Construction Technology Laboratories
A DIVISION OF THE PORTLAND CEMENT ASSOCIATION
5420 Old Orchard Road, Skokie, Illinois 60077 • Area Code 312

April 19, 1978

Mr. Chris L. Phillips
Project Civil Engineer
Daniel International Corporation
P.O. Box 146
Strawn, Kansas 66839

Re: Reactor Basement Concrete
Wolf Creek Generating Station

Mr. Phillips:

Attached are reports by D. H. Campbell and L. M. Meyer giving results of petrographic examination, compressive strengths and chemical analysis of concrete cylinders and other samples covered by your Purchase Order 7158-NS-00417 dated 3/27/78.

These reports will confirm information discussed with you at our meeting on April 6 and in subsequent telephone conversatio

I believe the reports are complete and self-explanatory, but please consider them tentative at this time.

It is our opinion that the concrete in the "basemat", as repre sented by the samples tested, is of high quality and most lik exceeds the 5000 psi strength requirement of the specificatio It would appear to us that the disparity between the 90-day strength data for the "basemat" and the more recent comparati series with PCA may have been due to improved maintenance of the testing equipment, and testing procedures by Daniel.

Sincerely yours,

J. J. Shideler

J. J. Shideler, Director
Administrative & Technical Services

lg
CT-0407

Copy to -
W. E. Kunze
E. Hognestad
L. M. Meyer
D. H. Campbell

Mr. Phillips:

This letter and report were transmitte by telecopier to you on 4/20/78 and to Mr. Bernie Meyers at Bechtel Power Corp on 4/20/78. Copy is also being mailed to Mr. Meyers.

4/24/78 J. J. Shideler

April 19, 1978

Subject: Wolf Creek Generating Station
(Daniel International Corp.)

This report concerns petrographic examination, air content, and compressive-strength tests.

Eleven compression-tested 6x12" concrete cylinders, and samples of coarse and fine aggregates, cement, and admixtures were received (late March) from Mr. Chris L. Phillips of Daniel International for study relating to reported loss of strength at 90 days. The samples represent materials reportedly used in the Wolf Creek Reactor Basemat. In addition, 20 previously untested 6x12" cylinders and 32 remnants of broken (compression-tested) cylinders were received on April 13, 1978, for further testing.

Petrographic examination and air content determinations were performed on the following cylinders:

Cylinder No.	90 Day Compressive Strength (psi, Daniel data)
6503	4190
6444	4640
6784	4780
6850	6640

Conclusions

Microscopic analysis reveals no evidence which could conceivably cause significant strength reduction at 90 days. Cylinder strength may have been affected slightly by minor differences in air content and water-cement ratio.

The concrete appears to be of high quality, with strengths apparently well above the 5000 psi specification at 90 days. PCA determined compressive strengths on 2x2" cubes cut from previously tested cylinders representing the December 12-13 pour. The average compressive strength of these cubes was 5970 psi with a minimum value of 5060. These values are 80 percent of the actual test values to correct for the difference between cylinder and cube strengths. In a series to determine the comparability of the Daniel testing procedures with those of PCA, twenty companion cylinders cast about January 14 (from the power block) were tested both by Daniel and PCA. There is remarkable aggreement between the two sets of test data. Cylinder fracture patterns developed on PCA-tested and Daniel-tested cylinders are broadly similar, being a combination of diagonal

and conical forms. It was noted that many of the untested 6x12" cylinders displayed rounded bottom-ends, reflecting a non-planar mold surface, and perhaps explaining the occurrence of diagonally formed breaks.

Methods

Each cylinder in the above list was sawn transversely at a distance of approximately 2 inches from the capped end. The capped end-pieces were then polished for determination of air content by Linear Traverse (ASTM C-457). A small core (3/4 inch diameter) was taken from each capped end-piece for thin sectioning. A thin section is a concrete slice mounted on a glass microscope slide with epoxy cement and reduced to a thickness of 25 microns for microscopic examination with plane polarized light. Thin sections were numerically coded so that observations would not be biased by strength data.

The remaining portion of the cylinder was crushed for cement content determination.

Description and Discussion

Cylinder No. 6784 - Fracture surface produced by compression test passes through aggregates. Fracture surfaces form subconical pattern with transverse crack at mid-cylinder. Paste is hard and firmly binds the aggregates. Aggregates appear evenly graded, properly proportioned, and uniformly distributed.

Coarse aggregate is crushed limestone described as fossiliferous, pyritic, medium-grained, microcrystalline, or combinations of these types. Aggregate top-size is 3/4 inch.

Fine aggregate consists of a natural sand containing quartz, microcline feldspar, and metaquartzite. Chert is scarce. Aggregate (limestone) dust occurs in trace amounts.

The aggregates are normally considered non-reactive in low-alkali cements and are judged to be of low porosity and permeability and moderate durability. No reaction products were observed.

The paste contains portland cement hydration products (calcium silicate hydrate and calcium hydroxide, primarily) and unhydrated portland cement grains (UPC's), the latter ranking 5 on a relative abundance scale of 0-10. UPC's consist mainly of dark ferrite and yellow-amber belite. The relative abundance of ferrite suggests an iron-rich cement. Residual alite crystals show prominent rims. Calcium hydroxide crystals occur as small irregular masses in the paste and adjacent to aggregates; blade-form crystals are common. The abundance of calcium hydroxide and UPC's suggest a moderate water-cement ratio. Minor concentration of UPC's adjacent to coarse aggregates suggests the possibility of some inadequate mixing. Most of the

voids contain traces of calcium silicate hydrate or ettringite occurring as very thin films only partially coating the void surfaces.

Cylinder No. 6444 - Fracture surfaces and aggregates as previously described. Fracture surfaces form half-conical patterns with transverse fracture at mid-cylinder. Paste characteristics are apparently no different from Cylinder No. 6784, except UPC's are slightly more abundant, ranking 5+. In addition, ettringite needles occur in trace amounts in a few voids.

Cylinder No. 6850 - Compression test fracture surfaces and aggregates as previously described. Fracture surfaces oriented mainly along cylinder length. Paste characteristics are generally similar to Cylinder No. 6784, but UPC abundance is higher, ranking 6+ on the 0-10 scale, suggesting a relatively low water-cement ratio. Relative air content is lowest in this sample.

Cylinder No. 6503 - Fracture surfaces and aggregates as previously described for Cylinder No. 6784. Fracture pattern show prominent orientation along cylinder length. Paste characteristics are also similar.

Results of Linear Traverse Tests (ASTM C-457)

Cyl. No.	Unit Wt. pcf	% Air	Voids/in.	Specific Surface $in.^2/in.^3$	Spacing Factor in.	Absorpt %
6503	145.5	4.8	7.7	640	.007	5.4
6444	146.3	5.8	8.7	600	.007	5.7
6784	145.8	5.6	8.9	639	.007	5.0
6850	147.1	3.3	4.3	515	.011	5.8

These data indicate a relatively low air content and water-cement ratio for the reported high strength cylinder, and may account, in part, for some of the differences in strength between the cylinders.

Compressive Strength Tests

Compressive strength data for the 2x2" cubes cut from selected broken cylinders, received April 13, 1978, are given in Table I. Note that these have been corrected by a value of 80 percent to indicate the difference between cylinder and cube strenghts. The compressive strength of the cylinders tested by Daniel, from which the cubes were cut, are also reported in the table. The average compressive strength of the cubes (corrected by the 20 percent) was 5970 psi as compared to 5370 psi on the cylinders. The average compressive strengths of the 20 cylinders tested by Daniel and PCA are 6470 and 6220 psi, respectively, which indicates good agreement.

April 19, 1978

Subject: Wolf Creek Generating Station
(Daniel International Corp.)

Attached is our chemical analysis report covering the results of tests for the cement content, approximate water-cement ratio and admixture content of hardened concrete. Also included are the results of selected tests performed on the two samples of Ash Grove Type II cement we received on April 13, 1978. This work was conducted relative to reports that concrete placed in the Reactor Basemat was low in compressive strength at 90 days.

Conclusions

1. The cement contents of all the samples selected for analysis were comparable to that specified in the concrete mix design (564 lbs/yd^3). The approximate water-cement ratios determined for the same samples were below the level indicated in the mix design.

2. The chemical admixtures specified in the mix design appeared to be present in the concrete samples we tested at the appropriate dosage levels. No indication of improper admixture formulation (Pozzolith 300-N and MBVR) was observed.

3. To date no significant differences between the two samples of Ash Grove Type II cement (C-UT-16 and C-UT-17) have been detected.

L. Michael Meyer

L. M. Meyer, Manager
Technical Services Section

Chemical Analysis Report

A. Determination of Cement Content and Approximate Water-Cement Ratio of Hardened Concrete

The cement contents and approximate water-cement ratios of the four tested cylinders chosen by Dr. Campbell for petrographic analyses and measurements of air content also were determined. The results are presented in the attached analytical report by Ms. D. L. Glochowsky.

The data shows the cement contents of Cylinder Nos. 6503, 6784 and 6850 were comparable to that specified in the concrete mix design (564 lbs/yd^3). Although the cement content of Cylinder No. 6444 was slightly below the specified amount, the value obtained was within the range of experimental error normally anticipated for this test ($\pm$ 30 lbs/yd^3). The approximate water-cement ratio of all four cylinders, assuming an overall aggregate absorption of 1.5%, was below the level indicated in the mix design (w/c = ~ 0.49).

B. Analysis of Chemical Admixtures

The samples of water-reducing admixture, identified as Master Builders Pozzolith 300-N (ASTM C-494, Type A), and air-entraining agent, identified as Master Builders MBVR (ASTM C-260), were subjected to certain chemical and physical tests for purposes of characterization.

The results of our tests showed both admixtures were similar in physical and chemical properties to other samples similarly identified and characterized previously at PCA. One of the major components of Pozzolith 300-N, lignin sulfonate, appeared to have been sulfonated to a somewhat lesser extent than had been found in the earlier samples, but we do not know what affect, if any, this might have on admixture performance at this time.

C. Analysis of Hardened Concrete for Presence of Chemical Admixtures

Four concrete cylinders were selected for chemical analysis on the basis of their reported 90 day compressive strength values. These cylinders were as follows: No. 6857 (6420 psi), No. 6432 (5020 psi), No. 6414 (5110 psi) and No. 6623 (2870 psi?). The latter two cylinders were combined into one sample because of insufficient sample size. The three concrete samples then were analyzed for the presence of a water-reducing admixture, Pozzolith 300-N and an air-entraining agent.

The results of our chemical analyses showed a water-reducing admixture similar in composition to Pozzolith 300-N was present

in all three samples of concrete at a level of less than 3 fl.oz./100 lbs of cement (approximate threshold level of detectability). No significant difference in admixture level was observed between the three samples.

Analysis of the concrete samples for the presence of the air-entraining admixture was more difficult due to some minor contamination by "oxidized" oils (possibly materials from lubricating agents or materials present in sulfur capping compound). The amount of these "oxdized" oils was less than 0.005% by weight of concrete. The air-entraining agent could have been masked by these "oxidized" oils, but it appears there was not an excess of air-entraining agent present in the concrete.

D. Analysis of Portland Cement

Two samples of portland cement, reported to be Ash Grove Type II (Chanute, Kansas plant) and identified as C-UT-16 (Bin #36, 11/21/77) and C-UT-17 (Bin #36, 12/12/77), were subjected to selected chemical and physical tests to determine if significant differences existed between them. The chemical tests included X-ray diffraction analyses (XRD) and determinations of SO_3 content and loss on ignition (LOI); the physical tests included specific surface (Blaine, air permeability) and particle size distribution (Sedigraph 5000).

The results showed there were no significant differences between cement samples based upon the test results obtained to date. Both XRD scans and Sedigraph particle size distribution curves were virtually identical. The other values obtained were as follows:

Sample	L.O.I. (% by wt.)	SO_3 Content (% by wt.)	Specific Surface (Blaine, cm^2/gm)
C-UT-16	1.07	2.08	3460
C-UT-17	0.96	2.09	3465

Project No.: CT-0407 Completion Date: 4/5/70

Test Method Sulfur Trioxide Method

Sample Identification:	6444	6503	6784	68
Cement content, lbs./yd.^{3}:	540	570	560	575
Unit Weight, lbs./ft.^{3}:				
S.S.D. -	145.4	145.5	145.8	147.
Oven Dry (@ 105°C) -	137.6	138.0	138.9	139.
Free water absorption, %: (Oven dry weight basis)	5.7	5.4	5.0	5.
Combined water content, %: (Oven dry weight basis)	2.41	2.61	2.59	2.
Total water, lbs./yd.^{3}: (Free water + combined water)	300	300	285	310
Approximate W/C: (Corrected for aggregate absorption)	0.47	0.45	0.42	0.
Total dry aggregate, lbs./yd.^{3}:	3085	3060	3090	3085
Approximate C.A./F.A.:	Not Determined			
Air void content -				
ASTM C457:	See report by D. H. Campbell			
Estimated:				

Comments:

ASTM C-114 (Modified)

Sample Concrete:	% SO_3 (by wt.)
#6444	0.33
#6503	0.35
#6784	0.34
#6850	0.35
Aggregates (Fine and Coarse)	Negligible

Cement SO_3 = 1.28% as determined by Leco Induction Furnace (total sulfur as SO_3).

D. L. GLOCHOWSKY
Assistant Research Chemist
Technical Services Section