Pease AFB	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY T16C1 T07A2 35	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number)	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	16. DATE HOLE — STARTED — COMPLETED
	17. ELEVATION TOP OF HOLE
7. THICKNESS OF OVERBURDEN	18. TOTAL CORE RECOVERY FOR BORING %
8. DEPTH DRILLED INTO ROCK	19. SIGNATURE OF INSPECTOR
9. TOTAL DEPTH OF HOLE	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			• cracking present in CA's in some cases extending into paste & infilled w/ white deposit	Petro		16 1/4" long
						6" diameter bit
			– 2" most cracks begin			surface cracks .15mm+ .08mm
			1mm parallel			Subangular CA 1-2"
			largest entrapped air 17mm ; infilling w/ white deposits, likely ASR gel			
	5"					
			– 1.75mm, possible plucking of CA along crack			
	10"		– .2mm			
			.6mm – in aggregate extending into paste			
	15"		.25 mm			

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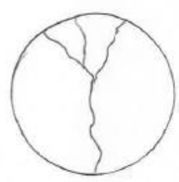
5 160159-12 **Hole No.**

DRILLING LOG	DIVISION	INSTALLATION	SHEET OF SHEETS

1. PROJECT AFCEC
2. LOCATION (Coordinates or Station) Pease AFB
3. DRILLING AGENCY TO 7A3
4. HOLE NO. (As shown on drawing title and file number)
5. NAME OF DRILLER
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE | STARTED | COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
			1.75mm runs along border of an agg.			14 3/4" long
			entrapped air up to 10 cm			6" diameter bit
			1.55m runs along borders of CA			surface cracks 0.5mm – 7mm ✓
						2 1/2" CA, angular to subangular
	5"		complete separation / delam			
			– 1.5mm			
			–.6mm			
			complete separation			
			– reaction rims on CA on the ends of the separated piece			heavily cracked
	10"					
			2.5mm propagates out of separated piece; near separation of piece			
			2.0mm			
	15"					

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1 160159-13

DRILLING LOG	DIVISION	INSTALLATION	Hole No.	SHEET OF SHEETS

1. PROJECT AFCEC
2. LOCATION (Coordinates or Station) Pease AFB
3. DRILLING AGENCY 24-T03A
4. HOLE NO. (As shown on drawing title and file number)
5. NAME OF DRILLER
6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE | STARTED | COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
		0.2mm crack 2mm crack	- throughout CA has cracks some extending into paste w/ white deposit w/in crack. ~~part of rebar~~ crack possible ASR gel reset in drill bit	Petro ASR testing	pH NaCl Rhod.	19" Long 6" Diam Bit 1 to 1½" ags subangular
	5		- 1mm to ¾" entrapped air voids w/ infilling w/ white deposit, most likely ASR gel - small cracks & voids infilled completely			 surface cracks less than 0.08 mm
	10					
	15					
	20					

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